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Some Aspects of the Biology and Population Dynamics of Skipjack *(Katsuwonus pelamis)* in Philippine waters[a]

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Abstract

Aspects of skipjack *(Katsuwonus pelamis)* biology and population dynamics in Philippine waters between 1977-1982 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 (L_{opt}) of skipjack caught by handlines increased with hook size, as did the selection range. Selection was very pronounced against smaller fishes. Growth of skipjack in Philippine waters was determined by: $L_t = 82.2\ (1 - \exp. - 0.48\ (t + 0.26)$. Growth performance was within observed values for skipjack elsewhere. Total mortality estimates of skipjack suggested that they are presently overfished.

Introduction

Skipjack *(Katsuwonus pelamis)* tuna landings in the Philippines have ranged from 31,000 to 61,000 tonnes per year between 1980 and 1985 with an average of 47,000 tonnes (BFAR 1985 and unpublished data), i.e., about 3.8% of the country's total marine landings.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 ring nets, 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 tuna have been reported upon by Ronquillo (1953, 1964), Bunag (1956), White (1982) and Yesaki (1983). In this paper, we present data on biology and population dynamics of skipjack sampled in the Bohol Sea and northwestern Luzon from 1977 to 1982.

Materials and Methods

The sources of data on skipjack analyzed in this paper are summarized in Table 1. Landings of skipjack were sampled in two locations in the Philippines, at Darigayos Cove, nothwestern Luzon and Opol, northern Mindanao (Fig. 1). Detailed accounts of these fisheries and sampling methods are given in Cortez-Zaragoza (1983) and Tandog (1984). The fishery at Darigayos Cove is composed of small (approx. 0.3 gross tons (GT) vessels from which skipjack are caught by handlines around "payaos", i.e., fish attractive devices which are particularly abundant in this area (Floyd and Pauly 1984). Some skipjack are caught in a similar manner in the Bohol Sea and landed at Opol or the nearby town of Initao. Skipjack caught by larger commercial ring net vessels ranging from 22-56 GT are also landed at Opol. Ringnet and handline caught fish were sampled and recorded separately.

Six maturation stages of skipjack gonads were recognized by macroscopic examination, as follows:

0	Gonads indistinct	III	Maturing ripe
I	Immature	IV	Ripe
II	Maturing	VI	Spent

These maturity stage were based on those given by Orange (1961) for yellowfin and skipjack tuna in the eastern Pacific.

Morphometrics of Hook Selectivity

Measurements were taken on fork length, eye diameter and head length of skipjack tuna captured off northwestern Luzon. Length-weight relationships were estimated based on samples from both sites.

Hook selectivity of skipjack was estimated using the Baranov/Holt method (Baranov 1914/Holt 1963), reviewed in Gulland (1983) and Pauly (1984). Hook size is defined here as the distance of the gap between the hook shank and point of the barb (Fig. 2).

The stomach contents of 148 specimens of skipjack, caught by ring nets at Opol were examined to determine feeding habits of this species. 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 and Initao. 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:

$$L_t = L \quad (1-e^{-K(t-to)})$$

where L_t is length at time t, L is the asymptotic size, K is a growth constant and t_o relates the origin of the curve to the time axis.

Total mortality rate (Z) was determined using length converted catch curves (Pauly and Ingles 1981; Gulland 1983). Here, length-frequency data pooled over a longer period are used to construct a plot whose x-axis represents the relative age (t-t_o) of the fish, and whose descending limb can be fitted with a straight line of the form

$$\text{Log}_e (Ni/ \quad t_i) = a + bt_i$$

where b = -Z, t_i is the relative age of the fish in length class i; t_i is the time taken to grow through length class i; and N_i is the number of fish in length class i.

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_o is accurately known, the monthly pattern of recruitment can be ascribed to actual months and compared directly with spawning data). The derivation of both the recruitment pattern and the catch curve are features of the ELEFAN II computer program (Pauly and Ingles 1981).

Results and Discussion

Seasonal Abundance

The mean monthly landings of skipjack for each month at the major fish market in Navotas, Manila are shown in Fig. 3. There are two very clear peaks in seasonal abundance between February to May and October to November. The landings of skipjack at Navotas come from all the Philippines and account for about 20% of the total national catch of this species. These data are thus likely to be representative of the general seasonal trends for skipjack production in the Philippines. This is supported by the landings data from Opol and to a lesser extent Darigayos Cove (Fig. 3). The annual length frequencies of these different landings are shown in Fig. 4.

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. A plot of the percentage of the numbers of these fish as a function of their length and based on the data in Table 2 is shown in Fig. 5. From this the 50% maturity length was estimated as 43.3 cm. (the data were insufficient to obtain separate estimates for females and males). A comparison with estimates of mean length at first maturity obtained elsewhere is given in Table 3.

Data on the maturity stages of skipjack from the Bohol Sea from 1977 to 1982 were summarized on a bimonthly basis to determine spawning seasonality. Two spawning peaks were tentatively identified, one from March to June and lesser one from November to December (Fig. 6). Note that the peaks in spawning intensity coincide with the production peaks of the fishery.

Recruitment Patterns

The recruitment patterns generated by ELEFAN II for samples from the Bohol Sea are shown in Fig. 7. Three out of the four length-frequency samples have two well-defined recruitment peaks. Twin recruitment peaks correspond to the twin spawning peaks discussed in the previous section. These results agree well with the findings of White (1982) and Yesaki (1983) who, similarly, 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 31 of the 148 skipjack sampled in the Bohol Sea contained any food. A summary of the stomach contents observations is given in Fig. 8. Fish and squids comprised the major component of the diet. In the Central Pacific, the major component of skipjack diet was fish and mollusks (Alverson 1967; Waldron and King 1963) whilst in the Eastern Pacific, crustaceans were the dominant food item, followed by squids and fish (Forsbergh 1980). Thus, skipjack appear to be opportunistic feeders which prey on whatever is available to them (see also Ronquillo 1953).

Morphometric Relationships

A summary of the different morphometric relationships of Philippine skipjack tuna is given in Fig. 9.

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, however. Fig. 10 shows for each of the other adjacent combinations, a double logarithmic plot of the catch ratio on fork length.

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. 10). The selection range (defined here as one standard deviation either side of the optimum length) versus optimum length was fitted with a straight line forced through the origin and the means of both variates (Fig. 12).

Both 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 Cortes-Zaragoza et al (1987).

Age and Growth

The results of the analysis of the length-frequency data from the Bohol Sea are shown in Figs. 13-16. and Table 6. Rough estimates of t_o, the origin of the growth curve, were obtained from the empirical equation:

$$\log_{10}(-t_o) = -0.3922 - 0.2752 \log_{10}L_\infty - 1.038 \log_{10}K$$

estimated by Pauly (1979) based on 153 sets of t_o, L_∞, and K values of a wide variety of fish species. The growth curve for skipjack from the Bohol Sea may thus be given as:

$$L_t = 82.2\,(1 - e^{-0.48(t+0.26)})$$

According to White (1982) skipjack attain, after the first, second and third year of life, lengths of 40, 58 and 68 cm, respectively, which agrees with the values generated by the above equation.

Pauly and Munro (1984) and Moreau et al.(1986) have shown that the parameters of the VBGF can be compared directly through the use of 0' computed from:

$$0' = \log_{10}K + 2\log_{10}L_\infty$$

The estimates of 0' for a given species should correspond to a normal distribution which is indeed the case with the available values for skipjack. The values of 0' for the Bohol Sea skipjack stock falls within the range of previous estimates (Fig. 17).

Mortality

The length-converted catch curves the Bohol Sea skipjack are shown in Fig. 18. A summary of the results is presented in Table 8. As no independant estimate of natural mortality (M) was available, Pauly's (1980) empirical formula was used to estimate an natural mortality:

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L \quad + 0.654 \log_{10} K + 0.4634 \log_{10} T$$

where L (cm) and K (year $^{-1}$)are the VBGF growth parameters and T(^{o}C) is the mean environmental temperature. Mean surface water temperature for Philippine waters is given by Dalzell and Ganaden (1987) as 28.2^{o}C. Annual fishing mortality (F) could be obtained by subtraction of M from Z, and the exploitation rate (E = F/Z) computed (Table 8).

Gulland (1971) proposed that optimum fishing mortality should be approximately equal to the natural mortality rate or F_{opt} = M, and hence E_{opt} 0.5. The estimates of E for those fish taken by ring nets are greater than 0.5 and suggest overfishing, thus confirming Floyd (1986). Apparent E for handline caught tuna is considerably lower. The reasons for this are most probably biases caused by hook selectivity.

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

Subject	Sampling: Location	Sampling: Years	Source
Morphometrics	N.W. Luzon	1981	Cortez-Zaragoza (1983) & Tandog (1984)
Hook selection	N.W. Luzon	1981	Cortez-Zaragoza (1983) Tandog (1984)
Reproduction	N. Mindanao	1977-1982	Bureau of Fisheries and Aquatic Resoures Regional Office, Region X, Opol
Catch size composition	N. Mindanao	1979-1980	Bureau of Fisheries and Aquatic Resources Regional Office & Tandog (1984)
Feeding habits	N. Mindanao		Tandog (1984)
Seasonality of production	Philippines	1980-86	Navotas Fish Port Complex, Manila
	N. Mindanao	1982	Tandog (1984)
	N.W. Luzon	1981	Cortez-Zaragoza (1983)

Table 2. Percentage of mature and immature skipjack from the Bohol Sea.

Mid-length	Maturity Stage		
	Stage I	Stages II-V	% Mature
20	4	0	0
24	8	0	0
28	17	0	0
32	26	0	0
36	4	0	0
40	3	1	25
44	6	8	57
48		33	100
52		17	100
56		12	100
60		21	100
64		18	100
68		7	100
72		15	100
76		2	100

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

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

Table 4. Catch by Length of Different Hook Sizes to Estimate their Selectivity for Katsuwonus pelamis, off Darigayos Cove, N.W. Luzon.

Midlength of size group in cm	Hook size				
	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

Table 5: Hook size and predicted optimum length of Skipjack tuna.

Hook size (cm)	Optimum Capture length (cm)[a]
1.2	19.6
1.3	27.1
1.4	36.1
1.5	42.4

[a] Where there was more than one optimum length for a hook size means are given.

Table 6 : Growth parameter estimates derived from application ELEFAN 1 to skipjack length frequency data from the Bohol Sea.

Year	Location	Gear	Loo (FL; cm)	K (yr -1)	ESP/ASP ratio
1979 - 80	Opol	Ringnet	84.7	0.54	0.337
1980 - 81	Opol	Ringnet	80.6	0.40	0.564
1981 - 82	Opol	Ringnet	80.0	0.42	0.523
1980 - 82	Initao	Handline	83.6	0.54	0.424

TABLE 7. Estimates of the growth parameters (Loo and K) in skipjack tuna with computed value of 0'(= logK + 2logLoo).

Area	Loo (cm)	K (y^{-1})	0'	Source
Hawaii	84.6	1.16	3.92	Uchimaya 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	Uchimaya and Struhsaker, 1981
Hawaii	92.4	0.47	3.60	Uchimaya and Struhsaker, 1981
Eastern Pacific	142.5	0.29	3.77	Uchimaya 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	This paper
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

TABLE 8. Estimates of mortality rates of skipjack captured in the Bohol Sea; all mortalities are expressed on an annual basis.

Year	Location	Gear	Z	M	F	E
1979-1980	Opol	Ringnet	3.00	0.89	2.11	0.70
1980-1981	Opol	Ringnet	2.64	0.74	1.89	0.72
1981-1982	Opol	Ringnet	1.76	0.77	0.99	0.56
1980-1982	Initao	Handline	1.38	0.90	0.48	0.35

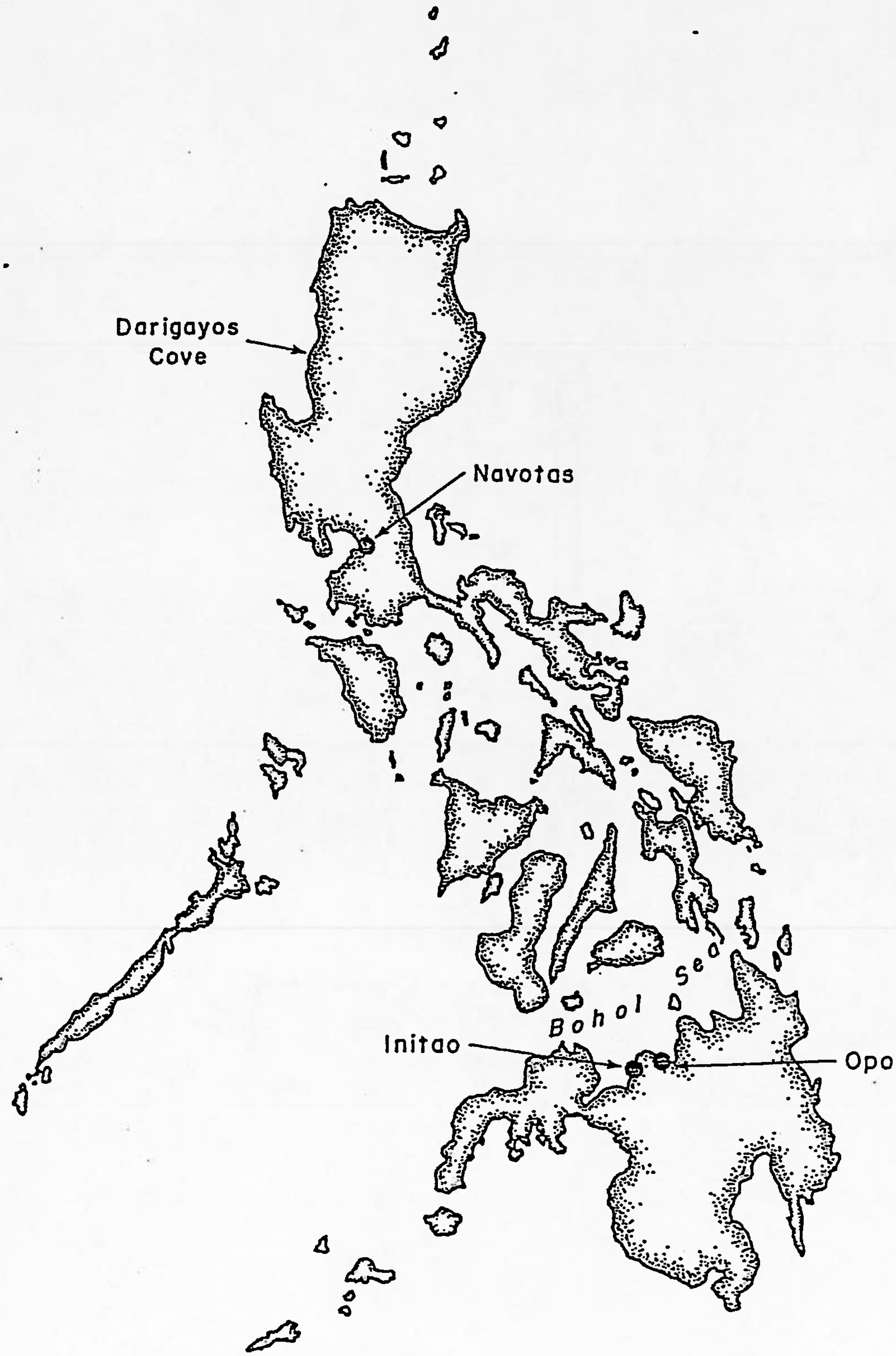


Fig. 1. Map of the Philippines showing locations from where sample data on skipjack were collected.

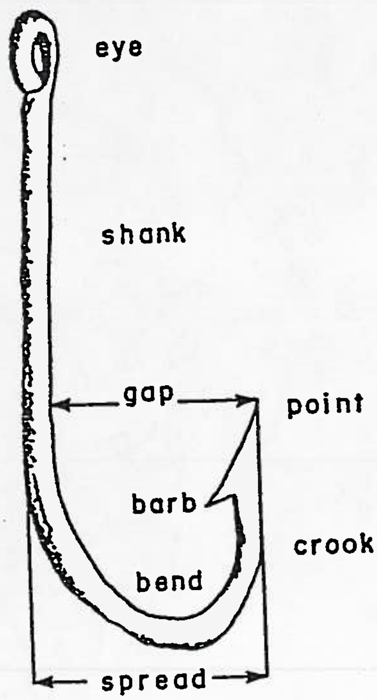


Fig. 2. Parts of a hook; "size" as defined here is the gap.

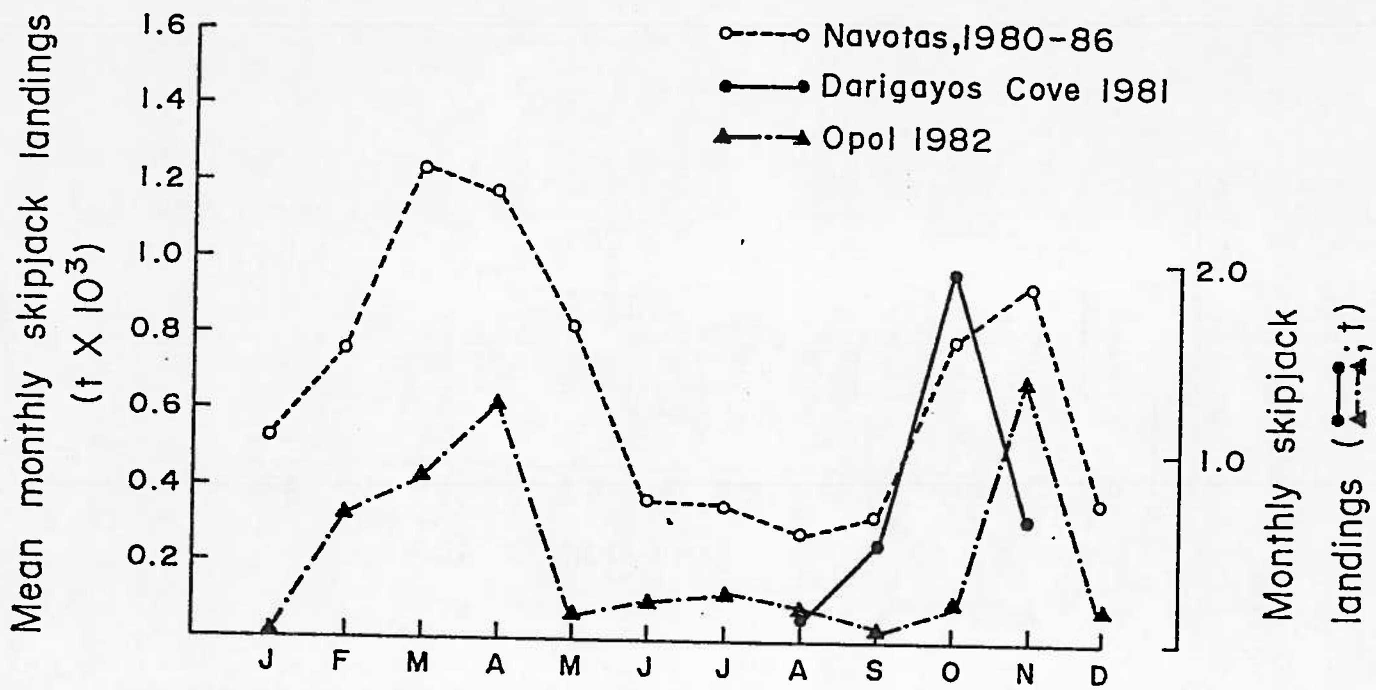


Fig. 3. Seasonality of production of skipjack tuna from different locations in the Philippines.

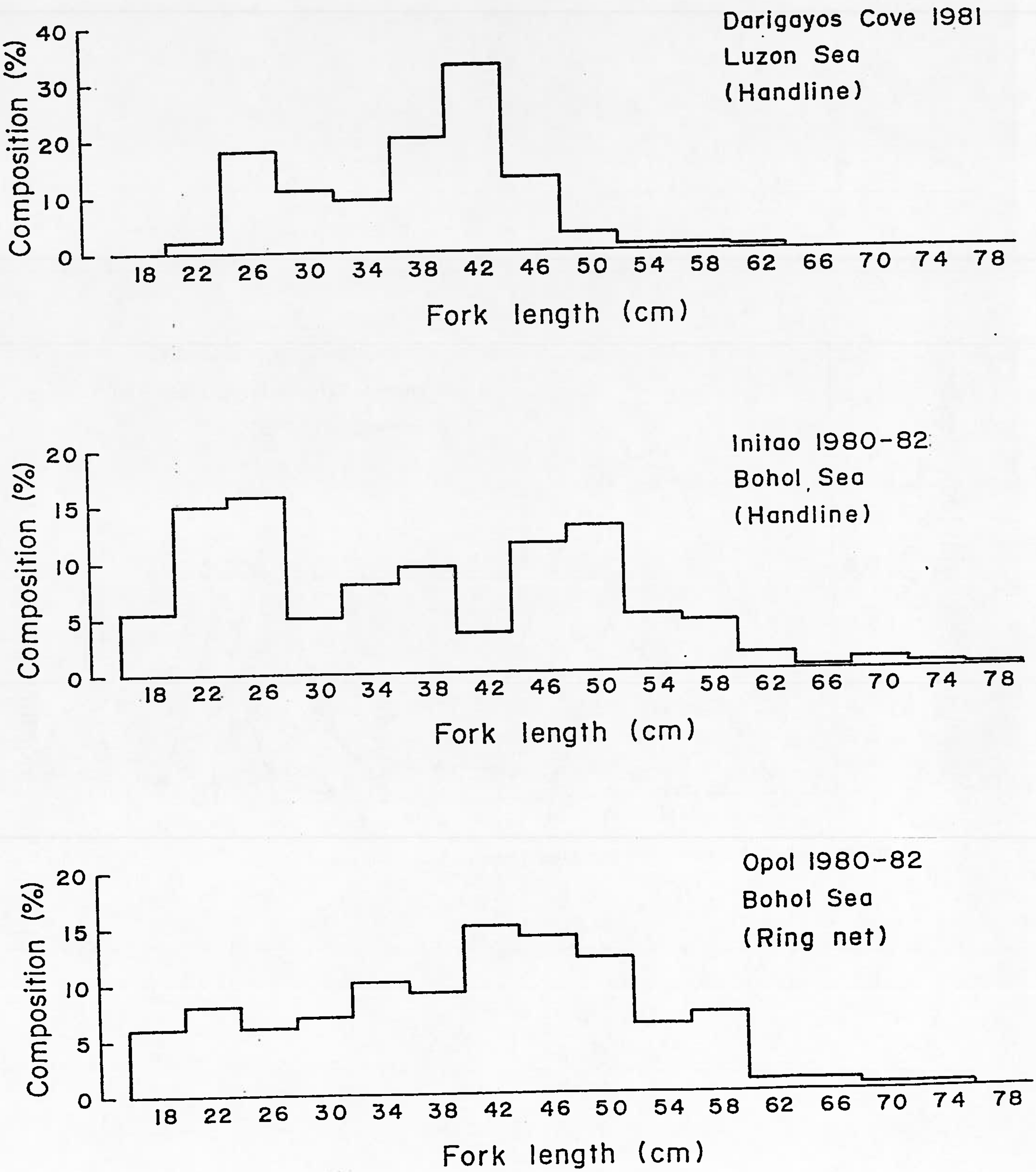


Fig. 4. Annual length-frequency distribution for skipjack off N.E. Luzon and Bohol Sea.

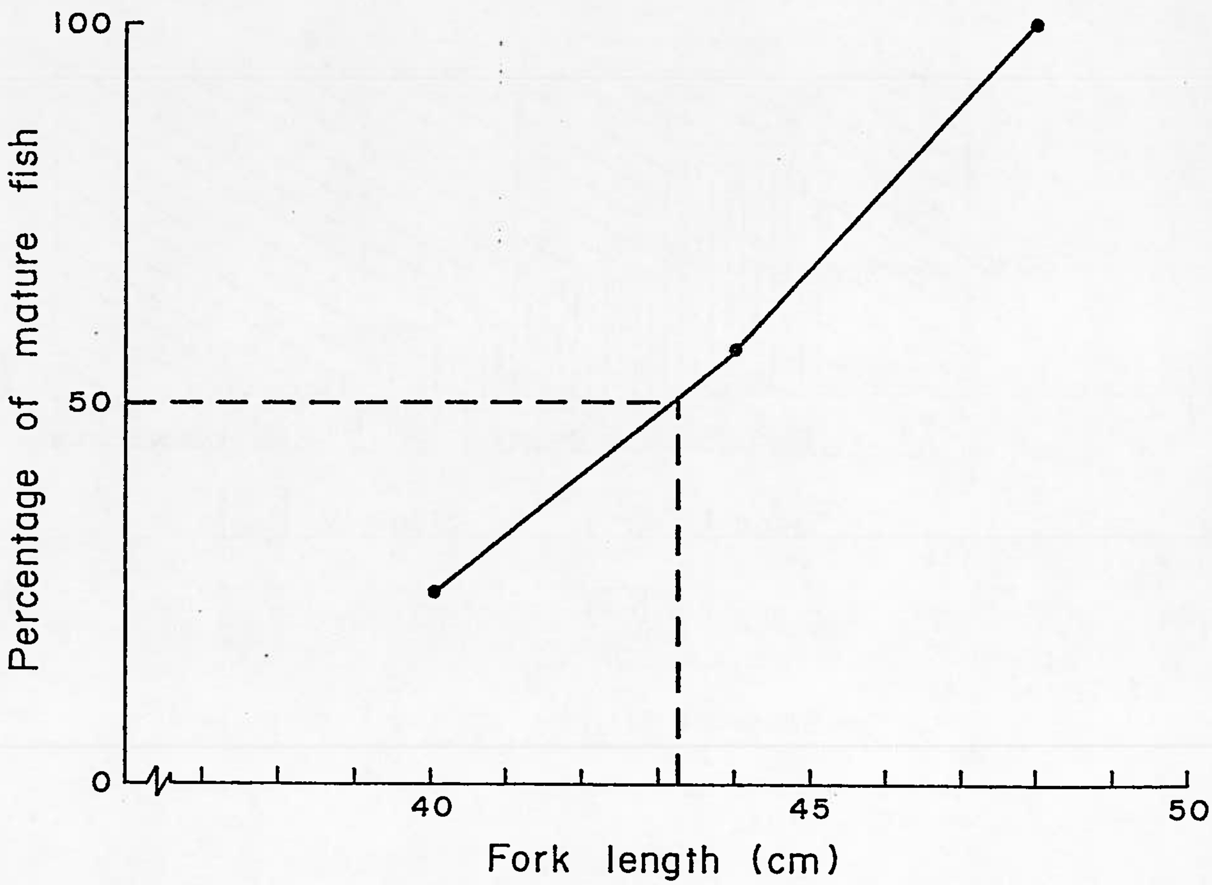


Fig. 5. Percentage of mature fish *vs.* fork length for skipjack tuna.

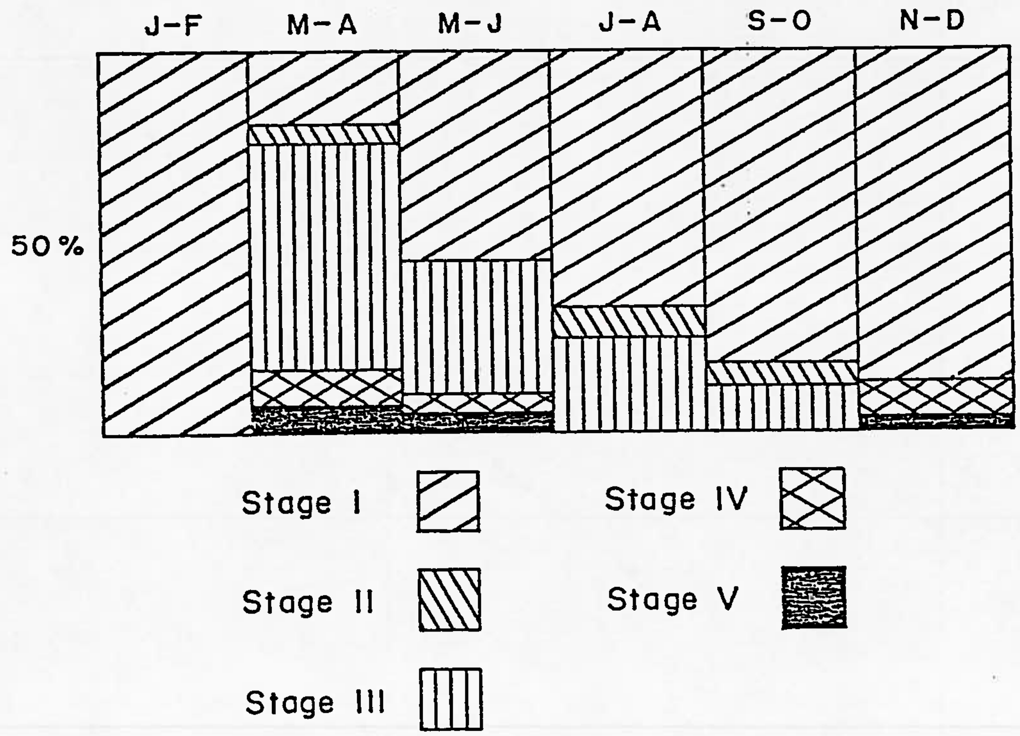


Fig. 6. Bimonthly percentage of different maturity stages of skipjack sampled from the Bohol Sea, 1977-1982.

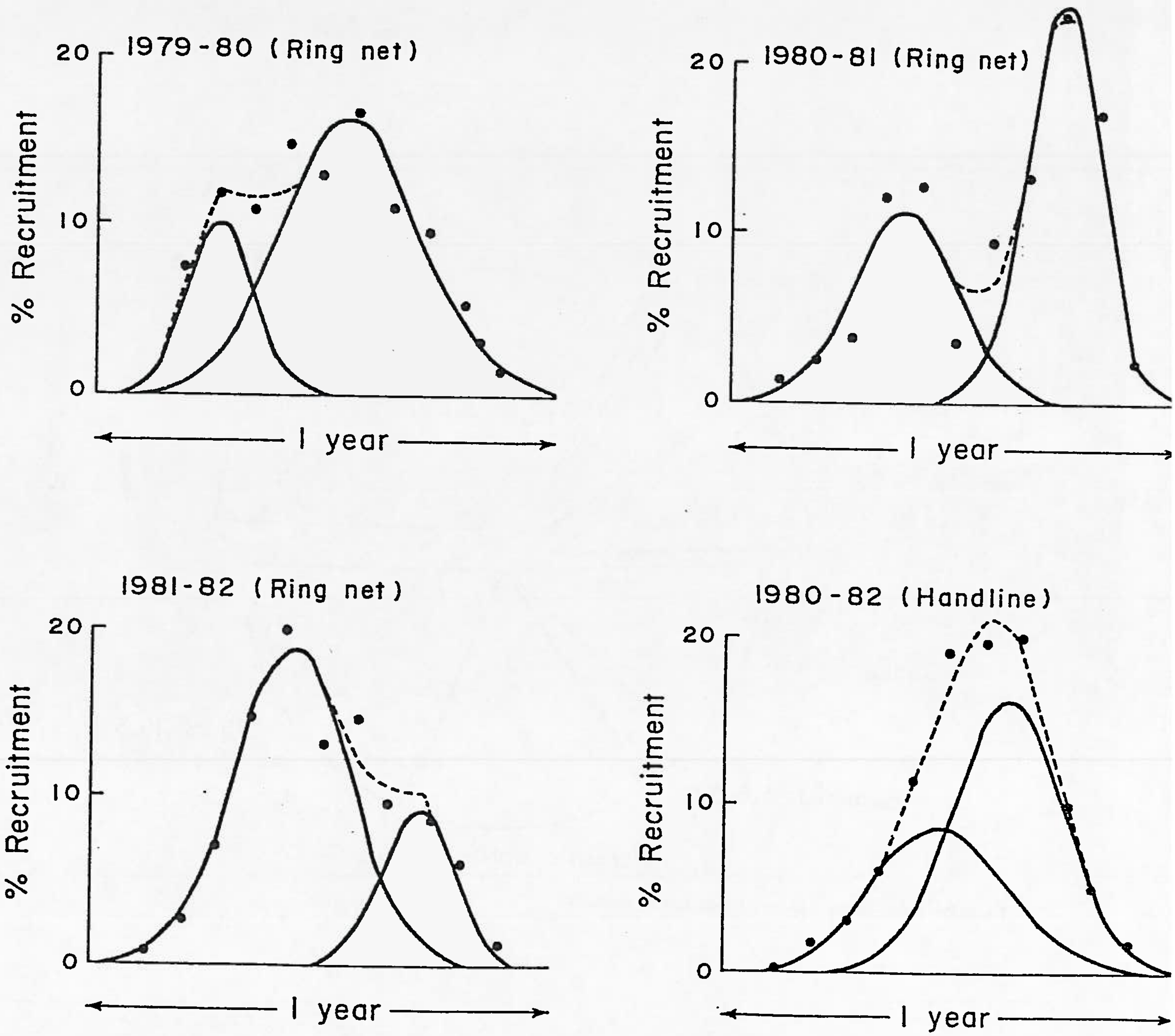


Fig. 7. Recruitment patterns of skipjack caught in the Bohol Sea, 1980-1982. Points represent estimates of relative monthly recruitment; normal curves represent recruitment pulses identified by applying the BASIC version, by Pauly et al. (1976), of the NORMSEP program in Abramson et al. (1971) to the data points.

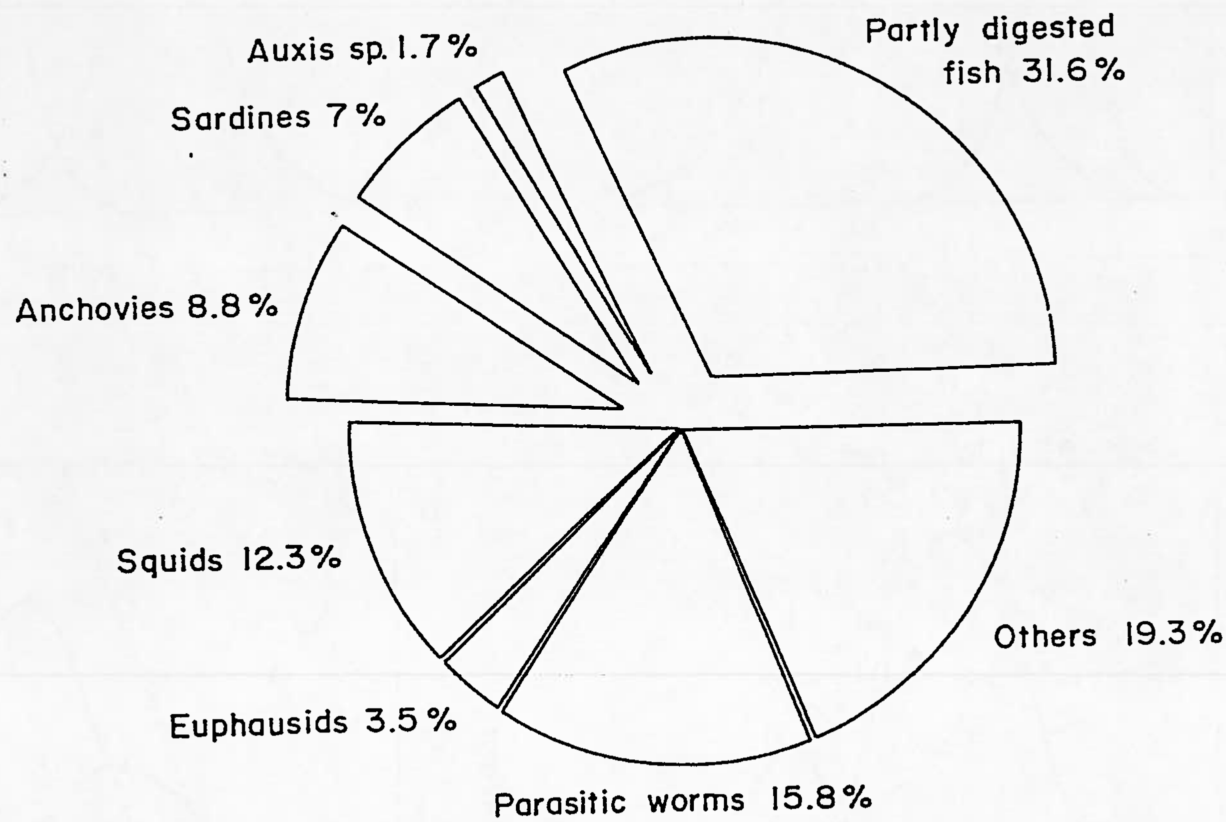


Fig. 8. Percentage composition of skipjack stomach contents.

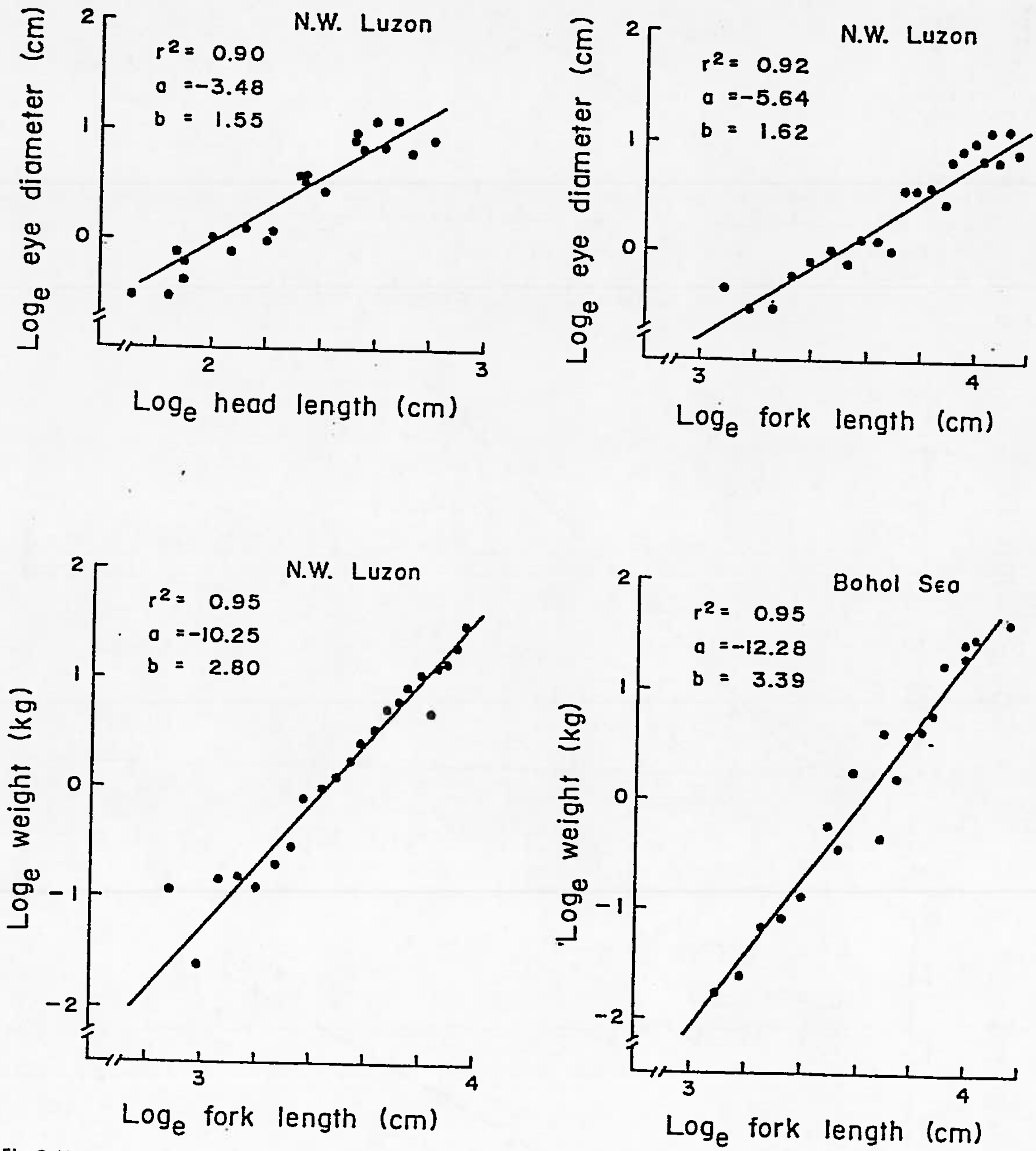
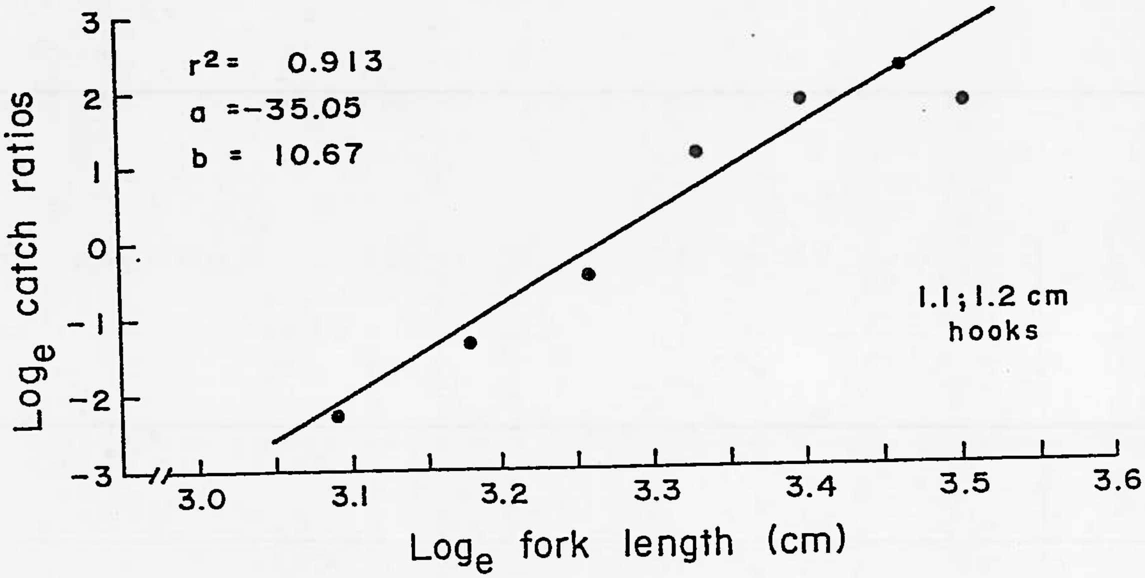
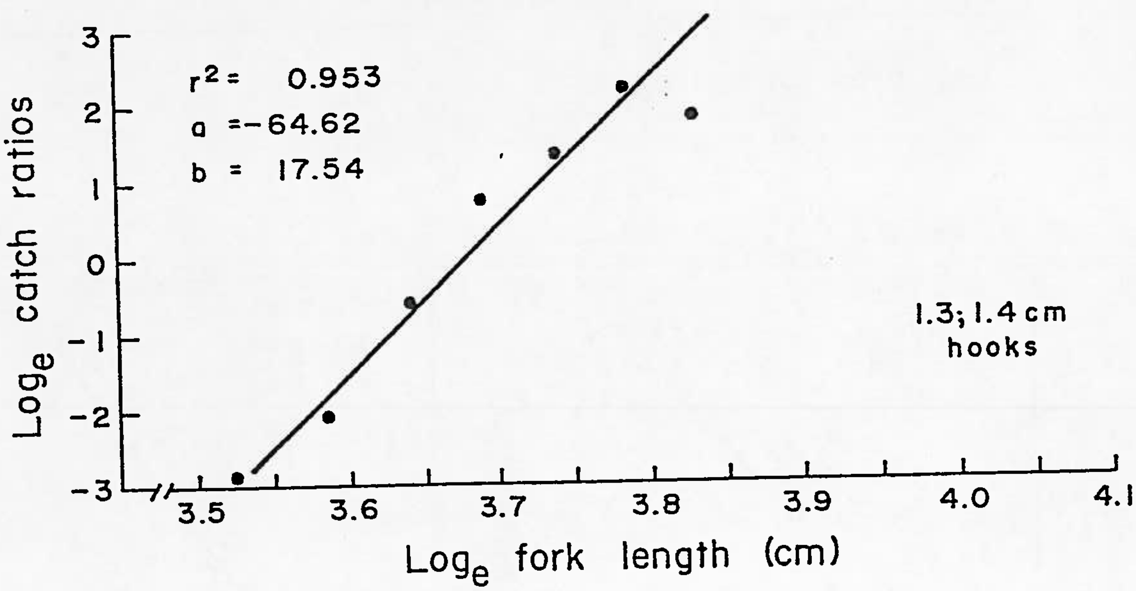


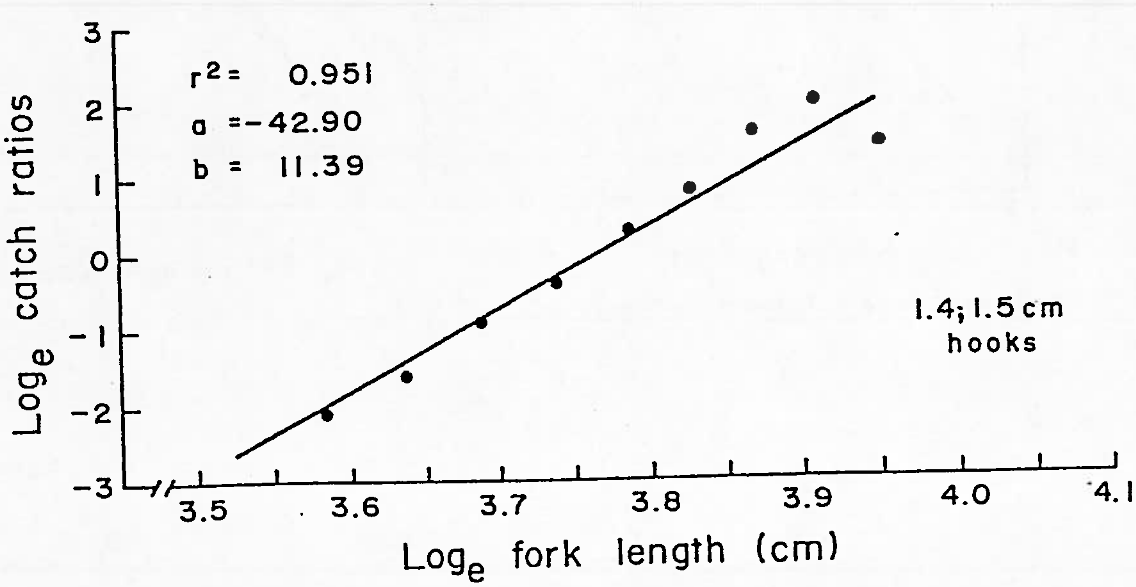
Fig. 9. Morphometric relationships for skipjack from Philippine waters.



r² = 0.913
a = -35.05
b = 10.67
1.1; 1.2 cm hooks
Loge catch ratios
3
2
1
0
-1
-2
-3
3.0
3.1
3.2
3.3
3.4
3.5
3.6
Loge fork length (cm)



r² = 0.953
a = -64.62
b = 17.54
1.3; 1.4 cm hooks
Loge catch ratios
3
2
1
0
-1
-2
-3
3.5
3.6
3.7
3.8
3.9
4.0
4.1
Loge fork length (cm)



r² = 0.951
a = -42.90
b = 11.39
1.4; 1.5 cm hooks
Loge catch ratios
3
2
1
0
-1
-2
-3
3.5
3.6
3.7
3.8
3.9
4.0
4.1
Loge fork length (cm)

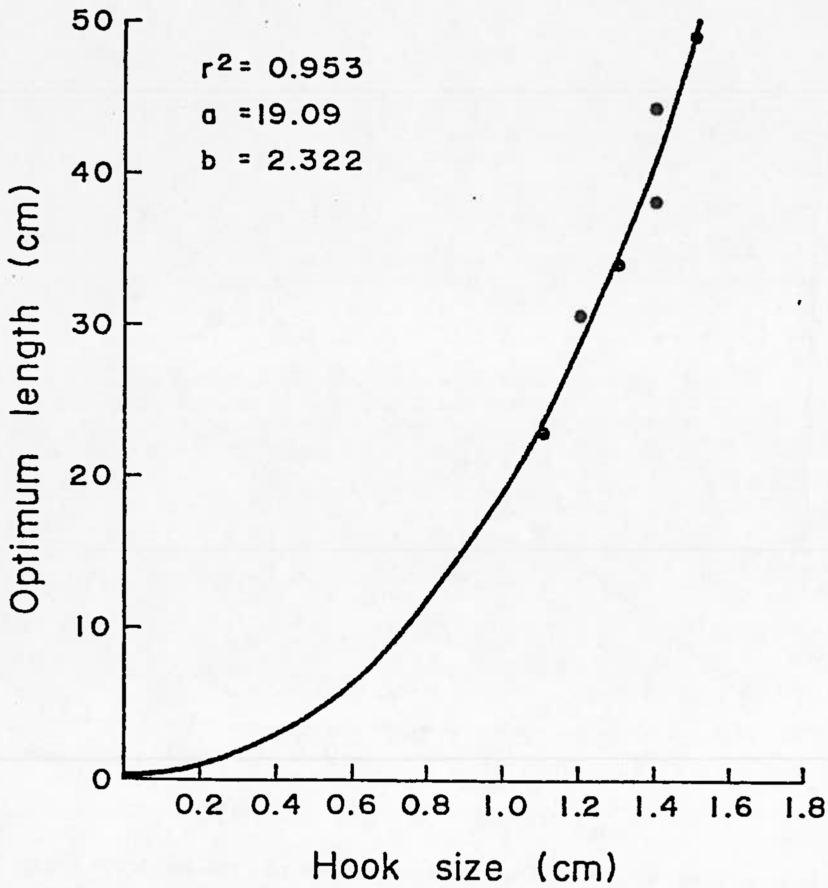


Fig. 11. Optimum length *vs.* hook size for Philippine skipjack tuna.

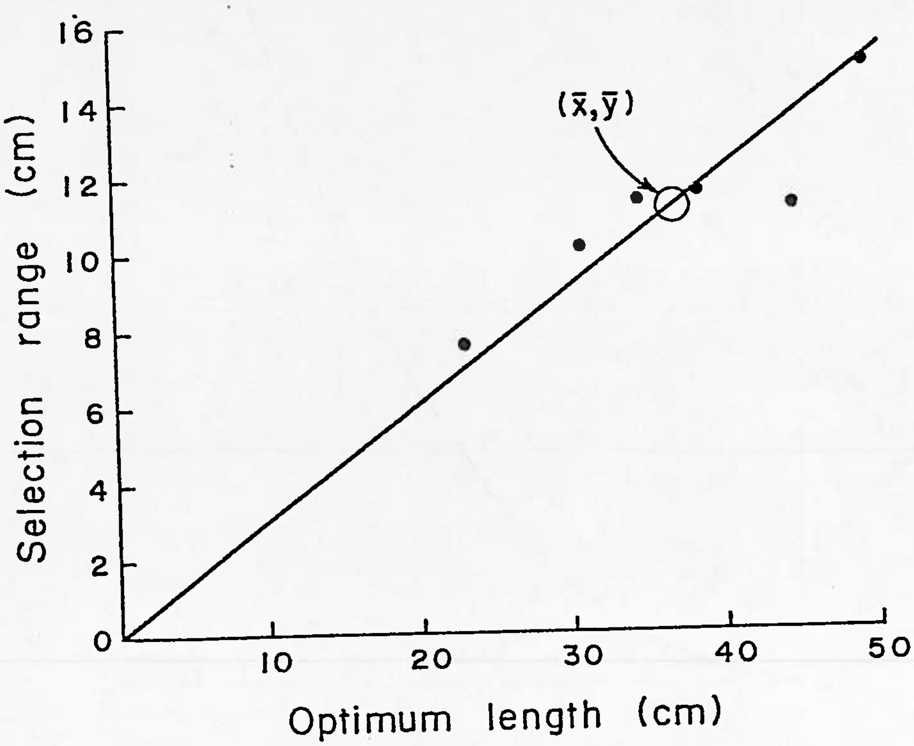


Fig. 12. Selection range (S.R.) *vs.* optimum length for skipjack tuna (see text for definition of S.R.).

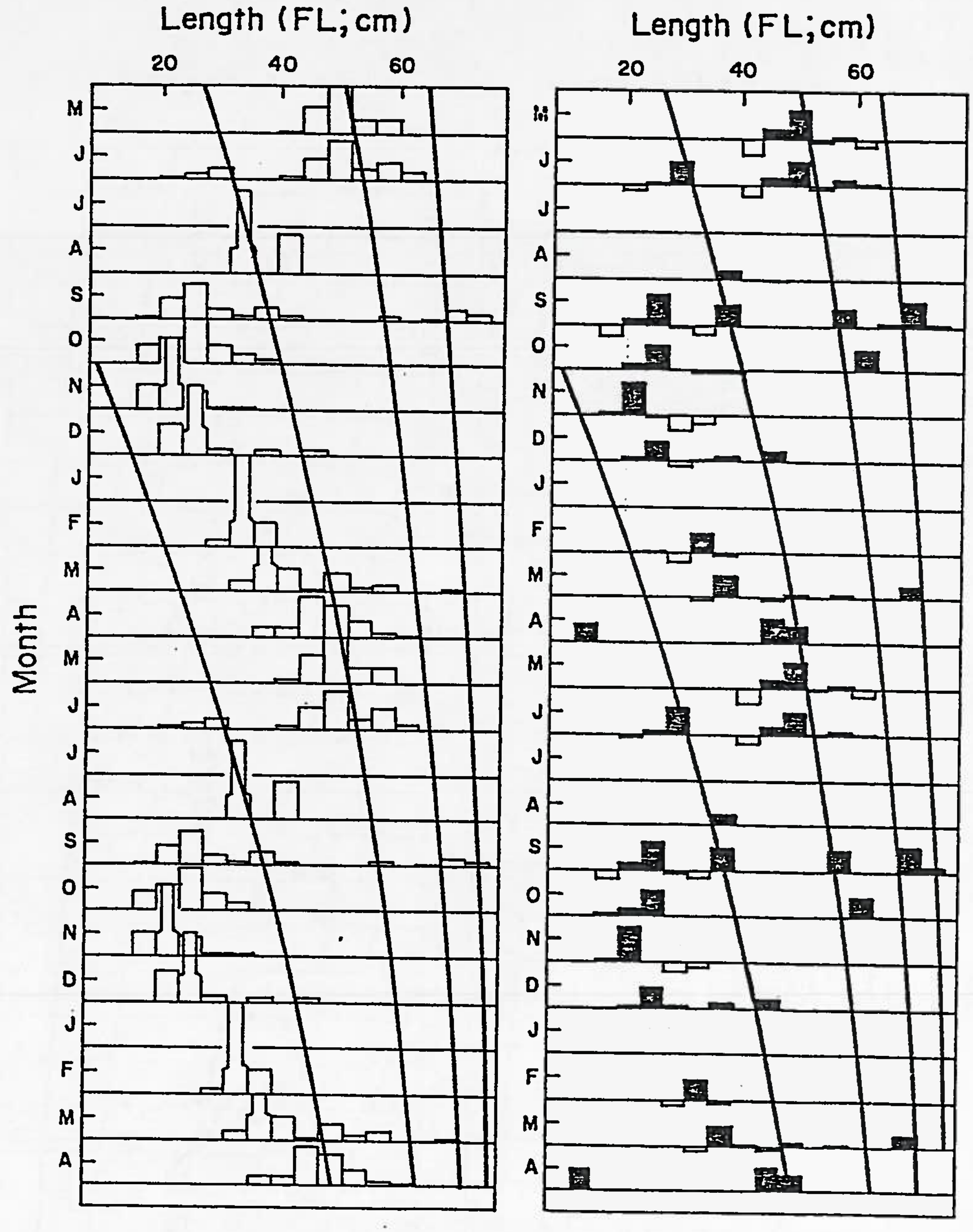


Fig. 13. Application of ELEFAN I to length-frequency data of skipjack landed 1980-1982 at Initao, Bohol Sea. *Left:* original data; *Right:* restructured data. Note that in both cases, some peaks are missed by growth curve, suggesting a second cohort (see text).

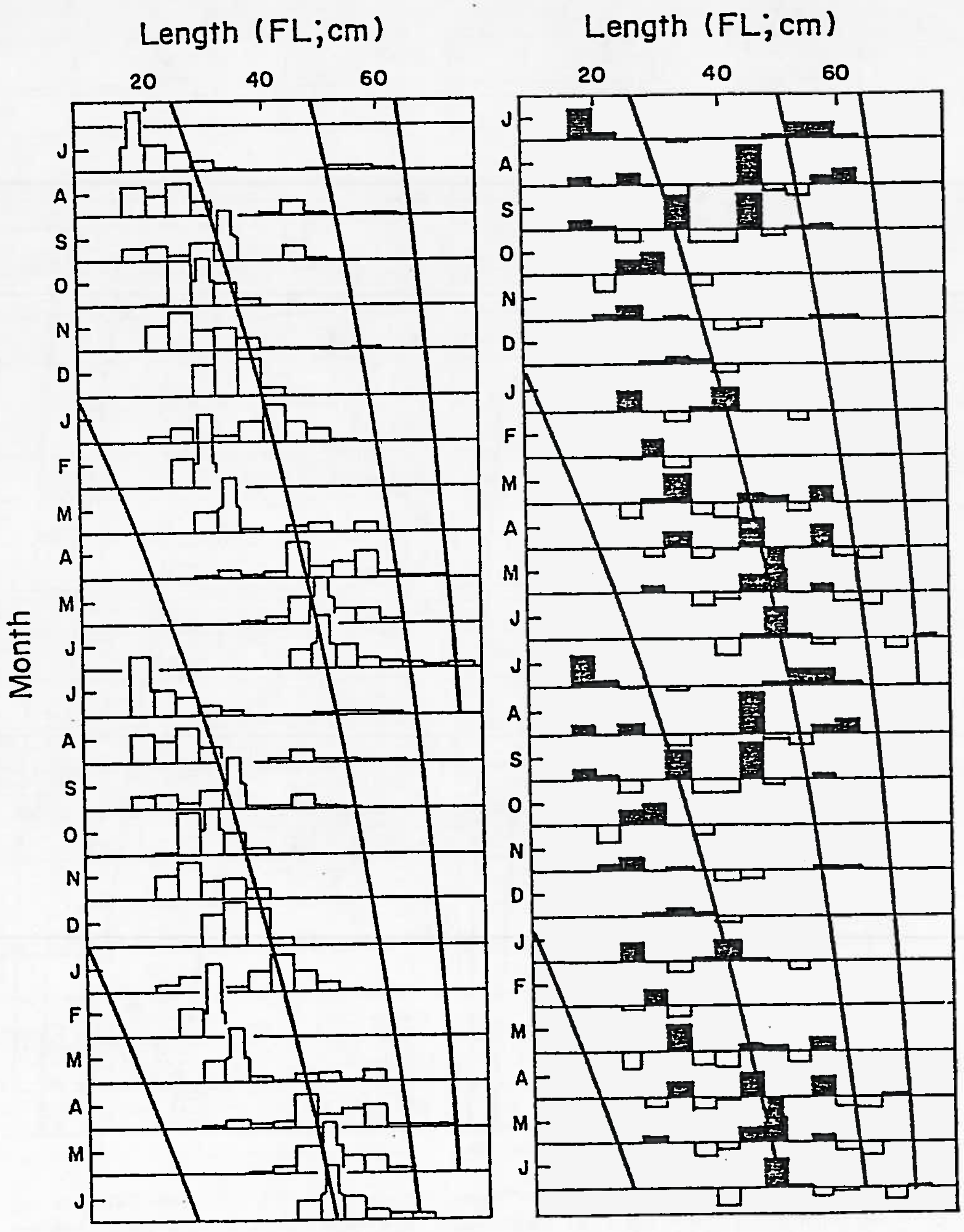


Fig. 14. Application of ELEFAN I to length-frequency data of skipjack landed 1979-1980 at Opol, Bohol Sea. *Left:* original data; *Right:* restructured data. Note that in both cases some peaks are missed by growth curve, suggesting a second cohort (see text).

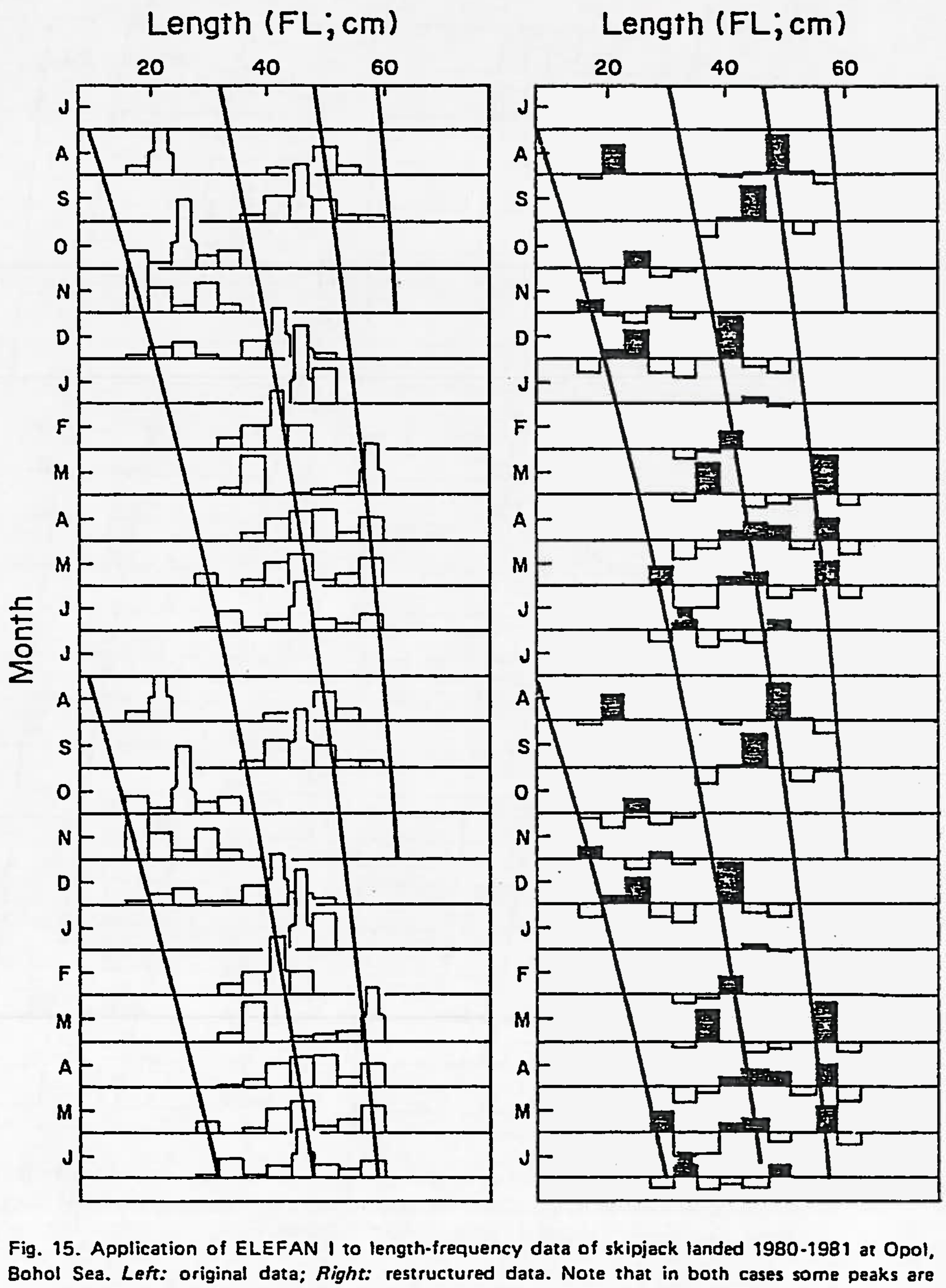


Fig. 15. Application of ELEFAN I to length-frequency data of skipjack landed 1980-1981 at Opol, Bohol Sea. *Left:* original data; *Right:* restructured data. Note that in both cases some peaks are missed by growth curve, suggesting a second cohort (see text).

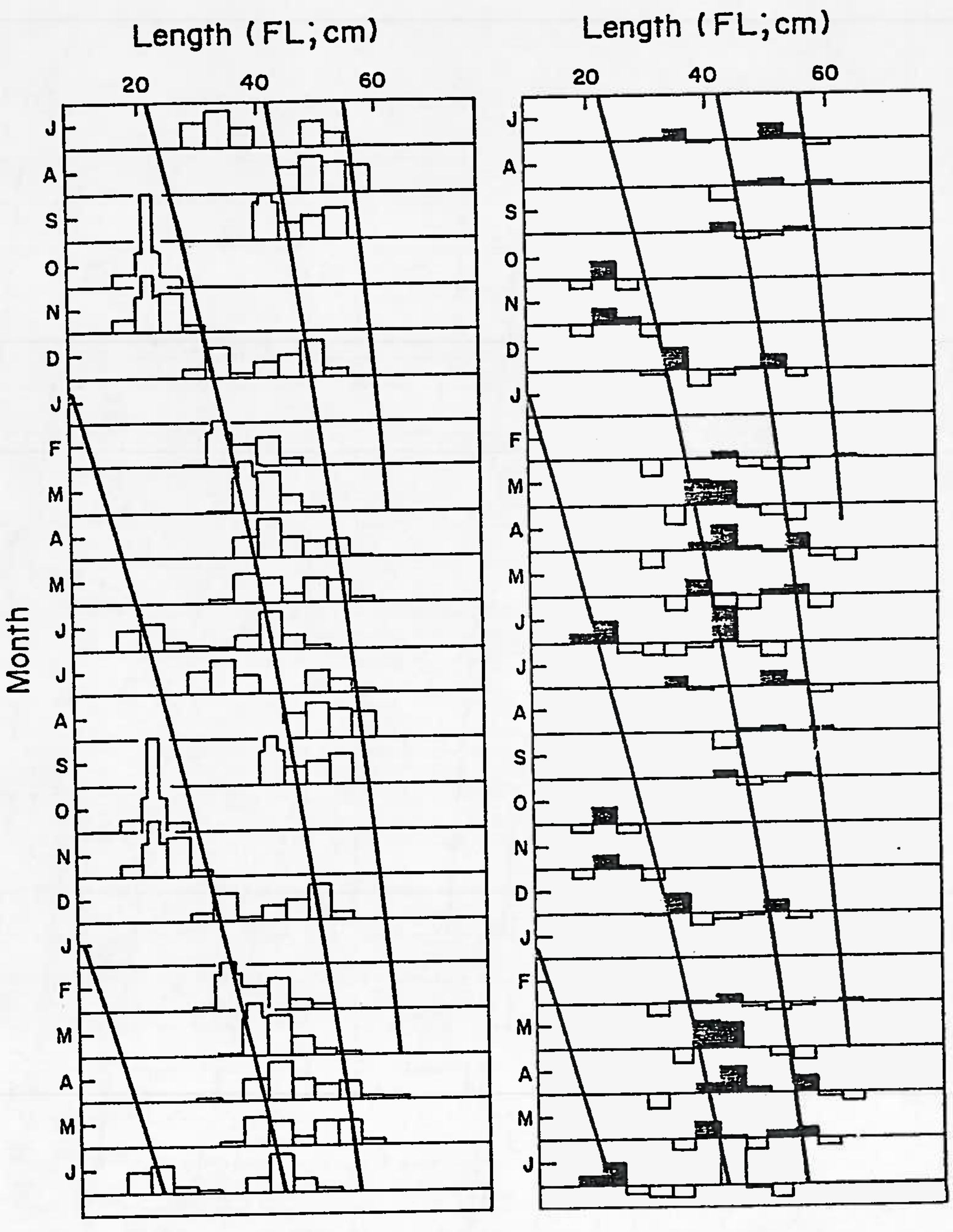


Fig. 16. Application of ELEFAN I to length-frequency data of skipjack landed 1981-1982 at Opol, Bohol Sea. *Left:* original daata; *Right:* restructured data. Note that in both cases some peaks are missed by growth curve, suggesting a second cohort (see text).

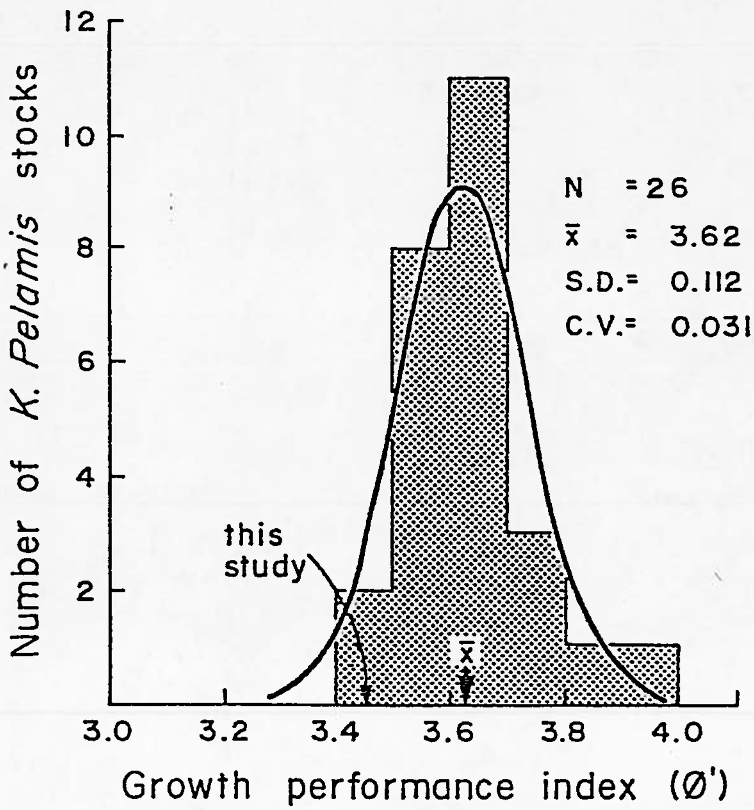


Fig. 17. Frequency distribution of ϕ' in 26 skipjack stocks.

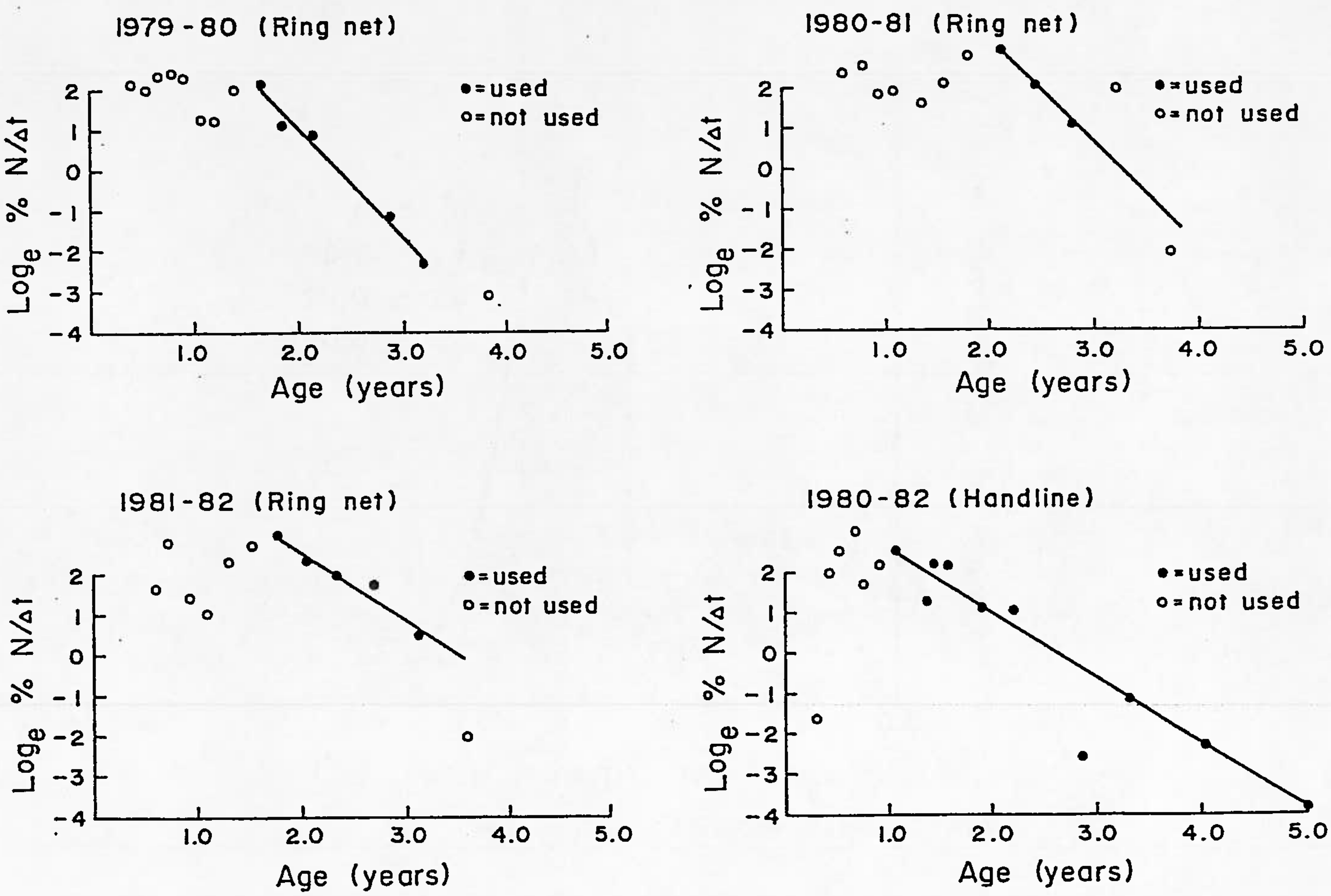


Fig. 18. Length-converted catch curves for skipjack caught by handline and ring net from the Bohol Sea, 1979-1982.