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PRELIMINARY OBSERVATIONS ON JUVENILE SKIPJACK FROM THE STOMACHS OF ADULT SKIPJACK CAUGHT BY POLE-AND-LINE GEAR

by

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1.0 INTRODUCTION

An important aspect of the Skipjack Survey and Assessment Programme is investigation of skipjack (*Katsuwonus pelamis*) feeding behaviour and early life history through examination of stomach contents. Studies of stomach contents from billfishes and tunas (e.g. Waldron and King, 1963; Yoshida, 1971; Mori, 1972) have provided some insight into the distribution, growth and relative abundance of juvenile tunas in the range of 2cm to 35cm. As well, cannibalism by tunas may have important population regulation consequences, as speculated by Kearney (1978). To examine these early life history and predator/prey relations, the Skipjack Programme made a special effort to collect and identify a large number of tuna juveniles from the stomach contents of tunas caught during the Skipjack Programme.

This background document to the Twelfth South Pacific Commission Regional Technical Meeting on Fisheries presents preliminary results of stomach analyses for tuna juveniles from the Programme's first two survey cruises, between October 1977 and July 1979. Due to the preliminary nature of these results, and because cruise three data are not yet available, results are presented in the form of tables and figures with minimal written comment. The presentation concentrates on skipjack since they were the primary species studied and were the dominate tuna species in the catch, as well as in the stomachs.

This aspect of the Skipjack Programme is a collaborative effort between the South Pacific Commission and Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM).

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2.0 COLLECTION METHODS

The Programme's primary biological objective is assessment of migration and stock structure for skipjack tuna in the western and central Pacific Ocean through tagging (Anon, 1975), thus most fish were released alive with tags. However, from each school that was fished by the Programme's pole-and-line vessel, the Hatsutori Maru, there were generally at least five fish which were unsuitable for tagging for a variety of reasons, e.g. hook injuries. During the first survey cruise, a maximum of five of these fish per school were measured (fork length and weight) and were examined for stomach content and maturity. Scientists on board the research vessel retained, from the stomachs, all individual fish (or portions of fish) that were thought to be tuna juveniles. All specimens from a single predator were placed in individual "press-seal" plastic bags, which in turn were punctured and placed in a plastic bottle containing 10 percent formalin.

For the second survey cruise, stomachs from up to an additional 15 fish per school were examined for tuna juveniles. Preservation of juveniles for this cruise involved initial fixation in 80 percent ethanol, followed several days later by placement in a clean ethanol solution. This was done to avoid damaging the otoliths.

Stomach examinations were of two types, full examination and examination for tuna juveniles only. A maximum of five fish from each school were given the full examination, that is all stomach contents were classified to broad, easily recognized taxonomic categories.

A total of 7,107 stomachs from tuna were examined for presence of tuna juveniles (Table 1); 23 percent of the samples were from temperate areas - New South Wales, Australia and North Island, New Zealand. Over 97 percent (794) of juveniles returned from the vessel were tunas, and two thirds of these (534) were skipjack (Table 2). Stomachs from 5,956 skipjack were examined; 3,312 of these stomachs were given a full examination.

3.0 IDENTIFICATION OF TUNA JUVENILES

Samples were accumulated on board the research vessel and were forwarded every two to three months to the Noumea laboratory of ORSTOM where one of us (F. Conand) identified each specimen to species, whenever possible, and measured intact specimens for standard length. For damaged skipjack specimens, standard lengths were estimated using one of the appropriate regression equations of Yoshida (1971), or in cases when this was impossible, lengths were estimated from pieces of the vertebral column and skull. Otoliths were removed and dry-stored with a view to estimating age, at a later date, in collaboration with scientists from the Inter-American Tropical Tuna Commission (IATTC).

TABLE 1 - NUMBER OF STOMACHS EXAMINED FOR THE PRESENCE OF TUNA JUVENILES

SAMPLING LOCATION	DATE	SKIPJACK	YELLOWFIN	OTHERS	TOTAL
Papua New Guinea	October 1977	164	29	35	228
Solomon Islands	November 1977	189	37	22	248
New Caledonia	December 1977 - January 1978	473	22	18	513
Vanuatu	December 1977 - January 1978	130	13	11	154
Fiji	February - April 1978	255	94	9	358
Tonga	April 1978	104	68	22	194
Wallis and Futuna	May 1978	324	20	9	353
American and Western Samoa	June 1978	63	23	31	117
Tuvalu	June 1978	348	71	28	447
Kiribati	July 1978	184	14	25	223
Marshall Islands	August 1978 and November 1978	6	0	0	6
Caroline Islands	August 1978 and October 1978	181	45	8	234
Mariana Islands	October 1978	28	7	1	36
Bonin Islands	October 1978	20	0	0	20
Tokelau	November 1978	24	2	0	26
Northern Cook Islands	December 1978	200	7	0	207
Southern Cook Islands	February 1979	6	0	0	6
Society Islands	December 1978 - January 1979	181	5	0	186
Tuamotu Archipelago	December 1978 - January 1979	531	35	1	567
Marquesas Islands	January 1979	263	2	0	265
New Zealand	February - March 1979	652	0	37	689
New South Wales	April 1979	595	3	49	647
Queensland	May 1979	270	35	2	307
Papua New Guinea	June 1979	765	219	92	1,076
TOTAL		5,956	751	400	7,107

TABLE 2 - NUMBER OF TUNA JUVENILES OBSERVED IN STOMACHS

SAMPLING LOCATION	DATE	SKIPJACK	YELLOWFIN + BIGEYE	ALBACORE	FRIGATE TUNA	MACKEREL TUNA	TOTAL
Papua New Guinea	October 1977	49	1	1	0	0	51
Solomon Islands	November 1977	15	2	0	15	3	35
New Caledonia	December 1977 - January 1978	48	0	0	5	4	57
Vanuatu	December 1977 - January 1978	40	3	1	69	4	117
Fiji	February - April 1978	26	0	0	0	0	26
Tonga	April 1978	7	0	0	3	0	10
Wallis and Futuna	May 1978	169	1	15	0	0	185
American and Western Samoa	June 1978	8	0	0	0	0	8
Tuvalu	June 1978	5	0	0	0	0	5
Kiribati	July 1978	1	0	0	0	0	1
Marshall Islands	August 1978 and November 1978	0	0	0	0	0	0
Caroline Islands	August 1978 and October 1978	10	1	0	0	0	11
Mariana Islands	October 1978	1	0	0	0	0	1
Bonin Islands	October 1978	0	0	0	0	0	0
Tokelau	November 1978	0	0	0	0	0	0
Northern Cook Islands	December 1978	16	0	0	0	1	17
Southern Cook Islands	February 1979	0	0	0	0	0	0
Society Islands	December 1978 - January 1979	1	0	0	0	0	1
Tuamotu Archipelago	December 1978 - January 1979	57	0	20	0	0	77
Marquesas Islands	January 1979	16	0	8	53	43	120
New Zealand	February - March 1979	0	0	0	0	0	0
New South Wales	April 1979	0	0	0	0	0	0
Queensland	May 1979	11	0	1	1	0	13
Papua New Guinea	June 1979	54	0	0	2	3	59
TOTAL		534	8	46	148	58	794

Most of the parameters used to identify tuna juveniles were based on the anatomy of the vertebral column. Figure 1, from Potthoff and Richards (1970), shows the general features of the axial skeleton and the key vertebral parts used for identification. Table 3 summarizes the important features used by various authors (principally Gibbs and Collette, 1967; Nakamura, 1965a; Potthoff, 1974; Potthoff and Richards, 1970) to speciate tuna juveniles. These features warrant careful use due to individual specimen variation and the delicate nature of some characters, particularly on specimens damaged by early digestion. The use of alizarin dye, which stains the bones red, was often helpful in exposing the more obscure characters (e.g.the hemal prezygapophysis). Whenever possible, several distinguishing characteristics were chosen before identification was finalized.

Identification of tuna juveniles to the generic level is quite easy; identification to the species level is also possible, however, there are some problem species within the genus Thunnus. For this genus it is relatively easy to separate albacore (T. alalunga) from yellowfin (T. albacares) and bigeye (T. obesus), but separation of the latter two species is most difficult. For the time being we have lumped bigeye with yellowfin and have retained all these specimens in the hope that with more material separation will be possible.

Eleven specimens were sent to Dr Shoji Ueyanagi, Far Seas Fisheries Research Laboratory, Japan Fisheries Agency, for verification of identification. All of our identifications were confirmed by Dr Ueyanagi and his staff (pers.com.): three Katsuwonus pelamis, two Auxis sp., two Euthynnus affinis, two Thunnus alalunga, and two questionable T. obesus or T. albacares.

4.0 THE TOTAL SAMPLE

Skipjack juveniles dominated the total sample of tuna juveniles, and were clearly the most common tuna juvenile in the stomachs of skipjack and yellowfin - 3.3 and 2.3 percentage occurrence respectively (Table 4). Close to 90 percent of the skipjack juveniles (471) were found in the stomachs of their "parents". Frigate tuna, the next most common juvenile, were found in less than one percent of the stomachs examined.

5.0 DISTRIBUTION AND ABUNDANCE

The research vessel travelled extensively between 134°E and 140°W longitude and 25°N to 42°S latitude, obtaining large samples from most locations where adult skipjack were abundant. The annual cruise pattern proceeded first to the east and southeast, then south and finally returned in a west to north-westerly direction to Japan. Both cruises covered approximately the same 10 month period, that is October through July.

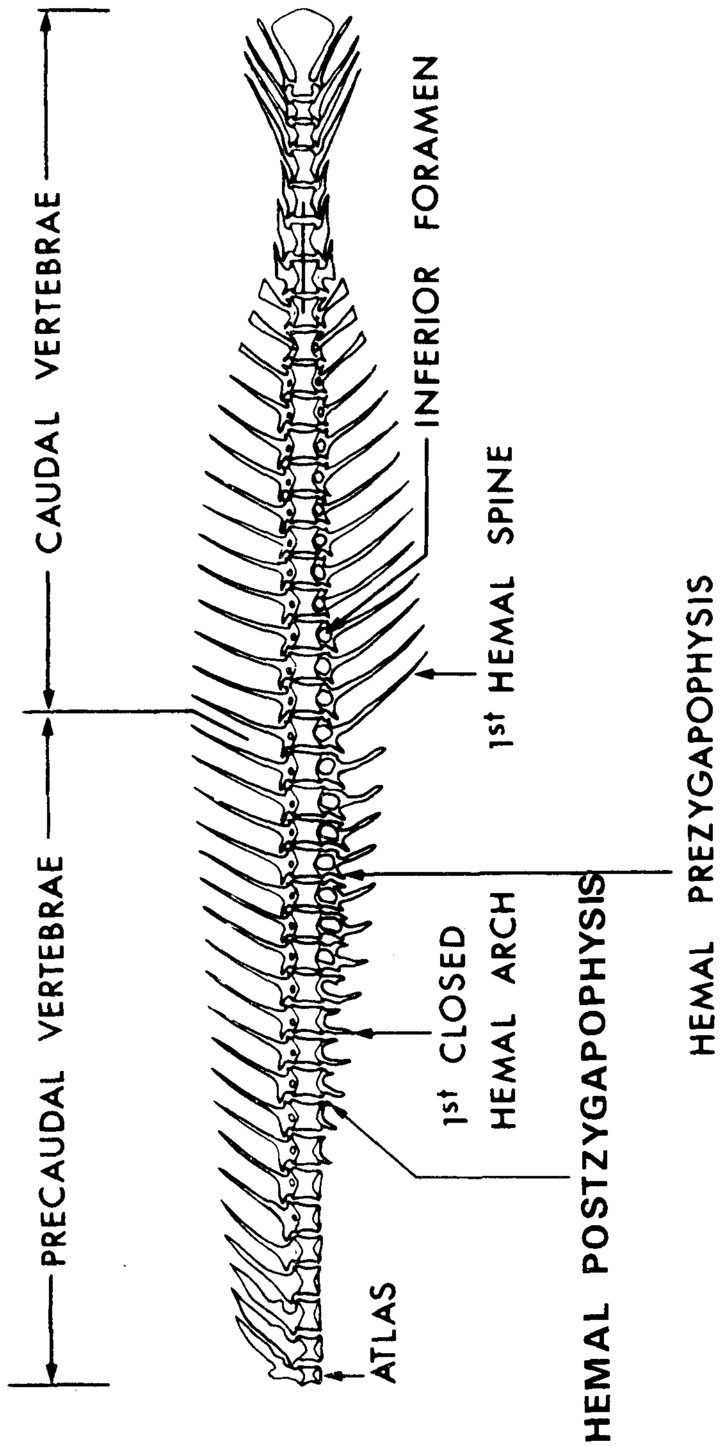

FIGURE 1 - The skeleton of *Katsuwonus pelamis* (65mm SL) showing diagnostic features used in this study (from Pothoff and Richards, 1970)

TABLE 3 - COMPARISON OF DIAGNOSTIC CHARACTERS FOR TUNA JUVENILES IN THE WESTERN AND CENTRAL TROPICAL PACIFIC*

	K. pelamis	*E. affinis*	*A. thazard*	*T. alalunga*	*T. albacares*	*T. obesus*
Number of vertebrae precaudal+caudal	20+21=41	20+19=39	20+19=39	18+21=39	18+21=39	18+21=39
First closed hemal arch on vertebra	12	16-18	17-21	10	11	11
First hemal prezygapophysis on vertebra	13-14	14-15	21-23	16-17	14-15	-
First hemal postzygapophysis on vertebra	-	-	-	8	6-7	6-7
First ventrolateral foramen on vertebra	13-15	16-17	27-30	23-25	20-22	22-23
Number of gill rakers on ceratobranchial	22-25	17-19	19-22	14-16	14-16	14-16

* Principal sources: Gibbs and Collette, 1967; Nakamura, 1965a; Potthoff, 1974; Potthoff and Richards, 1970)

TABLE 4 - PERCENTAGE OCCURRENCE OF TUNA JUVENILES IN THE STOMACHS OF PREDATORS

	PREDATORS		
Tuna Juveniles	Skipjack	Yellowfin	Other species
Skipjack *Katsuwonus pelamis*	3.32% (198)*	2.26% (17)	-
Yellowfin *Thunnus albacares*	0.12% (7)	-	-
Frigate tuna *Auxis thazard*	0.72% (43)	0.40% (3)	-
Albacore *Thunnus alalunga*	0.57% (34)	-	-
Mackerel tuna *Euthynnus affinis*	0.29% (17)	0.26% (2)	0.25% (1)
TOTAL	4.21% (251)	2.53% (19)	0.25% (1)
SAMPLE SIZE	5,956	751	400

* Number of fish containing juveniles in brackets

5.1 Geographical Distribution

The number of skipjack juveniles per 100 adult skipjack stomachs examined is presented for each survey area (Figure 2). Survey areas generally represent countries, or sampling divisions within a country where the distance covered was great (e.g. New South Wales and Queensland in Australia).

Numbers of juveniles per 100 stomachs represents an approximate index of juvenile tuna abundance, i.e. apparent abundance. From the Figure it appears that juveniles were most abundant near larger land masses in tropical countries such as Fiji, New Caledonia, Wallis and Futuna Islands, Western Samoa, Vanuatu and Papua New Guinea. North of the equator and south of 25°S, skipjack juveniles were less abundant. For example, none were found from large samples in temperate waters off south-eastern Australia and northern New Zealand.

5.2 Seasonal Distribution

Skipjack stomachs from the equator to 25°S contained skipjack juveniles during each of four three month intervals; differences in apparent abundance between these periods were not great (Table 5). With inclusion of data from the third cruise there will be a larger data base for more detailed examination of seasonal fluctuations.

TABLE 5 - SEASONAL INCIDENCE OF JUVENILE SKIPJACK IN THE STOMACHS OF ADULT SKIPJACK CAUGHT BETWEEN 0° AND 25°S

	Skipjack Examined (Nx)	Skipjack Juveniles Found (n)	Incidence (n/Nx)100
February to April	359	24	6.7
May to July	1,770	238	13.5
August to October	164	16	9.8
November to January	1,997	181	9.1

6.0 PREDATOR/PREY OBSERVATIONS

The observations presented below are for the full data set from the first two cruises. Seasonal and geographical differences may exist in this data set, although they were not obvious from the preliminary analyses. Final analyses of the full data set will fully explore these potential sources of variability.

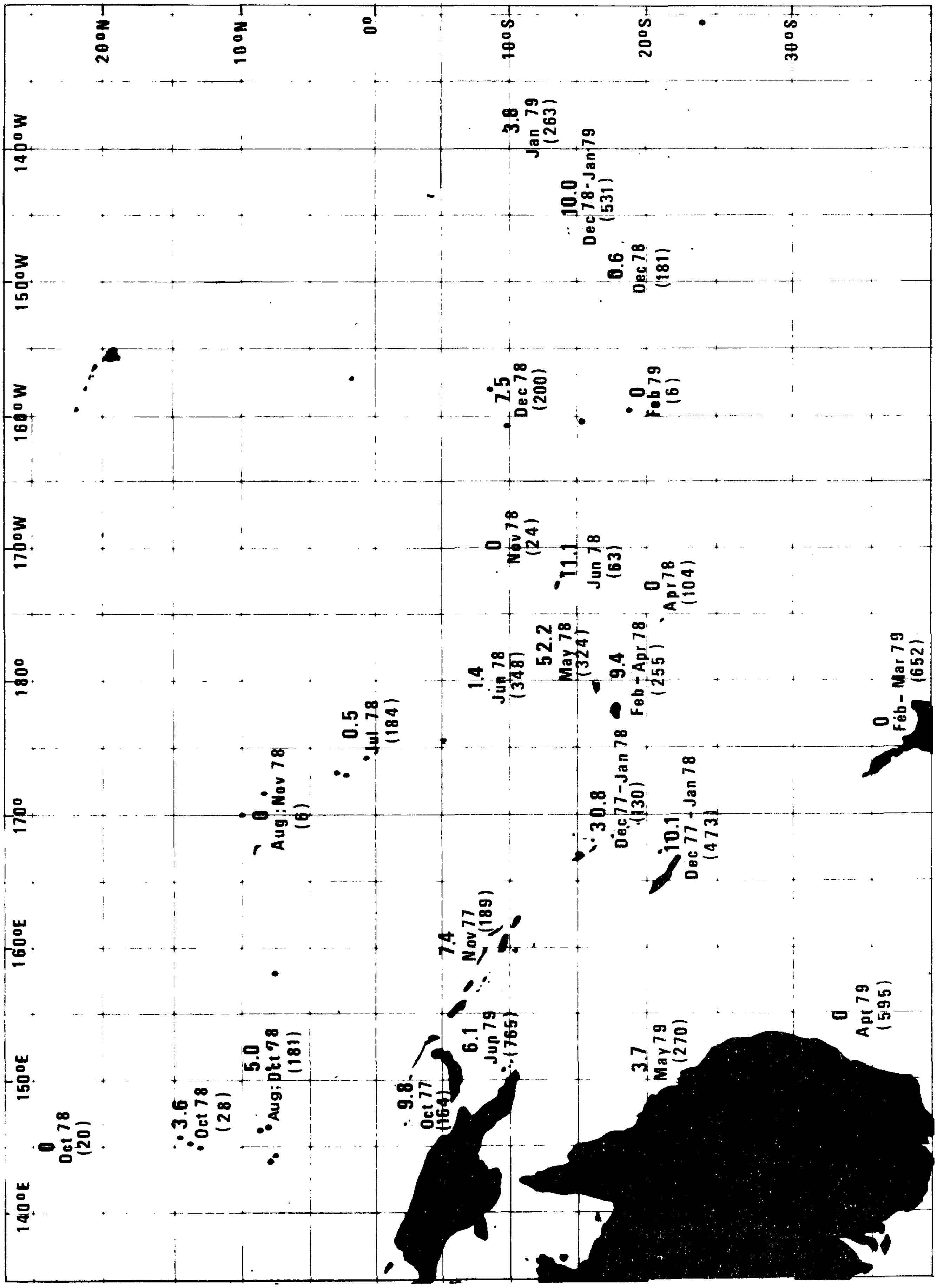

FIGURE 2 - Geographical distribution of the number of juvenile skipjack per 100 stomachs of adult skipjack examined, sample date and sample size (brackets) indicated.

6.1 Size

The modal length for skipjack prey fell between 7cm and 7.5cm (Figure 3). The frequency distribution of these standard lengths was skewed with a few prey larger than 20cm. Most juvenile skipjack fell within the range of 2cm to 14cm, a similar range to that found by Nakamura (1965b) for juvenile skipjack eaten by adult skipjack in the waters of French Polynesia.

Prey size was poorly correlated with predator size (Figure 4). On the other hand one can see that the scattergram presents an "envelope" of prey versus predator size, such that small skipjack predators (< 45cm) take primarily the small skipjack prey (< 10cm), whereas predators greater than 45cm capture skipjack prey from the smallest size, 2cm, up to 20cm standard length.

The tendency for large skipjack predators to prey on a wide size range of juvenile skipjack is further illustrated in Figure 5. What may be of greater importance is the relationship between predator size and frequency of occurrence of skipjack prey (the ratio No/Nx below where No is the number of predators containing juvenile skipjack prey and Nx is the number of predators examined for prey).

Size Class of Skipjack Examined (mm)	Prey Frequency of Occurrence No/Nx	Prey/Predator Examined n/Nx	Prey/Predator With Prey n/No
400-499	0.022	0.043	1.9
500-599	0.032	0.061	1.9
600-699	0.094	0.356	3.8

The largest skipjack had a higher frequency of occurrence of juvenile skipjack in their stomachs and presumably this reflects a higher predation rate. The relationship between total tuna juveniles found in skipjack predator stomachs and total skipjack stomachs examined, n/Nx, is more revealing : 40-49.9cm skipjack averaged 0.04 skipjack juveniles per stomach, whereas 60-69.9cm skipjack averaged 0.36 skipjack juveniles per stomach. Figure 6 suggests that this relationship, n/Nx versus predator size, increases in a curvilinear fashion with respect to predator size. It follows that number of prey per predator, n/No, is highest for larger skipjack predators. These results were not entirely unexpected since fish prey have been found by others (Dragovich, 1970; Dragovich and Potthoff, 1972; Yuen, 1959) to increase in importance in skipjack diets with increased skipjack size. As well, data from Waldron and King (1963) suggested that as skipjack increased in length, they shifted to oceanic fishes in their diets, e.g. to Scombrids and Nomeids.

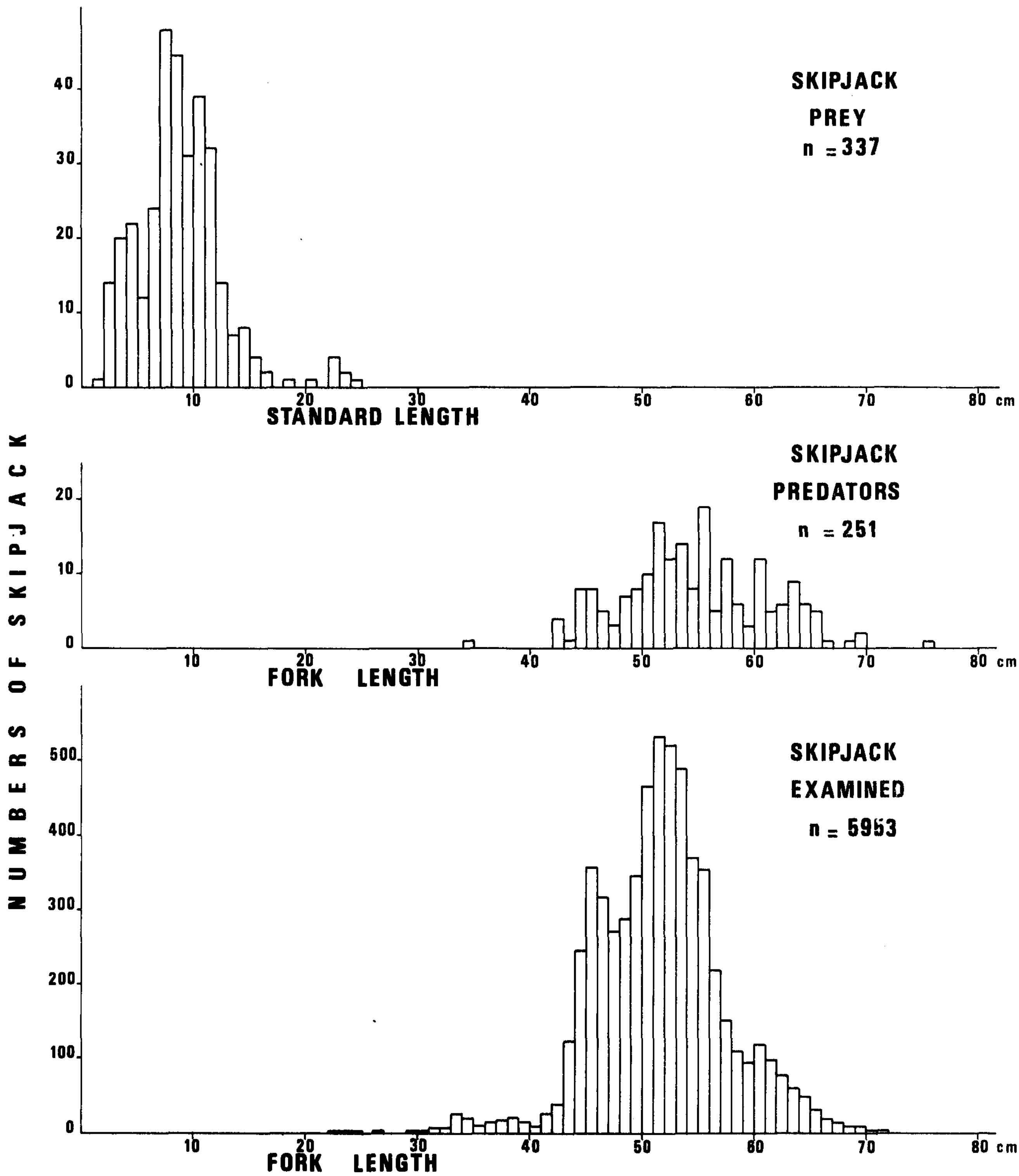

FIGURE 3 - Size distribution of skipjack juveniles from the stomachs of predators, where juveniles with estimated lengths are excluded (upper graph); skipjack with juveniles in their stomachs (middle); and all skipjack that were examined for presence of tuna juveniles (lower).

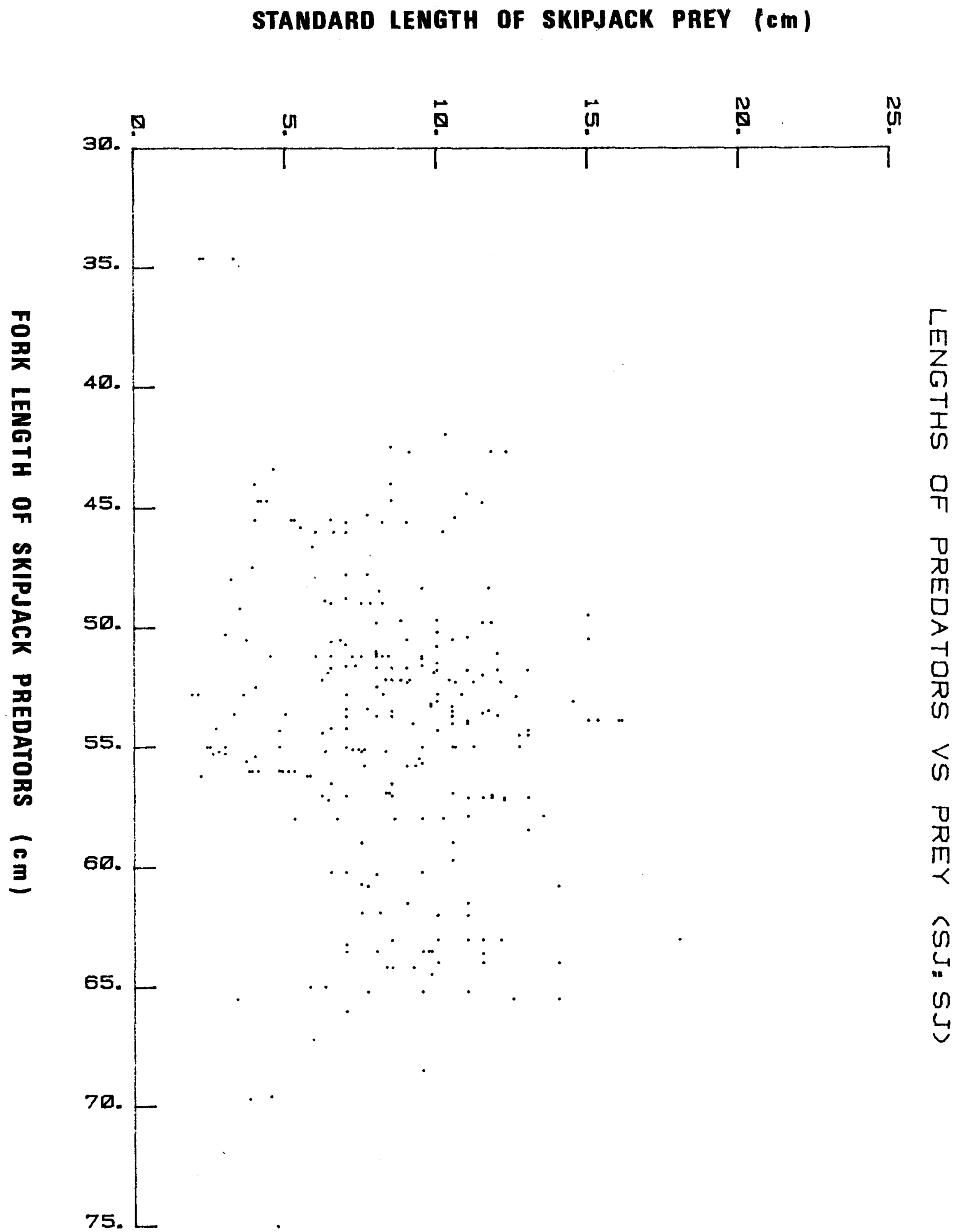

FIGURE 4 - The relationship between size of skipjack juveniles in the stomachs of skipjack predators, and the size of skipjack predators.

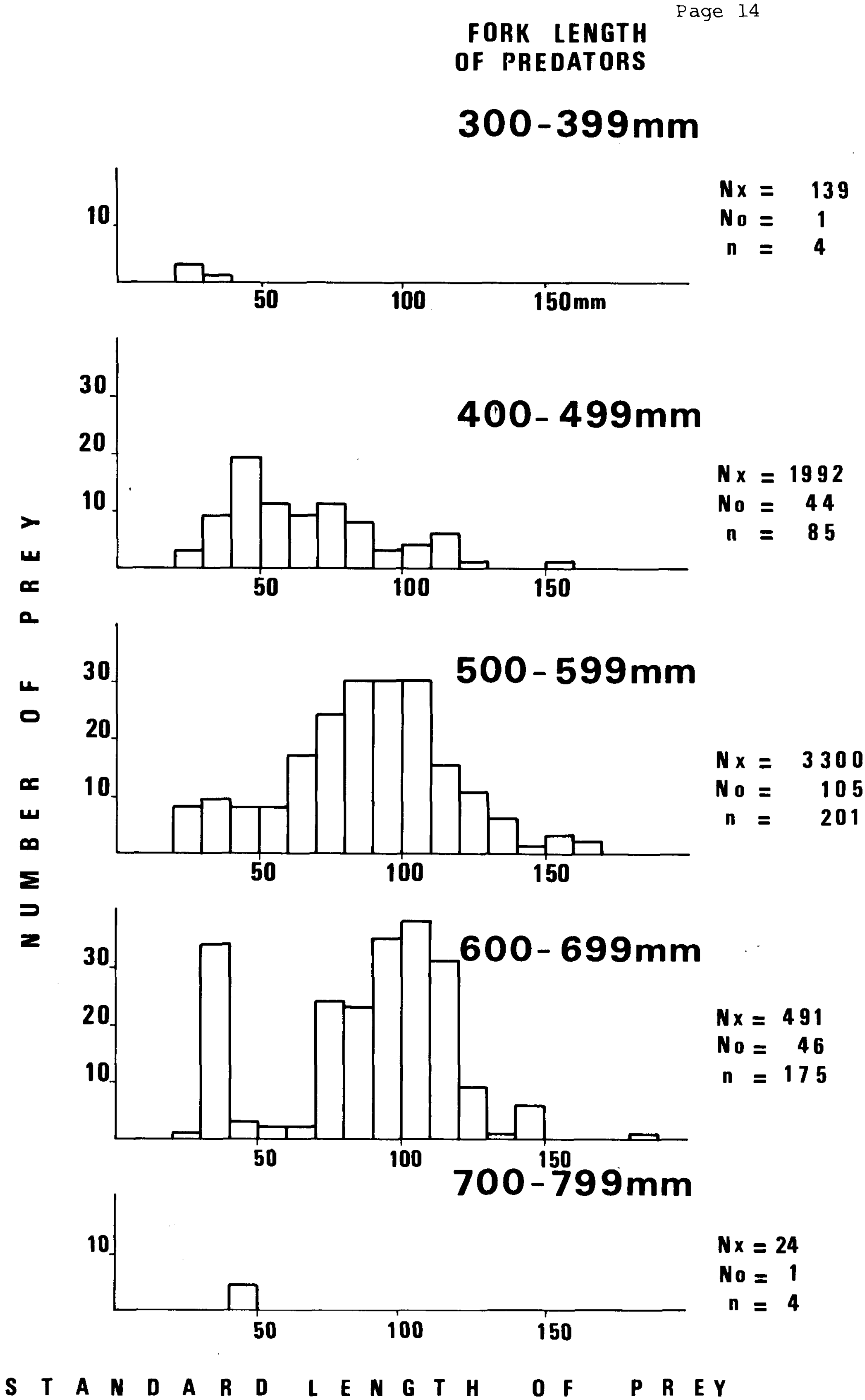

FIGURE 5 - Size frequency distribution for skipjack prey for each 10cm size class of skipjack predators on juvenile skipjack. N_x= number of skipjack examined for prey, N_o= number of skipjack predators with juvenile skipjack in their stomachs, n = number of skipjack juveniles found in skipjack predators. A few skipjack predators (and their prey) were excluded because they were missing fork length measurements.

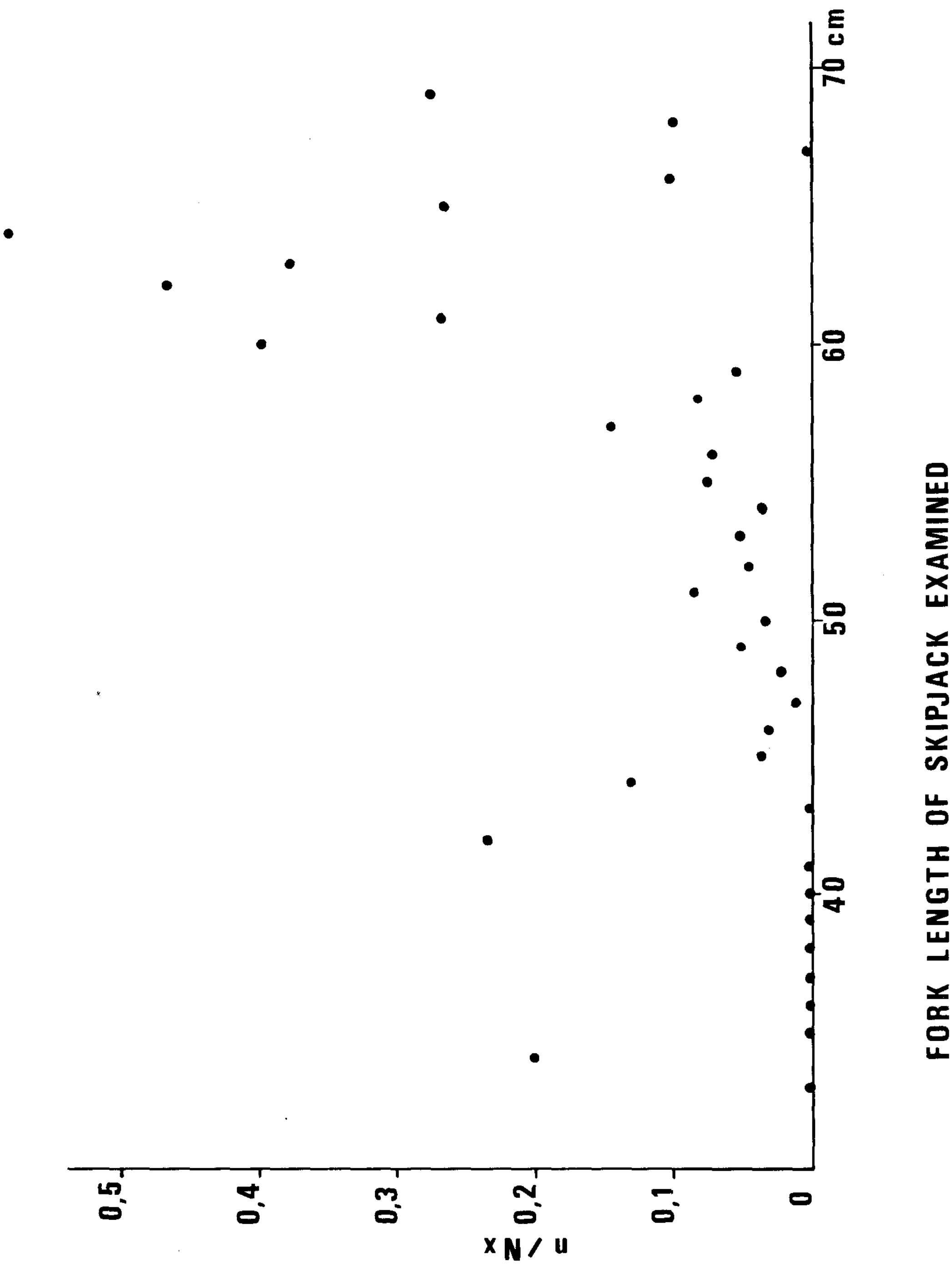

FIGURE 6 - Relationship between apparent abundance of skipjack juveniles (n/N_x) and the size of the skipjack that were examined for presence of skipjack juveniles. The relationship is graphed for each one centimetre length class of examined skipjack.

6.2 Time of Predation

Skipjack cannibalism appears most frequent in the early morning and late afternoon (Figure 7); as well, the number of prey per predator with prey, n/No, was highest between 0700 and 0800 hours (5.0 juveniles per adult predator), lowest midday (< 2.0), then rose slightly towards early evening (2.5). High values for the 1000 to 1100 hour interval result from a single skipjack school fished near Futuna Island in May 1978. For three combined time periods, as listed below, indicies showed significant (χ^2,1 df, $P < 0.05$) differences for the morning versus midday periods, and for the afternoon versus midday periods; with one exception; prey per predator was not significantly different for midday versus afternoon.

	Nx	100(No/Nx)	100(n/Nx)	n/No
0700 - 1000	1,738	3.8	12.5	3.74
1100 - 1400	1,976	2.2	4.0	1.95
1500 - 1800	2,128	4.2	8.2	1.97

6.3 Numbers of Prey per Predator

In Table 6 are the numbers of skipjack containing various numbers of skipjack juveniles in their stomachs. As discussed before, just over 3.3 percent contained one or more juvenile skipjack. Over 10 percent of the skipjack containing juveniles had over five juveniles in their stomachs - one had 22 in its stomach.

TABLE 6 - JUVENILE SKIPJACK IN THE STOMACHS OF ADULT SKIPJACK

Number Prey Per Predator	Observed Frequency	Percentage
0	5,750	96.67
1	100	1.68
2	46	0.77
3	19	0.32
4	11	0.19
5	4	0.07
6	5	0.08
7	3	0.05
8	6	0.10
11	1	0.02
13	2	0.03
22	1	0.02
TOTAL	5,956	100.00
MEAN NUMBER PER STOMACH	0.079	

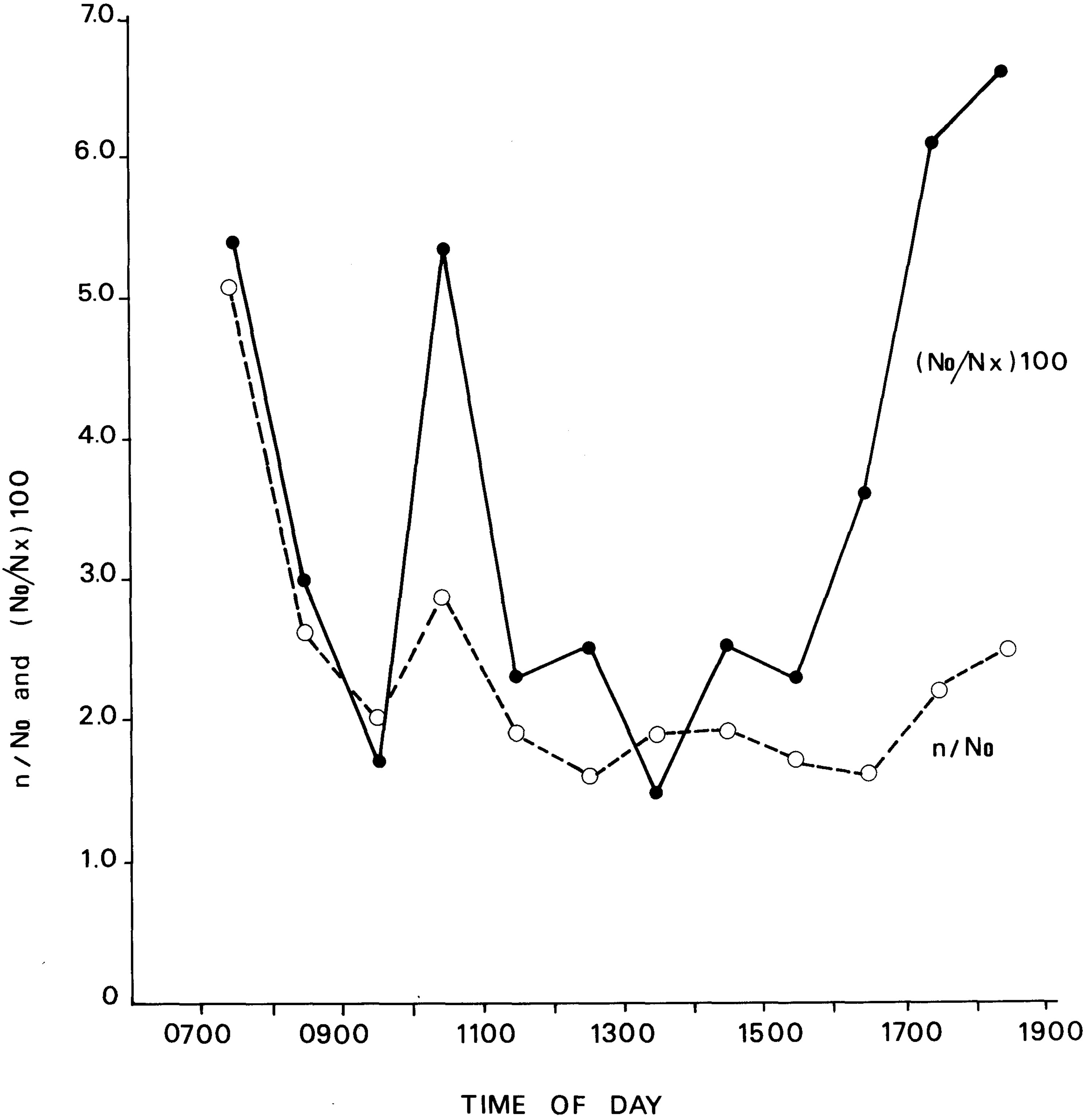

FIGURE 7 - Percentage occurrence of juvenile skipjack in stomachs of adult skipjack, 100 (N_o/N_x), and numbers of skipjack prey per skipjack predator, n/N_o, for skipjack captured during one hour periods between 0700 and 1900 hours.

The spatial distribution of juvenile skipjack may be clumped (perhaps due to a precursor schooling response), uniform or random. A chi-square comparison of observed and expected frequencies showed significant ($P < 0.01$) departure from a Poisson distribution. Since the variance/mean ratio was much greater than one, we conclude that the occurrence of juvenile skipjack is clumped (contagious distribution).

6.4 Other Stomach Contents

Stomach content analysis of tunas is a topic unto itself, and will be investigated further at a later date. For now we simply present the "other" stomach contents for 154 skipjack that contained tuna juveniles, and that were given a full stomach examination, in order to put consumption of tuna juveniles in some perspective.

The majority of skipjack with skipjack juveniles were caught during poling operations, rather than by troll gear, so it was not unexpected that various chum species were the dominant diet item (Table 7). In their stomachs these fish also had a wide spectrum of fish families (25 identified) and categories of crustaceans and molluscs (10), in addition to tuna juveniles (Table 7). Only 16 skipjack stomachs contained tuna juveniles exclusively, or tuna juveniles associated with chum. Thus in the total of 3,312 skipjack that were given a full stomach examination, 0.5 percent could be said to have been feeding exclusively on tuna juveniles prior to their capture.

7.0 SUMMARY

Stomachs from 5,956 skipjack, caught by pole-and-line gear over a wide area of the western and central Pacific Ocean were examined for the presence of tuna juveniles. Juvenile tuna were present in 4.2 percent of the skipjack stomachs examined. Juvenile skipjack in the range of 2cm to 14cm standard length were present in 3.3 percent of the skipjack stomachs examined. Juvenile skipjack apparent abundance, as measured by the number of juveniles per stomach examined, appeared highest near the larger land masses in tropical countries such as Papua New Guinea, Wallis and Futuna Islands, Western Samoa, New Caledonia, Fiji, and Vanuatu. Skipjack juveniles were absent from large samples taken in the temperate waters of Australia and New Zealand.

Within the size range of 30cm to 70cm, larger skipjack had a higher incidence of skipjack juveniles in their stomachs than did smaller skipjack. Skipjack juveniles were most common in their "parent's" diet in the morning, before 1000 hours, and in the late afternoon, after 1600 hours. Skipjack that were feeding on tuna juveniles also contained representatives from 25 fish families and 10 categories of invertebrates in their stomachs.

TABLE 7 - STOMACH CONTENTS OF SKIPJACK THAT CONTAINED TUNA JUVENILES

Item No.	Diet Item	Number of Stomachs	Percentage of Occurrence
	FISH		
1	Chum	112	72.73
2	Fish remains (not chum)	72	46.75
* 3	Acanthuridae	39	25.33
* 4	Holocentridae	22	14.29
5	Gempylidae	19	12.34
6	Carangidae (Decapterus spp.)	14	9.09
* 7	Balistidae	12	7.79
* 8	Mullidae	12	7.79
9	Siganidae	12	7.79
*10	Aluteridae	12	7.79
*11	Chaetodontidae	12	7.79
12	Engraulidae (Stolephorus buccaneeri)	9	5.84
13	Coryphaenidae	9	5.84
*14	Synodontidae	5	3.25
*15	Fistularidae	5	3.25
16	Exocoetidae	5	3.25
*17	Blenniidae	5	3.25
18	Sternoptychidae	3	1.95
19	Bramidae	3	1.95
*20	Anthiidae	2	1.30
21	Trichiuridae	1	0.65
22	Istiophoridae	1	0.65
*23	Diodontidae	1	0.65
*24	Leiognathidae	1	0.65
*25	Caesiodidae	1	0.65
*26	Scaridae	1	0.65
*27	Ostraciidae	1	0.65
28	Unidentified fish	5	3.25
	Total containing only Tuna Juveniles or Chum and Tuna Juveniles	16	10.39
	INVERTEBRATES		
29	Squids	77	50.00
30	Gastropods	2	1.30
31	Unidentified molluscs	1	0.65
32	Alima	20	12.99
33	Pelagic shrimp	14	9.09
34	Megalopa	5	3.25
35	Phyllosoma	5	3.25
36	Stomatopoda	1	0.65
37	Unidentified crustaceans	1	0.65
38	Coelenterata	1	0.65
	TOTAL STOMACHS GIVEN A FULL EXAMINATION	154	

* Reef originating fishes (from Nakamura 1965b)

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