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MONSOON-INDUCED SEASONALITY IN THE RECRUITMENT OF PHILIPPINE FISHES*

by

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Resumen

Se han estudiado en detalle los patrones del reclutamiento de 112 stocks de peces teleosteos de Filipinas, los cuales provienen de 23 familias, 34 géneros y 57 especies. El patrón de reclutamiento anual generalmente muestra una estructura bimodal con dos picos de fuerza diferente, separados por cuatro y ocho meses. Los estimados del reclutamiento fueron obtenidos por una proyección hacia atrás de los datos de frecuencia de longitudes, basándose en datos de 900 mil medidas de longitud realizadas entre 1958 y 1981.

Se muestra que esta periodicidad corresponde al patrón estacional del viento de los monzones en las Filipinas.

INTRODUCTION

Elucidating the factors which determine *between* year fluctuations in recruitment is one of the major tasks presently facing fisheries research (Bakun et al., 1982). However faced with the problem caused by a scarcity of data points, a number of workers have chosen to investigate *within* year fluctuations of recruitment in an attempt to identify factors which may affect reproductive success (see Johannes, 1978 for a review).

This paper is an investigation of the seasonality of recruitment of Philippine fishes based on the detailed analysis of a large body of length-frequency data using the computer programs ELEFAN I and II (Pauly and David, 1981; Pauly, 1982).

Pending a more detailed analysis, which will include a set of climatological and hydrological data, the general features of the recruitment patterns of Philippine fishes are presented here to allow comparisons with data obtained from areas with oceanographic and climatological regimes different from that of the Philippines.

The data presented here also allow for comparisons with inferences drawn earlier by other authors on the spawning and recruitment seasons of Philippine fishes. Concerning these earlier studies, it must be mentioned, however, that the conceptual difference between a *spawning* and a *recruitment* season had generally not been made, i.e., studies on gonadal maturation stages and analyses of length-frequency data were both used in inferences regarding "spawning seasons". In the present study, we report only on the periodicity of *recruitment*.

MATERIAL AND METHODS

The materials used for this paper consist of length-frequency data sets from approximately 0.9 million fish, collected by individual researchers and the staff of several agencies (foremost, the Bureau of Fisheries and Aquatic Resources) from 1958 to 1981 at various locations throughout the Philippines (Fig. 1). The data cover 112 stocks of teleostean fishes, ranging in size from gobies to tuna and covering 23 families, 34 genera and 57 species (Table 1). These raw data and their sources are fully documented in Ingles and Pauly (1982) and detailed analyses are given in Ingles and Pauly (in press).

Each length-frequency data set was analyzed in terms of growth using the ELEFAN I program of Pauly and David (1981) Applications of this method have been presented in a number of papers (Pauly and David, 1981; Pauly and Ingles, 1981; Pauly and Tsukayama, this volume) and the reader is referred to these for details on the method. The growth parameters L_∞ and K of the von Bertalanffy Growth Function (VBGF) extracted from the length-frequency data described above are given in Ingles and Pauly (1982).

Once growth parameters pertaining to a given stock have been extracted, they can be used to project the data backward onto the time axis such that the pattern of recruitment which generated the structure of the length-frequency data set can be reconstructed (Fig. 2). A computer program named ELEFAN II (Electronic LEngth Frequency ANalysis) which has the computation of recruitment pattern as one of its major routines (Pauly, 1982) was used for this purpose.

Recruitment patterns, as defined and computed by ELEFAN II have the following features:

a) Their exact position on the time axis is known only when t_0, the third parameter of the VBGF, is known. Since length-frequency data alone do not allow the estimation of t_0, the abscissa of recruitment patterns is not fixed in real time, and is therefore labelled "1 year" (see Fig. 2).

b) They always include one month with zero recruitment. This is due to the fact that when the projections of the length-frequency data onto the time axis is completed, the lowest of their 12 monthly values of apparent recruitment is subtracted from each of the 12 monthly values; this is

Table 1. Summary of data on the recruitment patterns of 112 fish stocks from Philippine waters. Stock numbers refer to classification in Ingles and Pauly 1982 and Ingles and Pauly, in press.[a]

Stock identification #	Species	% in smaller of two recruitment pulses[b]	Smaller time between two recruitment pulses (mo)[c]	Sample size
1	*Sardinella fimbriata*	43.7	5.1	1253
2	*Sardinella fimbriata*	26.0	4.3	166
3	*Sardinella longiceps*	30.8	4.6	1870
4	*Sardinella longiceps*	–	–	6191
5	*Sardinella melanura*	28.3	3.0	794
6	*Sardinella sirm*	–	–	211
7	*Stolephorus commersonii*	8.3	3.4	9422
8	*Stolephorus heterolobus*	19.5	5.4	2087
9	*Stolephorus heterolobus*	8.9	4.3	2345
10	*Stolephorus indicus*	37.7	2.7	3402
11	*Stolephorus indicus*	–	–	6514
12	*Stolephorus zollingeri*	6.5	4.3	29388
13	*Stolephorus zollingeri*	28.0	3.3	40864
14	*Stolephorus zollingeri*	10.6	4.2	6029
15	*Saurida tumbil*	18.0	4.7	4174
16	*Saurida tumbil*	21.5	5.4	589
17	*Saurida undosquamis*	–	–	26262
18	*Hemirhamphus georgii*	35.3	3.3	5098
19	*Ambassis gymnocephalus*	17.4	6.7	1477
20	*Epinephelus sexfasciatus*	32.1	4.5	738
21	*Therapon plumbeus*	31.8	4.3	1588
22	*Therapon theraps*	30.7	2.4	2014
23	*Priacanthus tayenus*	33.7	5.4	3672
24	*Sillago sihama*	13.7	2.8	4652
25	*Decapterus macrosoma*	33.3	5.8	3349
26	*Decapterus macrosoma*	9.0	3.5	9781
27	*Decapterus macrosoma*	28.2	2.7	4075
28	*Decapterus macrosoma*	75.2	3.2	25021
29	*Decapterus macrosoma*	26.9	1.8	13528
30	*Decapterus macrosoma*	10.9	2.2	34836
31	*Decapterus macrosoma*	11.2	2.8	8108
32	*Decapterus macrosoma*	5.3	5.8	625
33	*Decapterus macrosoma*	0.8	3.5	1949
34	*Decapterus macrosoma*	2.9	3.9	3079
35	*Decapterus macrosoma*	16.5	4.8	339
36	*Decapterus macrosoma*	35.5	3.0	16919
37	*Decapterus macrosoma*	3.0	4.5	11985
38	*Decapterus russelli*	6.0	4.1	13462
39	*Decapterus russelli*	5.8	4.4	7026
40	*Decapterus russelli*	5.9	4.2	11091
41	*Decapterus russelli*	2.0	4.1	7092
42	*Decapterus russelli*	14.7	3.8	9116
43	*Elagatis bipinnulatus*	–	–	128
44	*Selar crumenopthalmus*	17.8	5.3	2287
45	*Selaroides leptolepis*	20.8	5.0	4440
46	*Selaroides leptolepis*	13.3	4.1	1389
47	*Mene maculata*	1.2	5.1	2160
48	*Gazza minuta*	34.1	4.9	854
49	*Gazza minuta*	14.8	3.4	511
50	*Leiognathus bindus*	16.1	4.7	6286
51	*Leiognathus bindus*	31.6	4.8	2074
52	*Leiognathus bindus*	1.7	4.0	1002
53	*Leiognathus blochii*	5.6	5.3	615
54	*Leiognathus blochii*	16.8	4.3	1401
55	*Leiognathus blochii*	48.2	2.8	931
56	*Leiognathus blochii*	20.6	3.6	936
57	*Leiognathus brevirostris*	28.7	4.3	29669
58	*Leiognathus daura*	–	–	4074
59	*Leiognathus daura*	3.7	5.2	6140
60	*Leiognathus daura*	3.7	4.1	1301

Table 1 (Cont.)

#	Stock identification Species	% in smaller of two recruitment pulses[b]	Smaller time between two recruitment pulses (mo)[c]	Sample size
61	*Leiognathus equulus*	45.4	5.0	9660
62	*Leiognathus leuciscus*	18.7	4.0	1754
63	*Leiognathus leuciscus*	–	–	1872
64	*Leiognathus lineolatus*	3.4	4.5	1530
65	*Leiognathus lineolatus*	3.3	3.3	3326
66	*Leiognathus lineolatus*	5.0	3.6	1685
67	*Leiognathus splendens*	7.3	4.9	58090
68	*Leiognathus splendens*	17.6	2.9	67005
69	*Leiognathus splendens*	1.5	4.1	33879
70	*Leiognathus splendens*	7.6	5.3	95253
71	*Secutor insidiator*	38.2	3.9	3835
72	*Secutor insidiator*	–	–	1253
73	*Secutor insidiator*	–	–	181
74	*Secutor ruconius*	18.7	5.0	38051
75	*Secutor ruconius*	34.8	3.3	10217
76	*Secutor ruconius*	6.5	4.3	1820
77	*Nemipterus japonicus*	37.4	4.7	3665
78	*Nemipterus nematophorus*	29.2	3.6	1290
79	*Nemipterus nematophorus*	10.5	4.2	1477
80	*Nemipterus ovenii*	35.3	4.2	3276
81	*Pentaprion longimanus*	–	–	6174
82	*Pentaprion longimanus*	45.3	4.6	3454
83	*Pomadasys argyreus*	–	–	2014
84	*Pomadasys argyreus*	4.6	4.9	18476
85	*Pomadasys argyreus*	25.0	3.5	15217
86	*Pomadasys argyreus*	25.3	3.2	7727
87	*Dendrophysa russelli*	24.2	3.9	779
88	*Otolithes ruber*	49.9	3.4	1444
89	*Otolithes ruber*	44.2	4.2	1629
90	*Pennahia anea*	28.3	3.1	4354
91	*Pennahia macropthalmus*	20.0	4.0	498
92	*Upeneus moluccensis*	19.2	5.3	8594
93	*Upeneus sulphureus*	30.5	4.8	48547
94	*Upeneus sulphureus*	14.6	4.0	787
95	*Upeneus vittatus*	10.1	5.0	3816
96	*Scatophagus argus*	18.1	5.3	1977
97	*Liza subviridis*	44.9	4.3	6104
98	*Glossogobius giurus*	16.5	2.8	2191
99	*Glossogobius giurus*	16.3	3.5	1577
100	*Trichiurus lepturus*	8.5	3.6	3711
101	*Trichiurus lepturus*	22.7	2.7	3128
102	*Trichiurus lepturus*	19.0	4.1	11993
103	*Auxis thazzard*	27.9	6.2	1518
104	*Auxis thazzard*	42.4	2.5	1048
105	*Katsuwonus pelamis*	7.4	3.7	1118
106	*Katsuwonus pelamis*	–	–	1908
107	*Rastrelliger brachysoma*	17.8	4.2	2966
108	*Rastrelliger brachysoma*	23.3	5.5	2970
109	*Rastrelliger kanagurta*	6.9	3.1	431
110	*Scomberomorus commerson*	43.2	5.6	444
111	*Thunnus albacares*	5.2	4.5	813
112	*Cynoglossus puncticeps*	45.3	3.6	2571
		$\bar{X}$ = 20.2 % S.E. = 1.33 %	$\bar{X}$ = 4.1 months S.E. = 0.09 month	Σ = 894119

[a]Dashes refer to recruitment patterns which could not be separated into two component distributions (see *K. pelamis* in Fig. 3 for an example).

[b]Percent of recruits in larger pulse = 100 – % in smaller pulse.

[c]Larger time (in months) between two pulses = 12 – smaller time between two pulses.

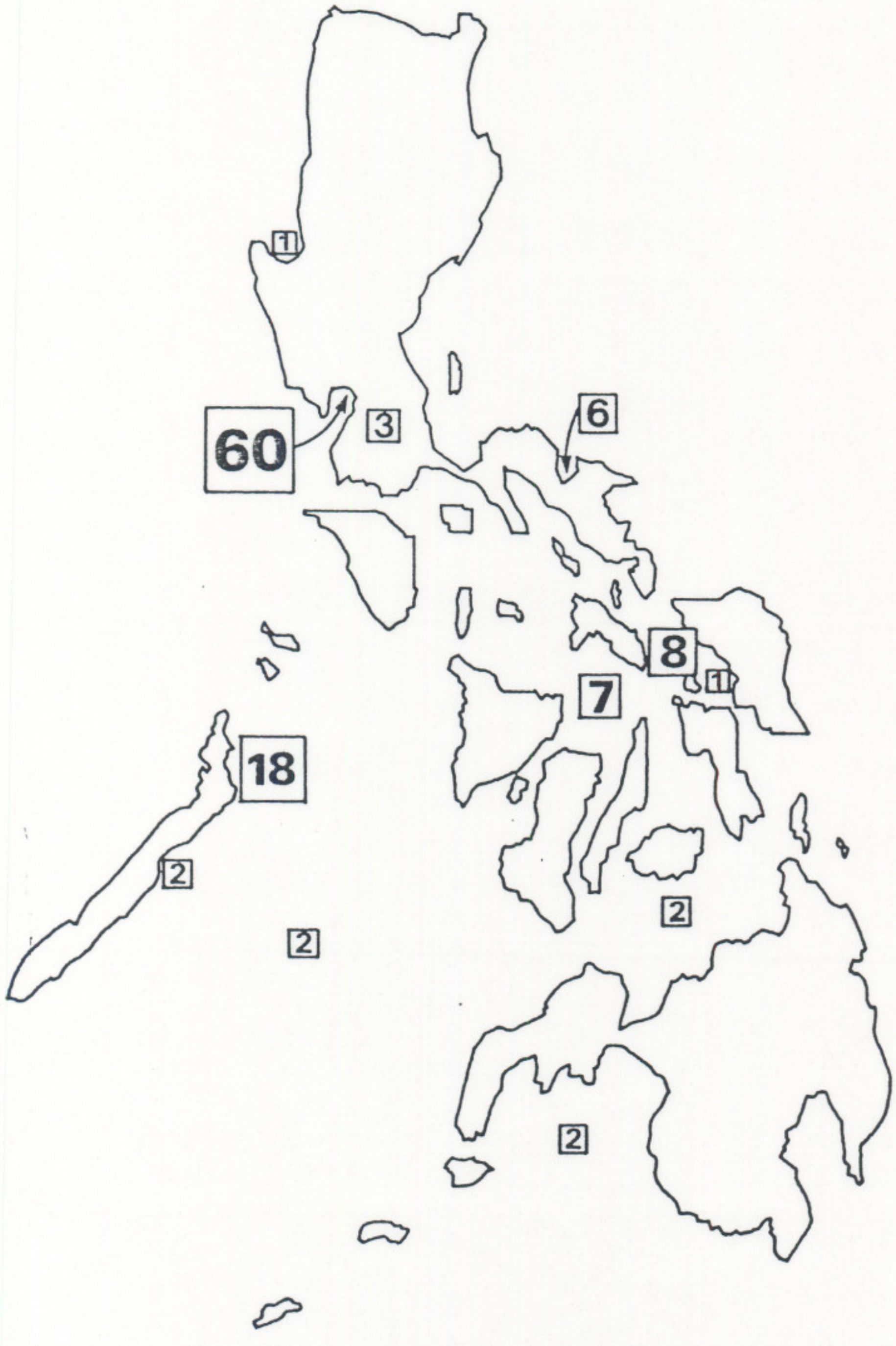

Fig. 1 Sampling location of length-frequency data discussed in this paper; the numbers refer to the number of stocks from each locality (total 112, see also Table 1).

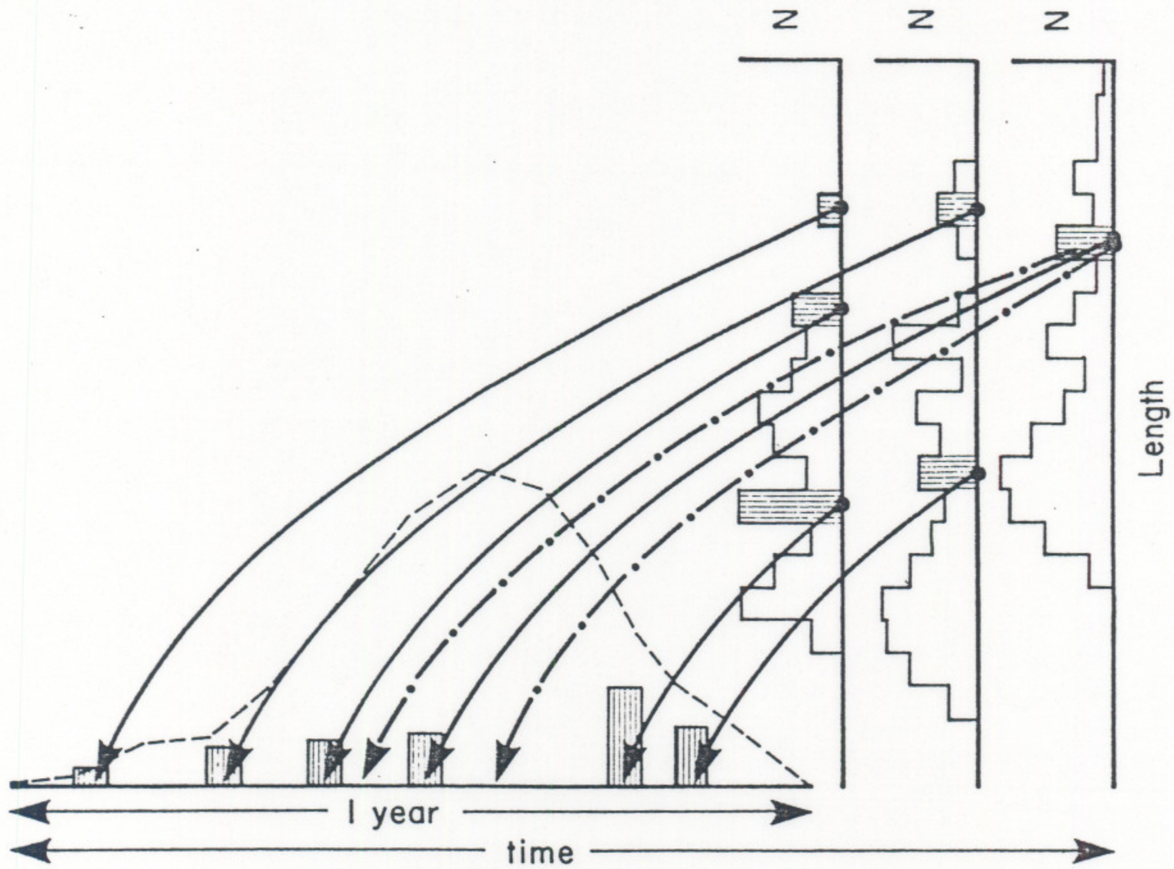

Fig. 2 Schematic representation of method for obtaining recruitment patterns using ELEFAN II. The steps involved are: 1) projection onto the time axis of the frequencies of a set of length-frequency data; 2) summation for each month of the frequencies projected onto given months (the dotted line gives the sums achieved for each month after the projection of frequencies suggested by the arrows is completed); 3) subtraction, from each monthly sum of the lowest of the 12 monthly sum, to obtain a zero value where apparent recruitment was lowest; 4) output of monthly apparent recruitment, in % of annual recruitment. The projection of only a few (shaded) frequencies is shown here. In reality, all frequencies are projected, resulting eventually in the superimposed recruitment pattern (dashed line). Note "blurring" effect of individual growth curves (—•—•—) differing from the mean growth curve of the stock (solid lines; also note that t_o is here assumed equal to zero, see text). (Adapted from Pauly et al., 1981).

done to reduce the "noise" due to fish having grown in a fashion different from that predicted by the growth parameters used (see Fig. 2).

Pauly (1982) showed how recruitment patterns, as obtained from ELEFAN II, can be used to objectively distinguish fish with one marked recruitment season from fish with two such seasons per year.

In this paper, we have carried this analysis one step further, and used the NORMSEP program of Abrahamson (1971)* to separate the recruitment patterns into normally distributed components. This analysis provided the following information for each recruitment pattern:

- number of normally distributed component distributions (number of recruitment pulses per year)
- standard deviation (s.d.) of each component distribution (the s.d. is proportional to the duration of a recruitment pulse)
- time (in months) separating different recruitment pulses
- proportion of recruits in the component distributions.

Fig. 3 gives examples of recruitment patterns separated into their component distributions.

RESULTS

Of the 112 recruitment patterns examined, only 12 did not consist of two major components (Table 1). The 100 recruitment patterns which separated readily into two component distributions had maxima which were, on the average 4.1 and 7.9 months apart. On the average, the major recruitment pulse of these 100 recruitment patterns contained 80% of the annual recruitment, while the minor pulse contained the remaining 20%.

In the case of five groups of fish, the results obtained here can be compared with inferences on recruitment and spawning seasons drawn earlier by other authors from analyses of length-frequency data (inference on recruitment) and studies of gonadal maturation stages (inferences on spawning). These five groups are as follows:

- *Stolephorus* spp.: Tiews et al. (1975b) concluded the following on the spawning of anchovies: "although *S. heterolobus* [...] breeds throughout the year, a peak spawning was noted during the northeast monsoon season (October to March)[...]. This can be distinguished from a period of little or no spawning activity from April to July. The findings for *S. bucanceri* are similar [...]. However, it is probable that the spawning time begins earlier in June and does not extend to February. No spawning was observed in March, April and May." In the case of *S. indicus*, Tiews et al. (1975b) suggest that it spawns and recruits over the major part of the year.

  Our results, on the other hand, showed that recruitment of the stolephorid anchovies, conform to the typical bimodal pattern presented above (see Table 1).

- *Saurida tumbil* (Synodontidae): Tiews et al. (1972) found that "the *S. tumbil* population in Manila Bay and adjacent waters had a protracted breeding period and spawns two or even three times a year in a quite irregular manner." Our results, based on data from the Visayan Sea and from Manila Bay, show that *S. tumbil* recruits twice a year (Table 1).

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*The version of NORMSEP we used is a translation into BASIC of the (FORTRAN) original; it was prepared by Mr. N. David. The program which was run on a Radio Shack TRS 80 Model III microcomputer is available from D. Pauly, ICLARM.

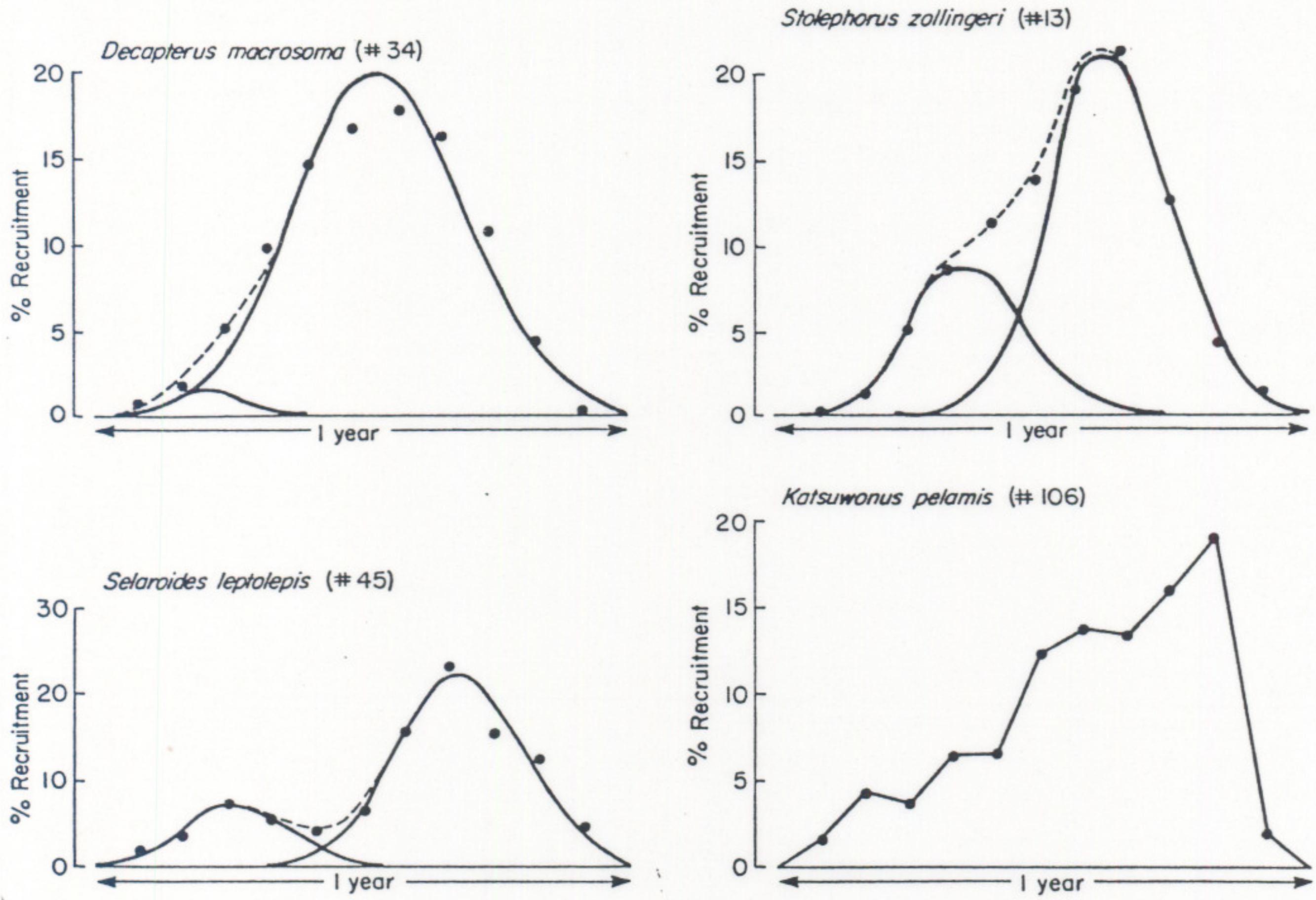

Fig. 3 Examples of recruitment patterns separated into their component distributions (dotted line obtained by combining two normal distributions). Note difficulty in deciding in cases such as that of *D. macrosoma* whether there are one or two recruitment pulses; also note good separations in two other cases, one with wide overlap (*S. zollingeri*), the other with little overlap (*S. leptolepis*). Last case (*K. pelamis*) is that of a stock where separation into a small number of components is not feasible. More details on 3 of these 4 cases are given in Table 1.

- *Decapterus* spp. (*D. macrosoma* and *D. russelli*): Tiews et al. (1975a) "concluded that the breeding period of both species extends from November to March in Palawan Waters [and that] spawning time seemed to be delayed by 1-2 months, thus extending to April and May."

  Our results suggest either one single, protracted recruitment season or two recruitment seasons, one much shorter than the other (Table 1).

- *Rastrelliger brachysoma*: Tan (1970) concluded that "spawning occurs from June to February" in Manila Bay. Our analysis of length-frequency data on this fish, collected in the Samar Sea, suggests that *R. brachysoma* is recruited twice a year, and follows the general pattern outlined above.

DISCUSSION

Although it is generally agreed that the *spawning* seasons of tropical fishes are generally longer than those of their temperate counterparts (Johannes, 1978), the demonstration is lacking that this also generally applies to their *recruitment* seasons. Thus, it could be that the eggs produced during a long spawning season generally encounter a "survival window" (Bakun et al., 1982) that is open during a short period only, resulting in sharply peaked recruitment pulses (Munro, in press).

This problem cannot be resolved at present because recruitment patterns (as defined here) from temperate fishes are not available for comparison. The data at hand allow, however, for the generalization that Philippine neritic fishes have pulses of recruitment twice a year - as opposed to their temperate counterparts which generally recruit once a year.

The two recruitment pulses that seem to be typical of Philippine fishes are of unequal strength, and their asymmetry is emphasized by the feature that, rather than dividing the year in two equal halves of 6 months each, the two recruitment pulses divide the year into two periods of unequal duration of about 4 and 8 months. This periodicity is close to the 5- and 7-month rhythm of the monsoon winds which, in the Philippines, blow from the northeast from September to March with peaks from November to January (northeast monsoon), then blow from the southwest from April to August with peaks in May-June (southwest monsoon) (Dickerson, 1928, p. 39).

This study thus supports the hypothesis of a relationship between spawning/recruitment patterns and monsoon winds, as suggested by Weber (1976) and Johannes (1978) for various areas of the tropical Indo-Pacific, including the Philippines.

Winds generally determine the extent of both horizontal advection and therefore upwelling events and vertical instability, which, as hypothesized in Bakun and Parrish (1981), may have crucial effects on the survival of fish larvae (see also Bakun et al., 1982).

Highly aggregated data such as those presented here do not allow testing of these and related hypotheses directly. However, the generalization presented here that the recruitment patterns of Philippine fishes match the monsoon wind patterns can be tested on a finer scale. We plan to compare single recruitment patterns pertaining to a given stock in a given year and place with the wind patterns (and the patterns of wind-driven phenomena such as upwellings and turbulence) prevailing when and where recruitment occurred. These tests may help establish in more detail the link between wind-driven oceanographic phenomena and increased larval survival in tropical areas such as the Philippines.

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