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Some Aspects of the Reproductive Biology of Stolephorid Anchovies from Northern Papua New Guinea

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Abstract

Batch fecundity, length at first spawning, spawning seasonality and ovarian development of *Stolephorus heterolobus* and *S. devisi* were determined by examination of preserved ovaries from fish captured during 1976-1981 and 1985. Batch fecundity was estimated from the number of eggs in the most advanced ovarian mode and was related to fish length and weight by an exponential function. Batch fecundity estimates were also made for two less common anchovies, *S. waitei* (= *bataviensis*) and *S. punctifer* (= *bucconeeri* and *zollingeri*). Both *S. heterolobus* and *S. devisi* appeared capable of spawning throughout the year with peaks in spawning intensity during June and November. Spawning intensity was thought to be regulated by the monsoon seasonality. From data on egg size versus fish length, it was estimated that *S. heterolobus* and *S. devisi* were first capable of spawning at 50 and 41 mm (fork length), respectively.

Introduction

The stolephorid anchovies are small schooling fishes commonly found around the coastal waters of the tropical and subtropical Indo-Pacific region. In Southeast Asia stolephorid anchovies are an important food resource and are consumed fresh or as various fermented products (Ruddle 1986). Catches of stolephorid anchovies in Southeast Asia amounted to about 215,000 t in 1983 (FAO 1986). Amongst the island states of the South and Central Pacific, stolephorid anchovies have in recent times assumed importance as live bait for tuna capture (Baldwin 1977).

There have been many studies of the reproductive biology of stolephorid anchovies, including those of Delsman (1931), Prabhu (1956), Dharmamba (1959), Nakamura (1970), Tiews et al. (1970), Sitthichockpan (1972), Weber (1974), Leary et al. (1975), Muller (1976), Luther (1979), Dalzell and Wankowski (1980), Chen (1984), Conand (1984), Evans and Nichols (1984) and Chen (1986). This paper presents information on the maturation, fecundity and spawning periodicity of *Stolephorus heterolobus* and *S. devisi* from northern Papua New Guinea. Some observations on two less common species, *S. waitei* (= *bataviensis*) and *S. punctifer* (= *buccaneeri* and *zollingeri*) are also included.

Materials and Methods

Specimens of *S. heterolobus* and *S. devisi* were obtained from Ysabel Passage (Fig. 1) between 1976 and 1981 and during 1985. The specimens were collected once every 3-5 days from samples of live bait catches of a now defunct pole-and-line tuna fishery based at New Ireland. Details of the fishing methods, sampling methodology and routine laboratory procedures are given by Dalzell and Wankowski (1980). The fishing season at the Ysabel Passage normally extended from March to mid-December. The periods between fishing seasons were marked by strong winds and heavy rains from the northwest monsoon which made both tuna and bait fishing impracticable.

Samples of baitfish were preserved in 10% buffered formalin. The fork length, total body weight and ovary weight of *S. heterolobus* and *S. devisi* from each sample were recorded. Fork length was recorded to the nearest millimeter and weights to the nearest 0.001 g. A gonad index for each specimen was estimated from

$$\text{gonad index} = \text{gonad weight} \cdot (\text{body weight})^{-1} \cdot 100$$

Ova diameter measurements were made on 77 female *S. heterolobus* and 98 *S. devisi* in all stages of sexual maturity. After measuring the fish and obtaining the total body weight and ovary weight, a small portion of the ovary was cut away, weighed and macerated in a glass phial with a little water. The separated eggs were then pipetted onto a Bogorov tray and the diameters of 100 eggs were measured with an ocular micrometer mounted in a dissecting microscope at 25 times magnification. Eggs smaller than 5 micrometer units were not measured. Seven stages were required to define ovary development:

Stage 0	Gonads indistinct	Stage IV	Maturing Ripe
Stage I	Inactive	Stage V	Ripe
Stage II	Immature	Stage VI	Spent
Stage III	Maturing		

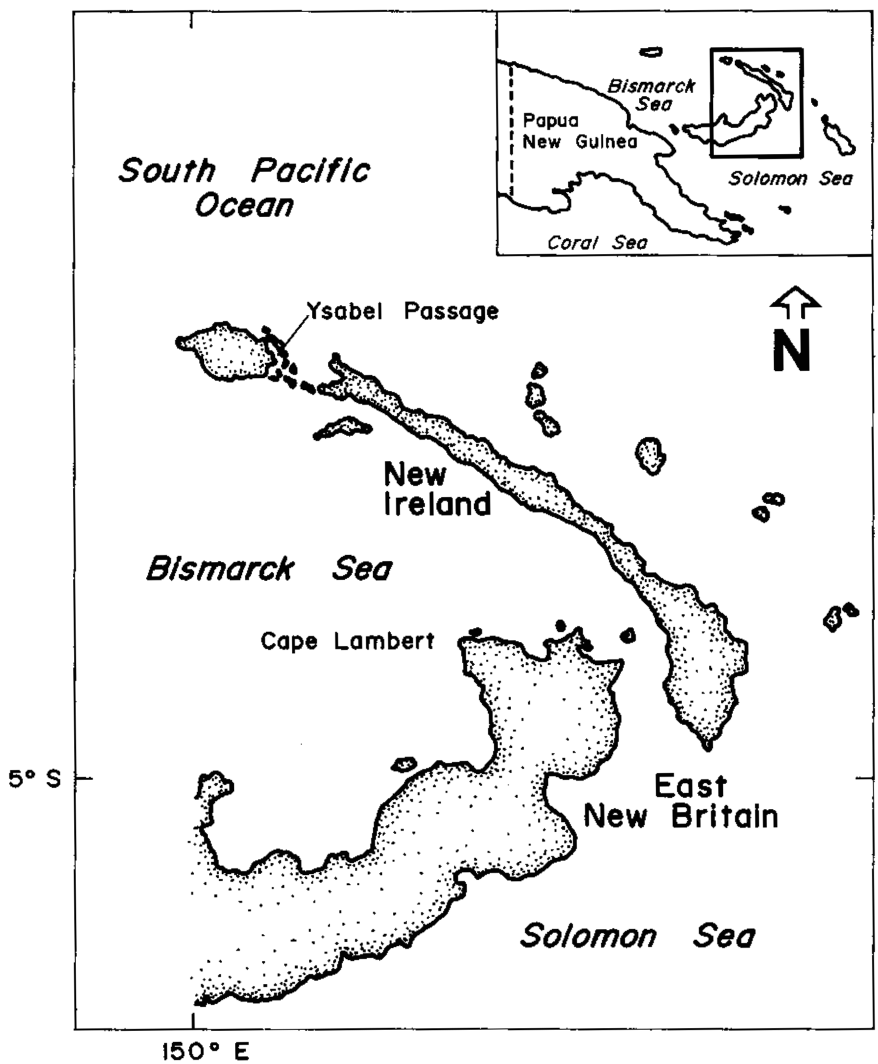


Fig. 1. Map of Papua New Guinea showing location of Ysabel Passage and Cape Lambert bait grounds.

The same classification was used by Dalzell and Wankowski (1980) and Dalzell (1985) for the banded blue sprat, *S. gracilis.*

The ova diameter measurements for a number of fish in Stages I-V of ovarian development were grouped according to the respective development stage to observe changes in ova size frequency with increasing gonadal maturation. The ova size-frequency polygons were smoothed with a running average of three units.

Batch fecundity was defined as the number of maturing eggs in the ovary as determined from ova diameter measurements. The lower limit of the mode of maturing eggs was determined from the ova diameter measurements and all eggs in the ovary greater than or equal to this size were counted. The total number of maturing eggs in the ovary was then calculated by simple proportionality (using the weight of sample including excised portion of the ovary and weight of whole ovary). Ripe Stage V ovaries were not used since some eggs may have been shed prior to capture (Leary et al. 1975). Fecundity counts were confined to fish with Stage III and Stage IV ovaries. The relative fecundity of each fish was estimated from the division of the batch fecundity by the total body weight.

Stage III-IV ovaries of seven *S. waitei*, obtained during 1980, were used to estimate the fecundity of this species. Nine similar *S. punctifer* ovaries obtained during 1977 from another bait ground at Cape Lambert (Fig. 1) were also used for fecundity estimates. The eggs of *S. heterolobus, S. devisi* and *S. punctifer* are elliptical in shape and the major axis of the elipse is referred to as ova diameter. The eggs of *S. waitei* are also eliptical but contain a small knob at the micropyle on the animal pole. Ova diameter measurements made along the major axis of the eggs of *S. waitei* included the small knob. The morphology of stolephorid anchovy eggs is dealt with in detail by Delsman (1931).

Results

The ova diameter polygons of the maturity stages I-V for *S. heterolobus* and *S. devisi* are shown in Figs. 2 and 3. The progressive maturation of the ovaries of the two species is reflected by the increase in the size of the modal group of eggs to between 0.8-1.1 mm at spawning time.

The progression of eggs to maturity is also evident from Fig. 4 where the mean sizes of the maximum mode of eggs in the ovaries of *S. heterolobus* and *S. devisi* were plotted against the gonad index. At

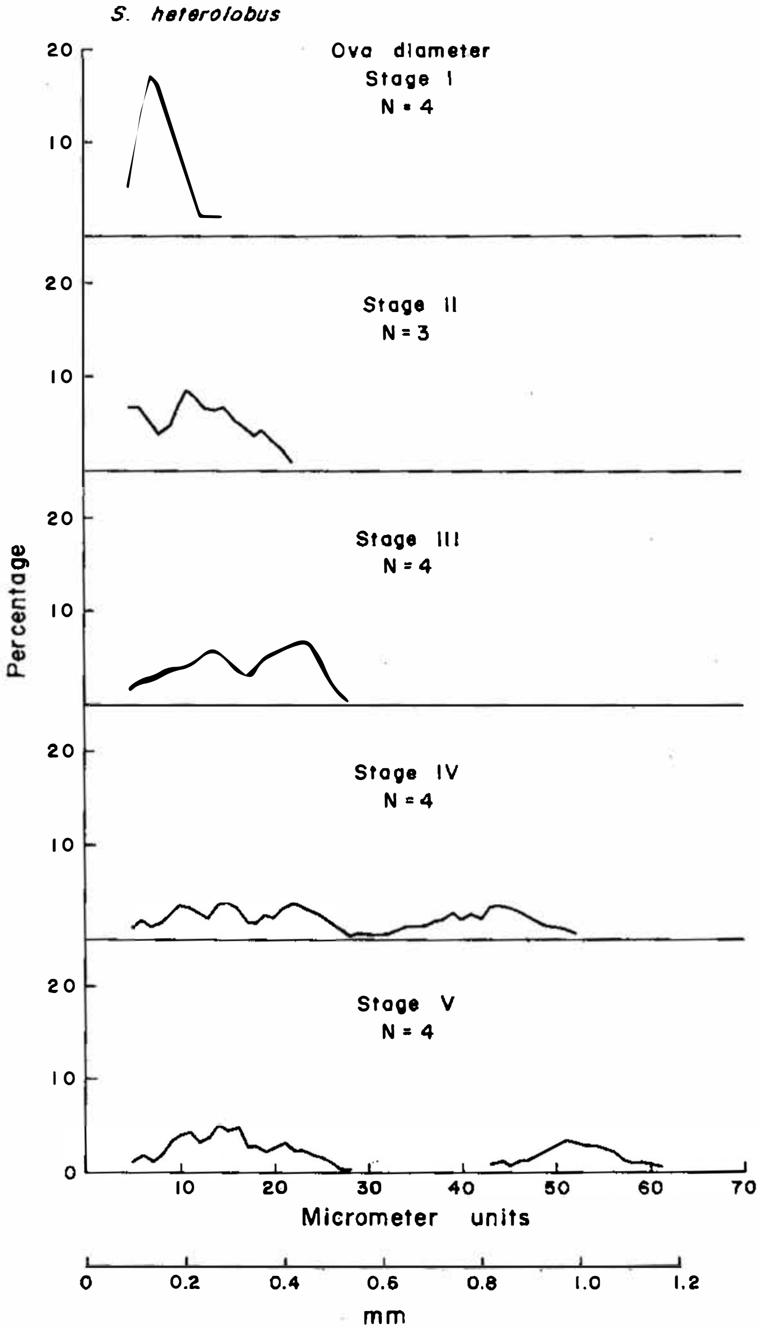


Fig. 2. Progressive development of maturing eggs of *S. heterolobus* in relation to ovarian maturation. N = number of fish.

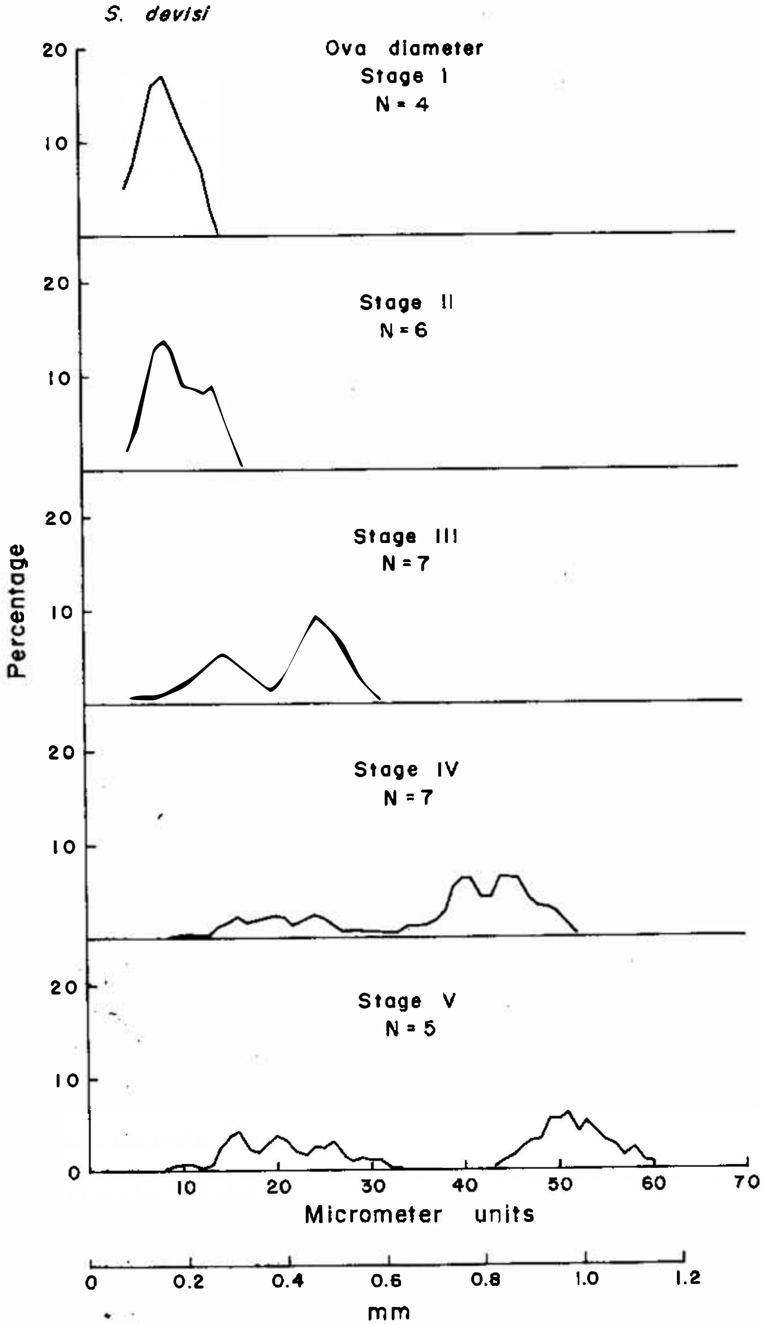
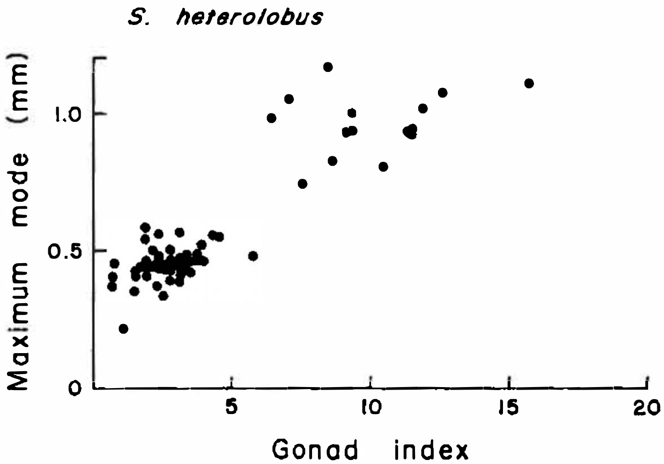


Fig. 3. Progressive development of maturing eggs of *S. devisi* in relation to ovarian maturation. N = number of fish.



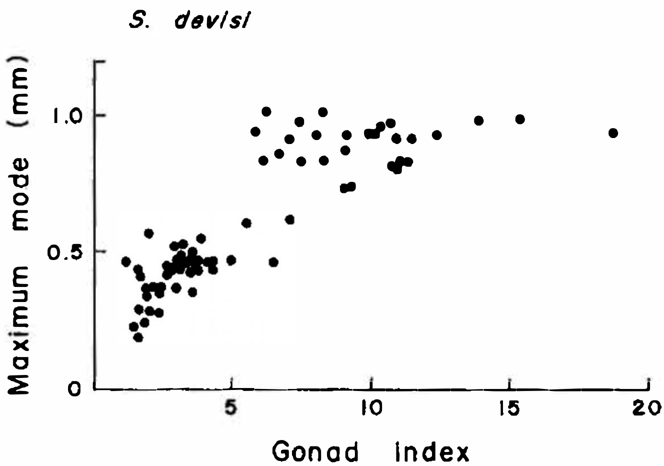


Fig. 4. Relationship between diameter of most advanced mode of eggs in the ovary and gonad index for *S. heterolobus* and *S. devisi.*

a gonad index of 6 and above the size of the eggs becomes constant. Further, the nature of the scatters of points suggests that there is a rapid increase in the egg size at full maturity.

A similar conclusion may be drawn from the plots of mean size of the maturing mode of eggs against the corresponding length of fish (Fig. 5). In both instances, there is distinct separation of mature from maturing eggs. From these scatters the minimum sizes at maturity of *S. heterolobus* and *S. devisi* were 50 and 41 mm, respectively.

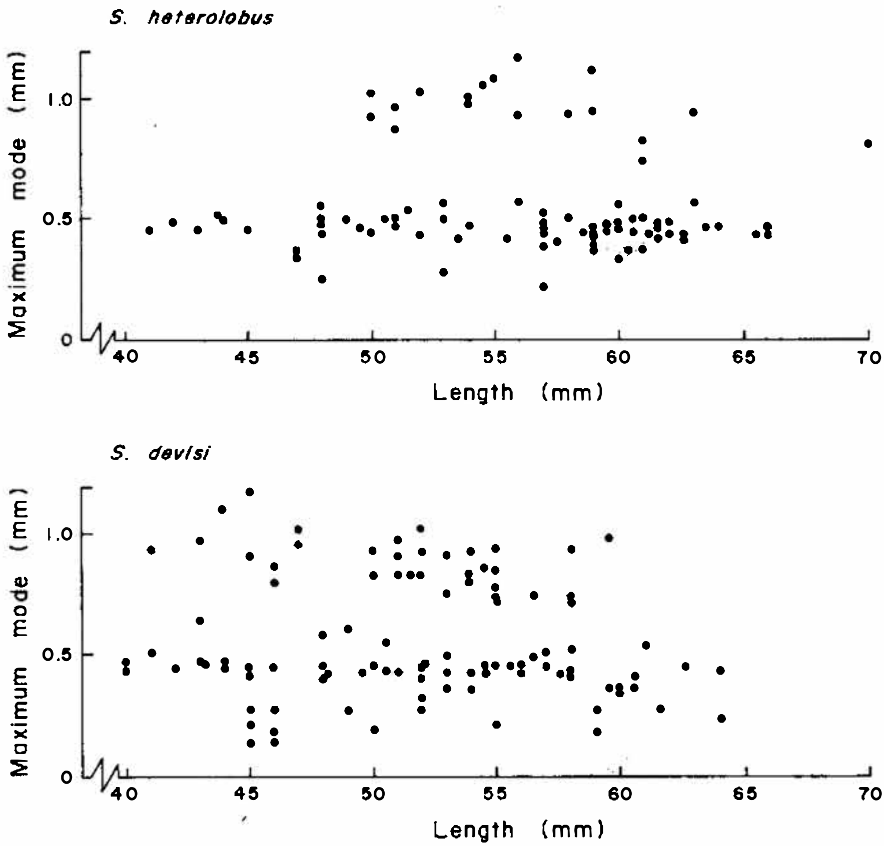


Fig. 5. Relationship between the diameter of the most advanced mode of eggs in the ovary and fork length for *S. heterolobus* and *S. devisi.*

Specimens of *S. devisi* smaller than 40 mm contained ovaries with oocytes which were all less than 5 micron units in diameter.

The patterns of spawning for the years 1976-1981 and 1985 for *S. heterolobus* and *S. devisi* were determined by plotting the percentage of ripe female fish with a gonad index of greater than 6 for each month (Figs. 6 and 7). The "average" seasonality of spawning activity from plots of the mean percentage of ripe females in each month from the different years is also shown. Some spawning occurs practically all year round but with clear peaks in May-June and October-November.

The results of the fecundity estimates are presented in Tables (1-4). The regressions of the natural logarithms of fecundity (F) against the logarithms of corresponding lengths (L) and weight (W) were all

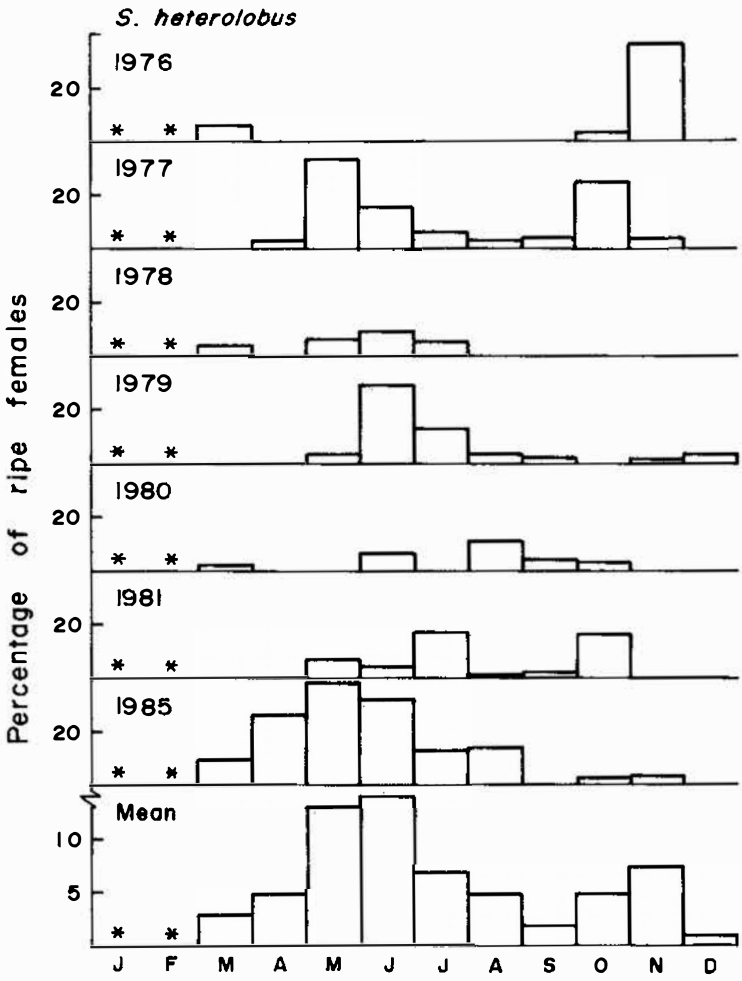


Fig. 6. Percentage of ripe female *S. heterolobus* in catch samples each month from 1976 to 1981 and 1985. Asterisks indicate no samples.

significant (P < 0.05) (Table 5). The regressions for *S. waitei* and *S. punctifer*, however, covered a range of only 15 and 10 mm, respectively. The mean relative fecundities for the four anchovies are given in Table 6 along with estimates of relative fecundity for stolephorid anchovies from other locations. From the present data, it is apparent that fecundity varies markedly between *S. heterolobus* and *S. devisi* although they are closely related species. The least fecund of the stolephorid anchovies studied was *S. waitei*.

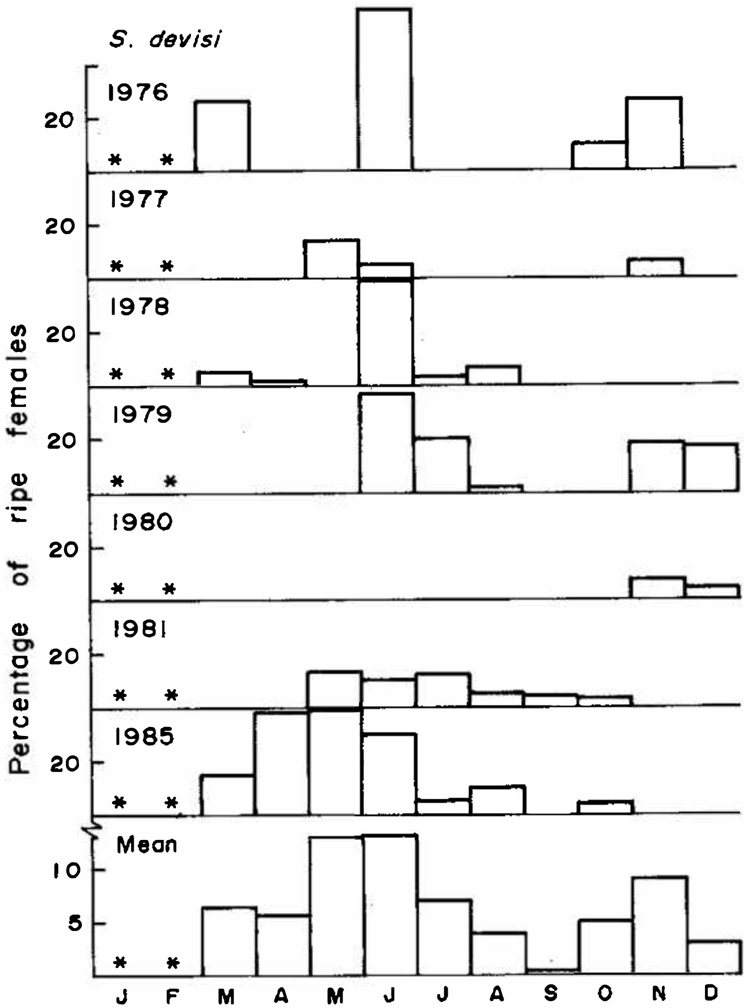


Fig. 7. Percentage of ripe female *S. devisi* in catch samples each month from 1976 to 1981 and 1985. Asterisks indicate no samples.

Discussion

Rapid hydration of eggs, resulting in increased size, is a typical step in the maturation of pelagic eggs such as those of stolephorid anchovies (Leary et al. 1975). Hydration is achieved by the secretion

Table 1. Length, weight and fecundity data for *S. heterolobus* from Ysabel Passage.

Length (mm)	Weight (g)	Batch fecundity	Relative fecundity
53	1.366	522	382
53	1.402	977	697
58	1.846	1,306	707
49	1.051	616	586
51	1.156	455	394
48	0.938	668	712
48	0.894	456	510
51	1.252	636	508
70	3.096	1,575	509
73	3.343	2,262	677
72	3.101	2,406	776
66	2.711	1,533	565
67	3.277	1,145	349
59	2.038	1,345	660
61	2.191	1,583	723
55	1.455	841	578
56	1.538	1,126	732

Table 2. Length, weight and fecundity data for *S. devisi* from Ysabel Passage.

Length (mm)	Weight (g)	Batch fecundity	Relative fecundity
56	1.752	1,603	915
58	1.933	2,442	1,263
58	1.791	1,191	665
55	1.550	1,437	927
55	1.737	2,063	1,188
58	1.932	1,804	934
55	1.627	1,734	1,066
53	1.418	1,491	1,051
63	2.274	2,513	1,105
40	0.461	374	811
48	0.868	968	1,115
57	1.101	1,072	974
64	0.659	681	1,033
46	0.724	831	1,148
45	0.598	772	1,291
47	0.790	1,033	1,308
49	0.825	712	863

Table 3. Length, weight and fecundity data for *S. waitei* from Ysabel Passage.

Length (mm)	Weight (g)	Batch fecundity	Relative fecundity
78	6.128	1,345	219
74	5.881	1,516	258
76	6.144	1,291	210
75	5.695	1,263	222
74	5.467	1,100	201
69	4.272	1,058	248
68	4.483	943	210

Table 4. Length, weight and fecundity data for *S. punctifer* from Cape Lambert.

Length (mm)	Weight (g)	Batch fecundity	Relative fecundity
59	2.210	1,512	713
65	2.575	3,441	1,336
68	3.681	2,369	644
55	1.836	781	425
64	3.333	2,984	895
61	2.718	2,465	905
70	4.669	6,237	1,336
69	3.917	2,927	747
66	3.671	3,199	871

Table 5. Relationship between batch fecundity (F), length (L) and weight (W) for stolephorid anchovies from northern Papua New Guinea.

Species	Fecundity equation	r^2
S. heterolobus	(L) log exp F = 3.341 log exp L − 6.636	0.815
	(W) log exp F = 1.050 log exp W + 6.358	0.710
S. devisi	(L) log exp F = 3.866 log exp L − 9.151	0.854
	(W) log exp F = 0.967 log exp W + 6.936	0.878
S. punctifer	(L) log exp F = 2.505 log exp L − 3.665	0.604
	(W) log exp F = 0.177 log exp W + 6.129	0.700
S. waitei	(L) log exp F = 6.361 log exp L − 18.613	0.766
	(W) log exp F = 1.595 log exp W + 6.058	0.719

Table 6. Relative fecundities of stolephorid anchovies from the Indo-Pacific Region.

Species	Location	Relative fecundity (eggs/g body wt.)	Standard deviation	Sample size (N)	Source
S. heterolobus	Ysabel Passage	592	133	17	This paper
S. heterolobus	Palau	450	156	9	Muller (1976)
S. heterolobus	Singapore	694	164	10	Tan (1968)
S. devisi	Ysabel Passage	1,039	176	17	This paper
S. punctifer	Cape Lambert	875	301	9	This paper
S. waitei	Ysabel Passage	224	21	7	This paper
S. purpureus	Hawaii	538	292	41	Leary et al. (1975)

of fluids with lower specific gravity than seawater into the egg by follicle cells which results in a volume increase of up to 400% and assures the eggs will float (Smith 1957). Rapid maturation of eggs has also been observed by Leary et al. (1975) for the Hawaiian anchovy, *Stolephorus purpureus*, and the northern anchovy, *Engraulis mordax* (Hunter and Goldberg 1980).

Age and growth estimates for stolephorid anchovies suggest that these species have an average life span of 1-2 years (Tham 1967; Burhanuddin et al. 1975; Muller 1976; Dalzell 1984; Ingles and Pauly 1984). In the context of these species, number of spawnings per lifetime is perhaps more appropriate than per year or per season. From the data presented here, it is not possible to state conclusively whether *S. heterolobus* and *S. devisi* are single or multiple spawners, although the latter is more probable.

The synchronous development of a secondary mode of eggs as the mature eggs ripen in the ovary has been cited as evidence of multiple spawning for several stolephorid anchovy species (Prahbu 1956; Dharmamba 1959; Muller 1976). Further, both Tham (1970) and Muller (1976), based on a variety of observations, suggested that *S. heterolobus* spawns every two to three months throughout the year. By contrast, Leary et al. (1975) argued that *Stolephorus purpureus* the Hawaiian anchovy, was capable of only a single spawning per lifetime. This conclusion was based on the lack of evidence of synchronous development of the secondary mode of eggs in this species coupled with a short lifespan (about six months) and very high mortality rate. In the northern anchovy, *Engraulis mordax,* the frequency of spawning is age related with older females (4+ years) capable of 24 separate periods of batch development and release during a spawning season (Parrish et al. 1986). A one-year old female has an average of five spawnings during the first season. Histological examination of *E. mordax* ovaries by Hunter and Goldberg (1980) showed that during the peak of the spawning season, the period between release of separate egg batches was 6-8 days.

The spawning peaks of *S. heterolobus* and *S. devisi* are co-incedent with transition in direction of the prevailing winds (Dalzell and Wankowski 1980). The May-June period marks the end of the northwest monsoon and commencement of the southeastern trade winds. The winds generally reverse again between October and November. While *S. heterolobus* and *S. devisi* are capable of spawning year round in the Ysabel Passage, the distinct seasonality of spawning intensity is almost certainly linked to the monsoonal climate.

Tester (1955) showed that *S. purpureus* in Hawaii has a clear spawning peak during May-September, which coincides with the peak in the annual sea temperature cycle. More recently, Sitthichockpan (1972) suggested that spawning periodicity of *S. heterolobus* in the Gulf of Thailand is not directly related to temperature or salinity but to plankton abundance. Sitthichockpan showed that the two peaks of *S. heterolobus* spawning activity between March-April and July-September were coincident with plankton blooms over the same period in the Gulf of Thailand. Chapau (1983) presented data on plankton abundance in the Ysabel Passage during 1981. These data, whilst limited to a single year, indicated peaks in monthly planktonic biomass between May-June and during October. Thus, the spawning peaks of *S. heterolobus* and *S. devisi* in the Ysabel Passage may coincide with increased planktonic abundance and hence increased larval food supply. Tiews et al.(1970) observed that peak spawning of *S. heterolobus, S. devisi* and *S. punctifer* in Manila Bay occurs in the summer months during the southwest monsoon when primary production is at its highest.

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