

## Seasonal Changes in the Gonad of *Nautilus belauensis* from Palau

Junzo Tsukahara and Yoshiko Kakinuma

Department of Biology, Faculty of Science, Kagoshima University,  
Kagoshima 890, Japan

### Abstract

The comparative studies of the reproductive organs of *Nautilus belauensis* in Palau were carried out between individuals collected in the summer season (from August to September, 1988) and in the winter season (January, 1989). The average weight of the testes and the ovaries collected in summer was found to be slightly heavier than those collected in winter. The maximum weight was recorded on the oocyte collected in summer. Although direct evidence of the natural reproductive period of *Nautilus belauensis* in Palau is still lacking, it appears likely that natural spawning of this species occurs before, during, and after the summer season.

### Introduction

The habitat of the chambered *Nautilus* is still obscure because they usually live at considerable depths. Haven (1977) reported the records of *Nautilus pompilius* trapped in the Tañon Strait, Philippines, which were kept for a one year period from August 1971 through August 1972. With respect to the reproductive season of the *N. pompilius*, the author suggested that it may be in summer (July or August) because of the variation of the maximum weight of the oocyte.

For an investigation into the natural reproductive season of the *Nautilus belauensis* in Palau, living specimens were collected in the summer season (from August to September, 1988) and in the winter season (January, 1989) and comparative anatomical studies of their reproductive organs were carried out.

### Materials and Methods

Specimens of *Nautilus belauensis* were trapped at depths of 140 to 450m in Mutremdiu Bay, Palau. Among 49 individuals captured in the summer season from August 22 to September 17, 1988, 26 specimens (14 males and 12 females) were dissected to obtain the gonads and other reproductive organs. These organs were immediately weighed and fixed for histological studies. In the winter season from January 6-13, 1989, 45 individuals were captured and 20 specimens (10 males and 10 females) of them were dissected for anatomical studies.

The gonad index (GI), defined as follows, was used in the present study.

$$\text{gonad index (\%)} = \text{gonad weight (g)} \times 100 / \text{soft part weight (g)}$$

To weigh the growing oocytes, ovaries containing clusters of oocytes were fixed with 3% glutaraldehyde in a phosphate buffer (pH 7.4) and 0.5M NaCl for two

to four days and dissected into individual oocytes. The weigh of each oocyte greater than 0.010g was carried out.

## Results

The weight data of the whole soft part and the reproductive organs such as testes, accessory organs, spermatophore sacs and penises of males are shown in Table 1. The average GI of the individuals captured in summer is 5.30%, and that of winter is 4.28%.

The weight data of the soft part, the ovary and the nidamental gland which is the secondary female sexual organ, of the female *Nautilus* captured in summer

Table 1. Weights of reproductive organs and gonad indexes of male *N. belauensis* in summer and in winter.

Naut. No: Number of Specimen, W: Weight (g), Acc.: Accessory organ, Sp. Sac.: Spermatophore Sac, GI: Gonad Index

### Summer

Naut.No	Softpart W	Testis W	Acc.W	Sp.Sac.W	Pennis W	GI
T2-1	915.0	66.9	10.1	1.7	1.1	7.31%
T2-14	304.9	4.6	—	—	—	1.51%
T3-1	887.2	58.3	9.6	1.6	1.3	6.57%
T3-2	877.0	52.6	9.0	1.6	0.9	6.00%
T5-1	845.3	47.6	8.7	1.5	0.7	5.63%
T5-2	953.0	55.6	8.8	1.6	0.7	5.83%
T8-2	946.9	51.2	8.1	2.1	1.1	5.41%
T9-1	925.2	51.5	8.9	1.3	0.9	5.57%
T9-2	859.7	50.7	8.9	2.1	0.8	5.90%
T9-4	700.4	39.7	8.4	1.1	0.4	5.67%
T9-6	1059.7	64.9	11.1	2.0	1.3	6.12%
T9-7	729.8	48.3	7.5	1.4	0.6	6.62%
T12-2	985.5	58.9	8.9	1.8	0.7	5.98%
T12-3	817.6	43.7	6.9	1.3	0.7	5.34%
Average	787.1	46.3	8.2	1.5	0.8	5.30%
Std.Dev.	181.6	15.0	1.1	0.3	0.3	1.31%

### Winter

T20-1	756.2	32.4	6.0	1.1	0.5	4.28%
T20-4	875.9	32.3	6.8	1.2	0.7	3.69%
T20-6	935.4	44.0	7.8	2.2	1.2	4.70%
T21-1	900.2	39.8	5.0	1.7	0.7	4.42%
T21-3	955.9	54.8	9.1	1.7	1.5	5.73%
T21-4	991.9	52.2	7.4	1.2	0.5	5.26%
T23-1	962.6	48.1	8.3	1.4	0.8	5.00%
T23-2	981.5	46.5	9.3	1.7	0.7	4.74%
T23-3	828.0	40.7	6.7	1.4	0.9	4.92%
T25-6	1057.1	46.1	10.2	2.2	1.0	4.36%
Average	840.4	39.7	7.0	1.4	0.8	4.28%
Std.Dev.	87.3	7.5	1.6	0.4	0.3	0.57%

Table 2. Weights of reproductive organs and gonad indexes of female *N. belauensis* in summer and in winter.

Naut. No: Number of Specimen, W: Weight (g), Ov.: Ovary, Nid.: Nidamental Gland, GI: Gonad Index

## Summer

Naut.No	Softpart W	Ov.W	Nid.W	GI
T2-4	563.4	21.6	12.3	3.83%
T2-10	652.1	28.7	14.1	4.40%
T5-3	598.5	33.3	11.8	5.56%
T5-4	656.0	35.6	11.9	5.43%
T8-1	550.9	31.3	11.9	5.68%
T9-3	685.4	42.7	15.6	6.23%
T9-5	581.3	37.3	14.0	6.42%
T11-1	578.8	26.3	15.1	4.54%
T12-1	752.1	38.4	13.2	5.11%
T12-4	782.9	36.4	13.9	4.65%
T13-3	633.4	28.8	10.8	4.55%
T13-4	698.2	32.9	13.9	4.71%
Average	644.4	32.8	13.2	5.09%
Std.Dev.	71.51	5.58	1.41	0.75%

## Winter

T20-2	707.1	30.6	12.1	4.33%
T20-3	713.3	34.5	13.5	4.84%
T20-5	661.6	35	11.8	5.29%
T20-7	714.7	33.82	13.6	4.73%
T20-8	659.1	29.2	14.9	4.43%
T21-5	408.5	0.9	1.9	0.22%
T25-1	502.3	1.3	1.9	0.26%
T25-2	668.1	31.2	12.5	4.67%
T25-4	568.6	4	4.5	0.70%
T26-5	667.2	32.7	14.3	4.90%
Average	627.1	23.3	10.1	3.44%
Std.Dev.	96.85	14.04	4.93	2.01%

and in winter are shown in Table 2. The average GI is 5.09% in summer and 3.44% in winter. According to these data slightly smaller GIs are shown in the winter season both in males and females.

The scatter plots of the soft part weight and GIs of the males are shown in Fig. 1 and Fig. 3, and those of the females are shown in Fig. 2 and Fig. 4. According to these results there is scarcely a difference in the soft part weight between those taken in summer and in winter. However, there is a clear seasonal difference in the GIs of males and females. T-test values of the male and the female GIs between two seasons are  $P < 0.027$  and  $P < 0.004$ , respectively, indicating that the seasonal difference is fairly significant.

Fig. 5 and Fig. 6 show the plots of the oocyte weight of *Nautilus* captured in summer (Fig. 5) and in winter (Fig. 6). Although the number of oocytes in the

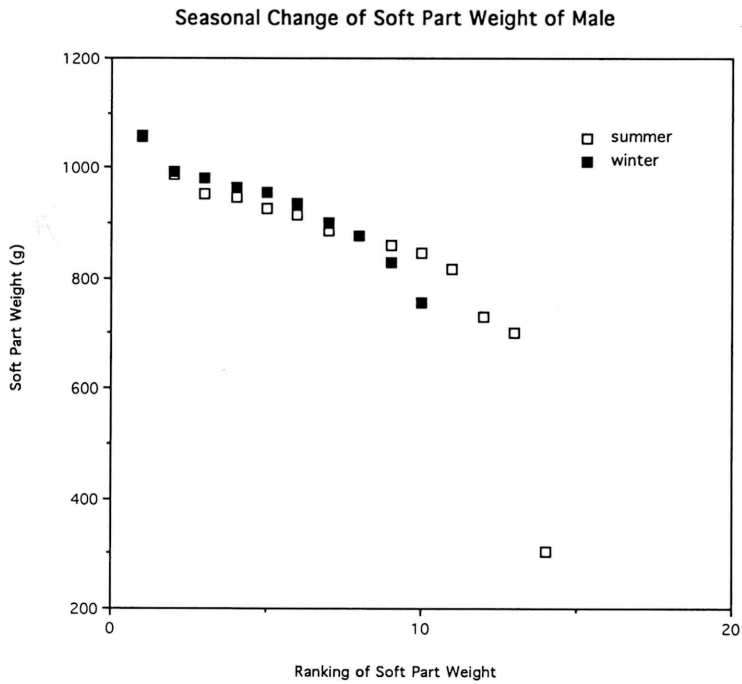


Fig. 1. Plots of weights of whole soft parts taken from males collected in summer and in winter.

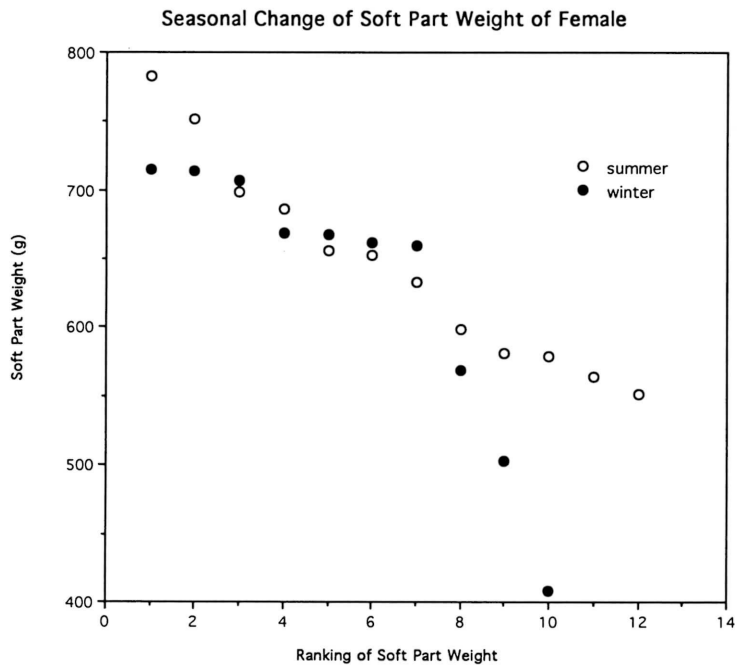


Fig. 2. Plots of weights of whole soft parts taken from females collected in summer and in winter.

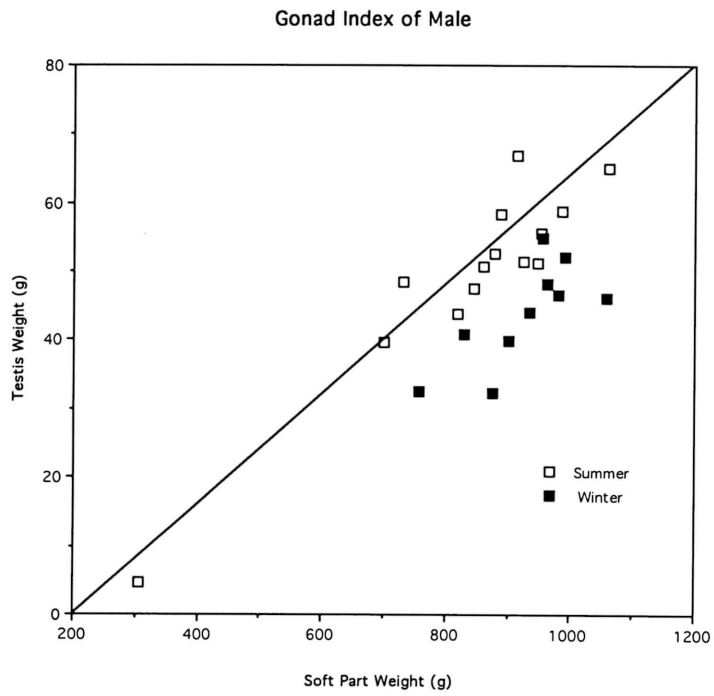


Fig. 3. Scatter plots of gonad indexes of male individuals.

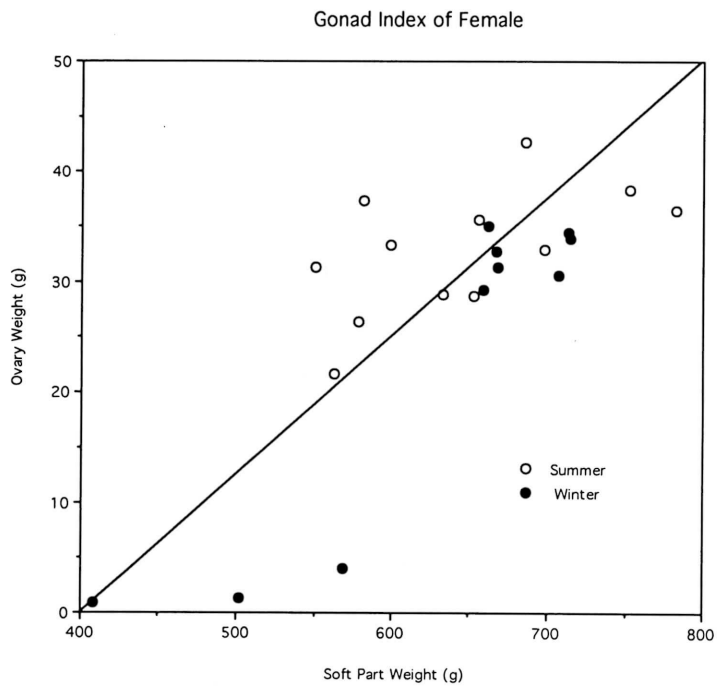


Fig. 4. Scatter plots of gonad indexes of female individuals.

Oocyte Weight of *Nautilus* in Palau (Summer)

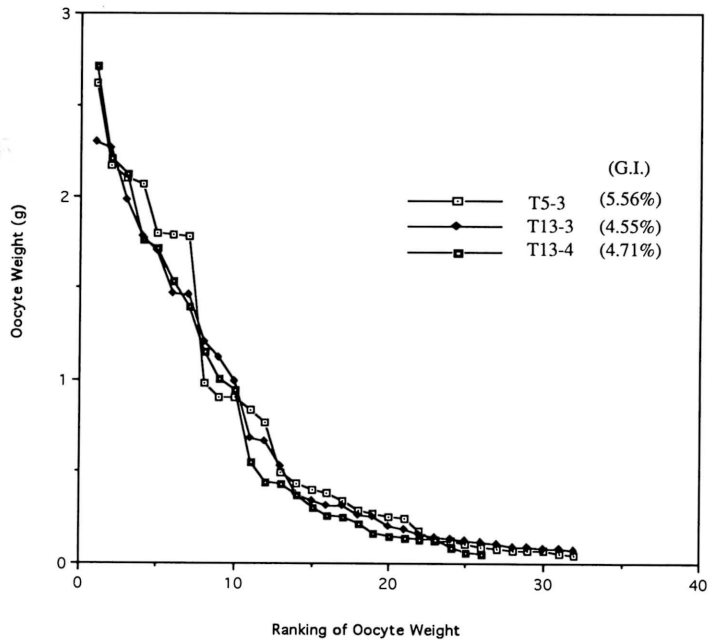


Fig. 5. Plots of the weight of oocytes greater than 0.010g taken in summer.

Oocyte Weight of *Nautilus* in Palau (Winter)

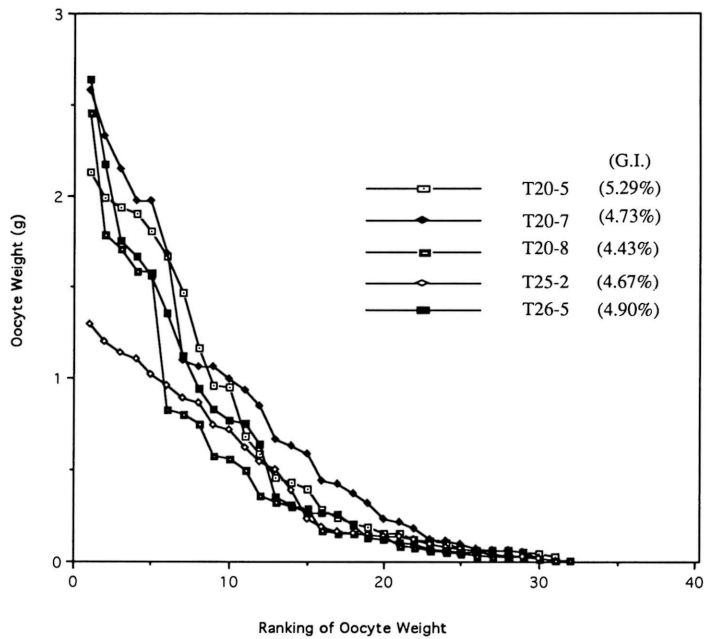


Fig. 6. Plots of the weight of oocytes greater than 0.010g taken in winter.

figure comprises only those heavier than 0.010g, amber yolk fluid can be found in oocytes heavier than 0.07g. When the oocyte weight reaches 0.3 - 0.4g, rapid deposition of yolks may have occurred (Fig. 5 & 6). The heaviest oocyte among *Nautilus* caught is 2.717g and 2.635g for summer and winter, respectively. A similar decrease occurred in the average weight of all larger (>1g) oocytes in each ovary (oocytes in summer: 1.746g; oocytes in winter: 1.577g). These results suggest that there may be a few seasonal differences in weight plotted between the summer and winter season.

### Discussion

Haven (1977) suggested that the reproductive period of *Nautilus pompilius* in the Philippines may be some time in the summer months, because the largest ovary of monthly collections were found in August, and the largest oocyte measured was in an ovary collected in late July. Willey (1898) obtained infertile eggs of *N. pompilius* in New Britain laid from July through September. In this study the average weight of testes or ovaries tend to slightly decrease in the winter season. It also shows that the different values of the largest oocyte weights between collections taken in summer and in winter is clear. Furthermore, the average of oocyte weights more than 1g in summer is larger than that in winter. These results suggest that the natural reproduction of *N. belauensis* in Palau probably occurs before, during, and after the summer season. It is necessary to compare large numbers of *Nautilus* in several seasons throughout the year.

Kakinuma *et al.* (1995) reported that *N. belauensis* captured in Palau spawned many fertile and infertile eggs in the aquarium installed in Kagoshima Marine Park. Several females were observed while held during the spawning period from January to October, 1989. For example, specimen number T13-1 captured on September 16-17, 1988, kept on spawning 14 oocytes in the period from January to May. From these data *N. belauensis* in aquariums may be able to spawn mature oocytes not only in summer but also in other seasons. It seems reasonable to suppose that the keeping conditions in aquariums change the reproductive behavior of *Nautilus*.

The GIs of male *N. belauensis* in Palau show higher values than those of *N. pompilius* collected in Papua New Guinea and Fiji (Tsukahara *et al.*, 1991). The difference of GIs between two species may be a reflection of peculiarities in specific species.

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