アオリイカの摂餌量,餌料効率および成長率

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Food Consumption, Food Conversion and Growth Rates of the Oval Squid *Sepioteuthis lessoniana* by Laboratory Experiments

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Food consumption, food conversion and growth rates of the oval squid *Sepioteuthis lessoniana* were measured on an individaul basis fed on three kinds of live organisms, namely, fish, mysid and squid hatchling. Squid used in the present study were all reared from egg to the experimental size, ranged from 0.06 to 42.1 g in wet body weight in an indoor aquarium. The daily food consumption rate ranged from 0 to 72% of body weight and depended upon the growth stage of the squid. Food conversion rate on a wet weight basis ranged from 15.4 to 43.8% and the rate was largely independent of the size of squid. Growth rate of the oval squid decreased with increasing size. The daily growth rate in body weight of hatchling reached 12.9% and that of the squid grown up to 30–50 g in body weight ranged from 1.8 to 4.1%. The growth was dependent upon quality of food. Squid fed on squid hatchlings showed the highest growth rate followed by those fed on fish. The daily growth rate increased with each increment of the daily food consumption rate.

The recent works show the very fast and high rates of food consumption, food conversion and growth of cephalopods (e.g. Wells and Wells,[1] LaRoe,[2] Van Heukelem,[3] Mangold[4]). The life span of the most cephalopod species is short, varying from about 6 months in small species to one, two, or three years in larger ones.[4]

Because of a difficulty of maintaining cephalopods in captivity especially of squids, direct measurements on feeding and growth of large species have not yet been worked out, except only some studies on loliginid squids[2,5–9] and *Illex illecebrosus*.[10,11]

The oval squid *Sepioteuthis lessoniana* is a common neritic cephalopod and one of the commercially important species and fisheries of this squid are distributed along the coast of Japan.[12] To meet the challenge to culture this squid, considerable numbers of papers have been available concerning experimental rearing (e.g. Choe and Oshima,[13] Oshima and Choe,[14] Choe,[6,15] Tsuchiya,[16] Segawa,[8]). However, it seems that the fundamental information of energy and nutrient flows of the squid are still lacking. In the present study, investigations were made on rates of food consumption, food conversion and daily growth of the oval squid in an indoor aquarium fed on three kinds of live food organisms on individual bases in order to supply more basic physiological data on feeding and nutrition of this promising species among neritic cephalopods.

Materials and Methods

Oval squid used in the present study were reared from eggs in an indoor aquarium. Squid eggs were collected in the vicinity of the Kominato Marine Biological Laboratory of the Tokyo University of Fisheries (now of the Chiba University) on the west side of Uchiura Bay located on the middle of the Pacific coast of Boso Peninsula, central Honshu, Japan. Squids ranged from 0.06 to 42.1 g in wet body weight (BW) and from 6 to 84.1 mm in dorsal mantle length (ML) were reared from eggs to the experimental size. Classification of early stages of growth follows Segawa.[8]

Through the period of this experiment, squids were kept individually in separate aquarium ($28\times35\times22$ cm about 20 *l* or $28\times68\times22$ cm about 40 *l* in capacity) under natural light condition with running seawater after acclimation of 6–7 days. During the acclimation period squids were maintained in the experimental aquaria with the same food under the same condition. Rearing periods were 10 days for squids sized 6–38.5 mm ML, 5 days for 50–76 mm ML, and 4 days for 80–85 mm ML, respectively. Water temperature during the experiment ranged

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from 23.5 to 26°C. Squids were fed on three kinds of live food organisms, namely, atherinid fish *Atherion elymus* in 10–30 mm TL, mysid *Siriella longipes* in about 15 mm TL and hatchlings of the oval squid, which were given to squid every morning with removal of the remaining. In feeding with atherinid fish, they were sized according to the size of squid to avoid the risk of bias caused by size difference of prey and predator. Whenever food organisms were consumed by squids, foods were supplemented. Hard parts of prey, such as skeleton, head and appendages, which were thrown off by squid were collected and removed carefully. Wet weights of food given to squid and the remaining were measured in fresh condition.

The rates for daily growth in BW (DGRW) and in ML (DGRL), and food conversion (gross growth efficiency) (FCR) were calculated according to Choe[8] and Mangold and Boletzky:[17]

$$\mathrm{DGRW}(\%)=\frac{w_2-w_1}{t(w_2+w_1)/2}\times 100$$

and

$$\mathrm{DGRL}(\%)=\frac{l_2-l_1}{t(l_2+l_1)/2}\times 100,$$

where w_1 is the initial BW, w_2 the final BW, l_1 the initial ML, l_2 the final ML, and t the experimental period in days.

$$\mathrm{FCR}(\%)=\frac{w_2-w_1}{F}\times 100,$$

where F is the total food intake in grams of wet weight.

The daily food consumption rate (DFR) was calculated with the following equations:

$$\mathrm{DFR}(\%)=\frac{F_k}{w_1+t_k(w_2-w_1)/t}\times 100,$$

where t_k is the number of days from the initial to kth day and F_k is the food intake in day t_k.

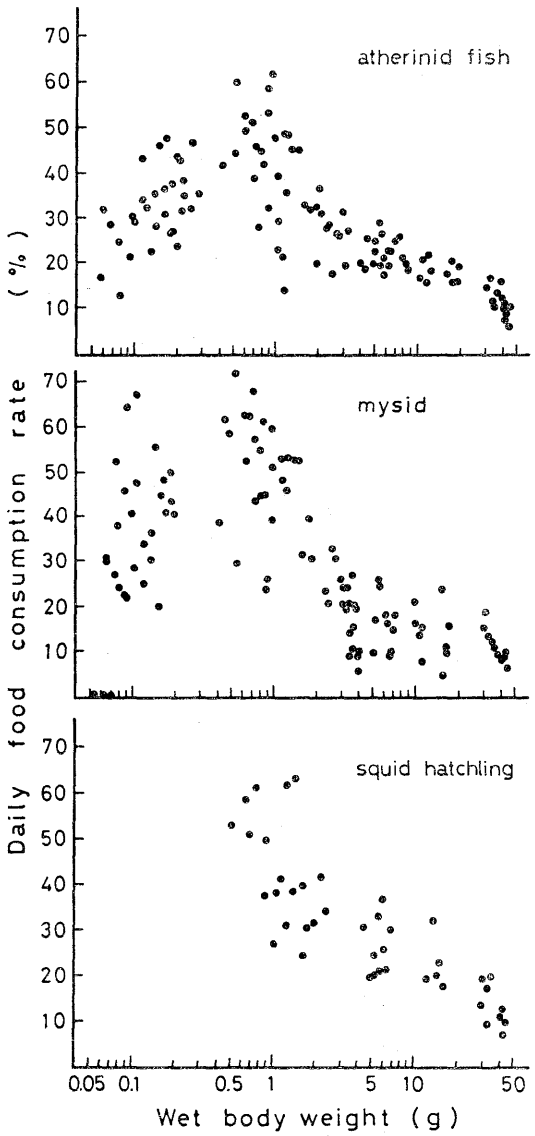

Fig. 1. Relationship between daily food consumption rate and wet body weight of the oval sqid fed on three kinds of food organisms.

Results

Food Consumption Rate

The daily food consumption rate changed with the size of squid and the rate increased abruptly with increment in body weight at the hatchling stage (0.06–0.15 g BW, 6–10 mm ML), while it decreased with size at advanced stages larger than 0.5–1 g BW (Fig. 1). For grown-up squid over about 3 g BW, food consumption rate ranged from 5 to 36%. Food consumption rate of hatchlings to atherinid fish was 12–32% and it increased with the size of squid and to the maximum rate of 60% for squid about 1 g BW. The rate decreased with the size of squid, 10–15% at about 40 g BW. Food consumption rate on mysid took a higher value (maximum rate of 72% for squid about 0.5 g BW) than those on atherinid fish for squid sized between 0.1 and 1 g BW in size, while it showed a lower rate on grown-up squids larger than about 3 g BW. The rate to squid hatchlings as food was highest among three kinds of food organisms and that to mysid was the lowest for squid larger than about 3 g BW.

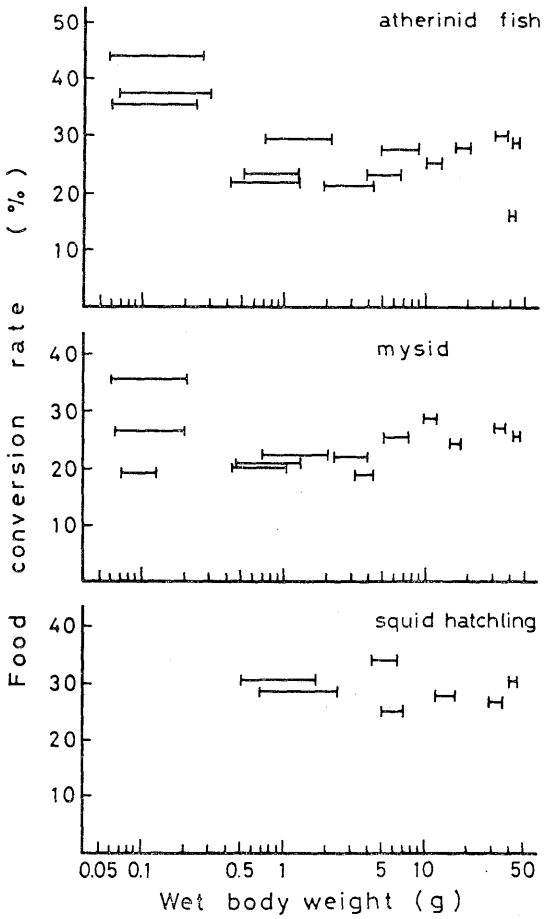

Fig. 2. Relationship between food conversion rate and wet body weight of the oval squid fed on three kinds of food organisms. Horizontal bar indicates the wet weight ranges from the initial to the end of the experiments.

Conversion Rate

Food conversion rate ranged 15.8–43.8, 18.6–35.6 and 25.0–34.1% for atherinid fish, mysid and squid hatchlings, respectively. The rate was almost constant regardless of the size of the squid, but it appeared to be higher in hatchlings fed on atherinid fish (Fig. 2) than else. The food convesion rate was generally independent of the food consumption rate and the kind of food organisms, except only in the case of squid hatchlings fed on atherinid fish (Fig. 3).

Growth Rate

The growth rate of the oval squid reared in the indoor aquarium with continuous existence of food organisms of three different kinds of food organisms decreased with size of squids both in ML (Fig. 4) and BW (Fig. 5). The daily growth

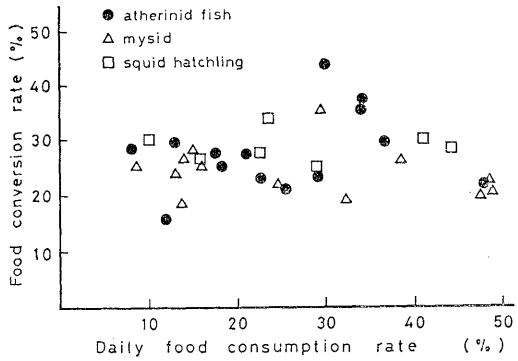

Fig. 3. Relationship between food conversion rate and daily food consumption rate of the oval sqid fed on three kinds of food organisms.

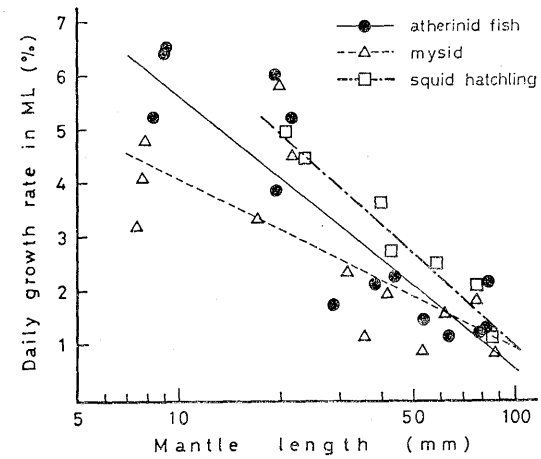

Fig. 4. Relationship between daily growth rate in mantle length and mantle length of the oval squid fed on three kinds of food organisms. See Table 1 for regression equation.

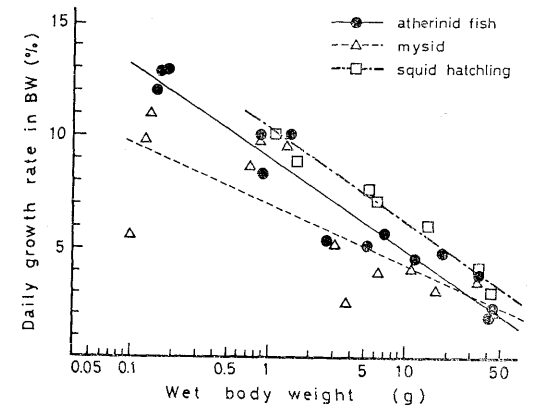

Fig. 5. Relationship between daily growth rate in wet body weight and wet body weight of the oval squid fed on three kinds of food organisms. See Table 1 for regression equation.

Table 1. Equations between the daily growth rate in mantle length (DGRL) and mantle length (ML), the daily growth rate in wet body weight (DGRW) and wet body weight (BW), and DGRW and the average daily food consumption rate (DFR) of the oval sqid fed on three kinds of food organisms

Equation	Food	BW (g)	n	r	a	b
DGRL=a+b log ML	Fish	0.07–41.9	14	−0.9007	11.043	−5.213
	Mysid	0.06–42.1	13	−0.7818	7.269	−3.164
	Squid	0.51–40.6	7	−0.9707	12.132	−5.523
	Total	0.06–42.1	34	−0.8076	9.071	−4.029
DGRW=a+b log BW	Fish	0.07–41.9	14	−0.9669	9.120	−4.172
	Mysid	0.06–42.1	13	−0.7827	7.003	−2.772
	Squid	0.51–40.6	7	−0.9828	10.457	−4.265
	Total	0.06–42.1	34	−0.8446	8.317	−3.320
DGRW=a+b DFR	Fish	0.07–41.9	14	0.8426	−0.218	0.292
		0.43–41.9*	11*	0.9461*	0.424*	0.225*
	Mysid	0.06–42.1	13	0.8753	0.981	0.188
	Squid	0.51–40.6	7	0.9271	1.549	0.196
	Total	0.06–42.1	34	0.8242	0.947	0.217

* Squid except in hatchling stage.

Table 2. The significance test among three different kinds of food organisms for equations between the daily growth rate in mantle length (DGRL) and the mantle length (ML), the daily growth rate in wet body weight (DGRW) and the wet body weight (BW), and the DGRW and the average daily food consumption rate (DFR) of the oval squid

Equation	Food organisms		nA+nB−4	t value	
	A	B		Intercept	Slope
DGRL=a+b log ML	Fish	Mysid	23	3.451	−1.951
	Fish	Squid	17	−0.470	0.201
	Mysid	Squid	16	−2.049	1.497
DGRW=a+b log BW	Fish	Mysid	23	4.410	−1.942
	Fish	Squid	17	−2.126	0.139
	Mysid	Squid	16	−2.846	1.151
DGRW=a+b DFR	Fish	Mysid	23	−1.057	1.719
	Fish	Squid	17	−0.981	1.230
	Mysid	Squid	16	−0.409	−0.144

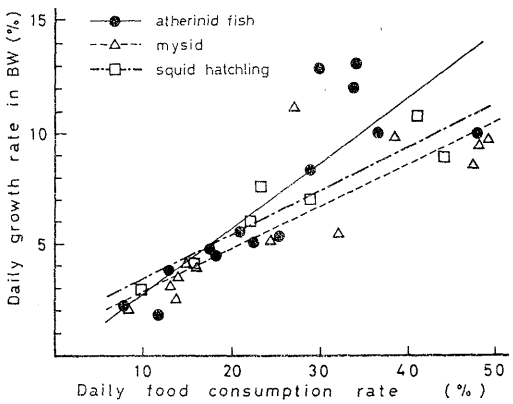

Fig. 6. Relationship between daily growth rate in wet body weight and daily food consumption rate of the oval squid fed on three kinds of food organisms. See Table 1 for regression equation.

rate in ML of hatchlings about 10 mm ML reached 6.5% and that of squid over about 50 mm ML was relatively low and constant rate (1–3%). The relationship between the daily growth rate in ML (DGRL) and ML of the squid was expressed as DGRL=a+b log ML for three food organisms (Fig. 4, Table 1). Among these equations, the intercepts and slopes were not significantly different from each other at the 95% confidence limits, except the intercept pairs of atherinid fish and mysid (Table 2).

The daily growth rate in BW (DGRW) also decreased with the increase of BW and expressed as DGRW=a+b log BW for three food organisms (Fig. 5, Table 1). The intercepts were significantly different from each other among the squid fed on three kinds of food organisms at the 95% confidence limits. However, the slopes were

not different from each other (Table 2). The rate of the squid of 30–50 g BW ranged from 1.8–4.1%, while that of hatchlings was 12.0–12.9% and 5.5–11.0% fed on atherinid fish and mysid, respectively.

The growth rate seemed to be dependent upon quality of food. For squids in hatchling and juvenile 1 stages (0.06–1.5 g BW; 6–25 mm ML), growth rate fed on athernid fish was higher than that on mysid. For squids in young stage (larger than 6 g BW and 40 mm ML), growth rate in cannibalism was the highest of all.

The daily growth rate in BW (DGRW) increased with increase of the daily food consumption rate (DFR) expressed as DGRW$=a+b$ DFR for three kinds of food organisms (Fig. 6, Table 1). The intercept and slope were not different from each other among these equations at the 95% confidence limits (Table 2). The daily growth rate of the squid fed on atherinid fish showed a little higher value than the others with the daily food consumption rate of 29.6–32.3% (Fig. 6). These high values were obtained only for squid hatchlings. The body weights of squid increased linearly with increase of food consumption rate ranging from 7.9 to 48% of their BW independent of the kind of food except for squid hatchlings.

Discussion

Food intake depends on growth stages of the squid.[18] The increment of daily food consumption rate at the hatchling stage observed in the present study on the oval squid (Fig. 1) is also reported for *Sepia esculenta*.[6] This is the result of acquisition of the ability of attack on prey organisms with their growth soon after hatching. As squids have enough ability of attack, the daily food consumption rate decreases with size as shown for octopuses,[4,17,19] *Sepia lycidas** and *Sepioteuthis sepioidea*.[2] Daily food consumption rate was obtained for some squid species; for *Sepia officinalis* (5.0–9.5%),[20] for *Loligo forbesi* (14.1±5.4%),[9] for *L. opalescens* (4–29, average 14.9%),[7] for *Sepioteuthis sepioidea* (17–101%)[2] and for *Illex illecebrosus* (3.5–6.7%).[11] The rates of 0–72% for oval squid in the present study are relatively higher than those for the other species except for *S. sepioidea*.[2] This may depend on the difference in water temperature of their habitat and also the difference in activity and behavior. Most of the previous data of the daily food consumption rate were obtained from squids in relatively cold water species.[7,9,11] Data on warm water cuttlefish shows lower food consumption rate than those on squids probably because of their lower activity in their quasibenthic life.

Food conversion rate for cephalopds, particularly for the octopus, is among the highest reported in the literature.[3,4] The rate of squid shows high values such as 15.8–43.8% for the oval squid (present study), 27% as on an average for *Loligo opalescens*,[7] and 25–36% for *Illex illecebrosus*.[11] For *Octopus* and *Sepia* species the values are still higher, showing 10–92% (average 46–69)[17,21,22] and 8.97–97.09%,[8,20] respectively, than squid species mentioned above. One of the reasons may be that the difference in maintenance costs comes from the difference of their standard metabolisms and locomotory activity.

When fed *ad libitum*, food conversion rate of the oval squid is largely independent of the size of animals except hatchlings. The rate of octopus is also independent of the size,[3,17] in contrast to mussels,[23] opistobranchs[24] and fish[25,26] that all exhibit declining tendency of the conversion rate with increase of size of animals. Decrease in the conversion rate at high food consumption levels appears to be general rule in fish[25,27,28] and the same tendency is also observed in mussels.[23] On the contrary, such a clear effect has been observed neither in the oval squid (present study) nor octopus.[3]

Food conversion rate of the oval squid roughly depends on the kinds of food organisms, like some cuttlefish *Sepia lycides** and octopi.[4,29] Mangold[4] suggested that the conversion rate is higher for octopus fed on a mainly proteinic diet than that fed on carbohydrates-rich food.

The estimate of growth of the oval squid from field observations and laboratory studies was already summarized.[8,30] In the present study, comparisons are made on the growth of squid fed on three different kinds of food organisms. It was found that the growth rate is higher for cannibalism than for fish diet or for mysid. Hirtle *et al.*[11] examined the difference of growth of *Illex* by fish diet and crustaceans. They obtained a similar result that the growth rate of *Illex* was higher for fish diet, however, the daily growth rates were comparable when the same quantities of fish or crustaceans were ingested by squid.

* I. Arima, T. Hiramatu, T. Norimatu, K. Segawa, and N. Tako: Fukuoka-ken Buzen Suisanshikenjo Kenkyu Houkoku, Fukuoka Prefectural Fisheries Experimental Station, Fukuoka, 1964, pp. 1–56.

Although some oval squid grow over 1 kg particularly in mature males,[31,32] the equation between the daily growth rate and BW or ML (Figs. 4, 5, Table 1) shows the existence of the crossing point to the rate of 0 for the daily growth rate at 153–335 g BW. This suggests that the slope of the equation (*b* value in Table 1) changes to a gentle one with increment of size influenced on sexual maturation or some other physiological factors.

There is a linear relationship between daily growth rate and daily food consumption rate of the oval squid (Fig. 6). O'Dor *et al.*[10] obtained the same relationship for *Illex illecebrosus*, and they found a critical value relating food consumption rate and growth rate which suggests the daily food consumption rate for maintenance ranged from 0.7 to 1.8%. For the oval squid in the present study no critical point was found because they were fed *ad libitum*.

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References

1) M. J. Wells and J. Wells: *J. Zool. Lond.*, **161**, 65–74 (1970).
2) E. T. LaRoe: *Mar. Biol.*, **9**, 9–25 (1971).
3) W. F. Van Heukelem: Growth, bioenergetics and life-span of *Octopus cyanea* and *Octopus maya*, Ph. D. Thesis, University of Hawaii, Hawaii, 1976, pp. 1–224.
4) K. Mangold: *Mem. Nat. Mus. Victoria*, **44**, 81–93 (1983).
5) A. C. Hurley: *Fish. Bull. U. S.*, **74**, 176–182 (1976).
6) S. Choe: *Korea J. Zool.*, **9**, 72–80 (1966).
7) W. T. Yang, R. F. Hixon, P. E. Turk, M. E. Krejci, W. H. Hulet, and R. T. Hanlon: *Fish. Bull. U. S.*, **84**, 771–798 (1986).
8) S. Segawa: *J. Tokyo Univ. Fish.*, **74**, 67–105 (1987).
9) R. T. Hanlon, W. T. Yang, P. E. Turk, P. G. Lee, and R. F. Hixon: *Aquacult. Fish Manag.*, **20**, 15–34 (1989).
10) R. K. O'Dor, R. D. Durward, E. Vessey, and T. Amaratunga: *ICNAF Selected Pap.*, **6**, 15–21 (1980).
11) R. W. M. Hirtle, M. E. DeMont, and R. K. O'Dor: *J. Shellfish Res.*, **1**, 187–192 (1981).
12) T. Okutani: *Saibai Giken*, **13**, 69–75 (1984).
13) S. Choe and Y. Oshima: *Venus*, **21**, 462–476 (1961).
14) Y. Oshima and S. Choe: *Nippon Suisan Gakkaishi*, **27**, 979–986 (1961).
15) S. Choe: *Bull. Mar. Sci.*, **16**, 330–348 (1966).
16) M. Tsuchiya: *Bull. Inst. Oceanic Res. Develop., Tokai Univ.*, **4**, 49–70 (1982).
17) K. Mangold and S. v. Boletzky: *Mar. Biol.*, **19**, 7–12 (1973).
18) R. Boucher-Rodoni, E. Boucaud-Camou, K. Mangold: in "Cephalopod Life Cycles Vol. 2" (ed. by P. R. Boyle), Academic Press, London, 1987, pp. 85–108.
19) L. M. Joll: *Aust. J. Mar. Freshw. Res.*, **28**, 45–56 (1977).
20) E. Pascual: *Inv. Pesq.*, **42**, 421–442 (1978).
21) J. W. Forsythe: *J. Zool. Lond.*, **202**, 393–417 (1984).
22) B. Hartwick, L. Tulloch, and S. Macdonald: *Veliger*, **24**, 129–138 (1981).
23) R. J. Thompson and B. L. Bayne: *Mar. Biol.*, **27**, 317–326 (1974).
24) T. H. Carefoot: *Comp. Biochem. Physiol.*, **21**, 627–652 (1967).
25) J. E. Paloheimo and L. M. Dickie: *J. Fish. Rse. Bd. Canada*, **22**, 521–542 (1965).
26) A. Hamada, T. Ida, T. Tsuda, and T. Kariya: *Nippon Suisan Gakkaishi*, **41**, 147–154 (1975).
27) J. E. Paloheimo and L. M. Dickie: *J. Fish. Res. Bd. Canada*, **23**, 869–908 (1966).
28) J. E. Paloheimo and L. M. Dickie: *J. Fish. Res. Bd. Canada*, **23**, 1209–1248 (1966).
29) M. J. Smale and P. R. Buchan: *Mar. Biol.*, **65**, 1–12 (1981).
30) Y. Ueta and Y. Jo: *Nippon Suisan Gakkaishi*, **55**, 1699–1702 (1989).
31) S. Suzuki, A. Kuwahara, and K. Washio: *Bull. Japan Soc. Fish. Oceanogr.*, **42**, 21–27 (1983).
32) G. L. Voss and G. Williamson: Cephalopods of Hong Kong, Hong Kong Govt. Press, Hong Kong, 1971, pp. 1–138.