Note

Body allometry and developmental characteristics of the three dominant pelagic ostracods (*Discoconchoecia pseudodiscophora, Orthoconchoecia haddoni* and *Metaconchoecia skogsbergi*) in the Oyashio region, western North Pacific

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If the dynamic roles played by various zooplankton groups in marine ecosystems are to be elucidated, information about the biomass of the individuals in the populations is a prerequisite, because most important physiological processes are related to body mass of the individuals (cf. Moloney & Field 1989, Hansen & Bjørnsen 1997). From a practical viewpoint, measuring the body masses of numerous small individuals is an often difficult, if not impossible task, but body length is generally a good indicator for body mass estimation. The precision of this practice depends on acquiring accurate length-mass relationships of the zooplankters of interest. To date, the relationship between body length and mass has been established for many of the dominant components of marine zooplankton, including many species of copepods (Mauchline 1998), euphausiids and mysids (Mauchline & Fisher 1969; Mauchline 1980). However, such information is currently lacking for planktonic ostracods, which are a sub-dominant zooplankton group characterized by small body size (mostly between 1 and 2 mm) with a rather poorly defined trophic function (cf. Angel 1999).

This study investigates the allometric relationships between shell length (SL) and dry weight (DW) and ash-free dry weight (AFDW) of the three most numerous planktonic ostracods in the Oyashio region of the western North Pacific, *Discoconchoecia pseudodiscophora* (Rudjakov), *Orthoconchoecia haddoni* (Brady & Norman) and *Metaconchoecia skogsbergi* (Iles). The data for SL, DW and AFDW of each instar have been used to investigate species-specific differences in the developmental patterns between the consecutive instars of the three ostracod species.

In the Oyashio region, the bathymetric depths at which the majority of the population of each species is distributed are: *D. pseudodiscophora* 300–400 m, *O. haddoni* 450–800 m and *M.*

skogsbergi 650–900 m. All the specimens used in these analyses were preserved in 5% (v/v) formalin-seawater buffered with borax. Details of the sampling procedures, the identification of instars, and the ecology of the three species have been reported elsewhere (Kaeriyama & Ikeda, Submitted). Preservation in formalin does result in the loss of some of the organic matter (Fudge 1968; Hopkins 1968; Williams & Robins 1982). Nevertheless, the magnitude of the error resulting from formalin preservation is relatively small and was assumed unimportant for making intercomparisons between the developmental stages and species of ostracods. Instars II through VIII (i.e. adult males and females) of *D. pseudodiscophora* and *O. haddoni*, and instars III through VIII (males and females) of *M. skogsbergi* were analysed. Shell length (SL: distance between the tip of rostrum and posterior end of shell) was measured under a compound microscope fitted with an eye-piece micrometer to the nearest 0.01 mm. For each instar, between one and 15 specimens (depending on the size of the specimens) were picked out, rinsed briefly with a small amount of distilled water and then dried for five hours in an electric oven (60°C) before being weighed using a microbalance (Mettler Toledo MT5) to a precision of 1 μg to give the dry weight (DW). Ash weights (ASH) were then determined by re-weighing the dried specimens after they had been incinerated in an electric muffle furnace (480°C) for 5h. Ash-free dry weights (AFDW) were then calculated as AFDW=DW−ASH.

SLs of the instars increased steadily with the progress of development (Table 1). In *D. pseudodiscophora*, SL increased from 0.26 mm (instar II) to an adult (instar VIII) mean size of 1.34 mm. The SL increase in *O. haddoni* was 0.34 (instar II) to 3.02 mm (instar VIII), and that in *M. skogsbergi* 0.40 mm (instar III) to 1.52 mm (instar VIII). There was a steady pattern of increase with development in both DW and AFDW in all three species (Table 1). The relationships between SL and DW, and SL and AFDW are best expressed by power regression models

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Table 1. Summary data on shell length (SL), dry weight (DW), ash-free dry weight (AFDW) and ash (%DW) of *Discoconchoecia pseudodiscophora*, *Orthoconchoecia haddoni* and *Metaconchoecia skogsbergi*. Values are mean±SD. Number of replicates is in parenthesis.

Species	Instar	SL (mm)	DW (μg)	AFDW (μg)	Ash (%DW)
Discoconchoecia pseudodiscophora					
	II	0.26±0.01 (606)	0.53±0.02 (3)	0.42±0.01 (3)	24.5±6.6 (3)
	III	0.31±0.01 (1464)	0.73±0.09 (4)	0.71±0.16 (4)	15.1±1.6 (4)
	IV	0.40±0.02 (1341)	1.32±0.00 (4)	1.17±0.10 (4)	11.4±7.6 (4)
	V	0.52±0.02 (1426)	2.83±0.16 (4)	2.43±0.16 (4)	14.2±0.8 (4)
	VI	0.70±0.02 (2319)	6.33±0.54 (4)	5.51±0.30 (4)	12.7±2.8 (4)
	VII	0.94±0.04 (3004)	19.90±2.87 (4)	18.40±2.50 (4)	11.4±5.7 (4)
	VIII (male)	0.98±0.05 (1257)	11.15±2.00 (4)	10.40±2.63 (4)	14.8±7.0 (4)
	VIII (female)	1.34±0.06 (2137)	34.15±6.68 (4)	30.90±5.91 (4)	9.4±1.8 (4)
Orthoconchoecia haddoni					
	II	0.34±0.02 (372)	1.38±0.05 (4)	1.12±0.10 (4)	19.0±7.9 (4)
	III	0.45±0.15 (1442)	1.97±0.21 (3)	1.53±0.15 (3)	22.0±0.9 (3)
	IV	0.59±0.03 (874)	3.70±0.53 (4)	2.70±0.38 (4)	27.0±1.9 (4)
	V	0.85±0.04 (842)	9.50±0.64 (4)	5.92±0.42 (4)	37.6±4.3 (4)
	VI	1.28±0.06 (695)	24.75±4.19 (4)	17.75±5.68 (4)	29.1±12.8 (4)
	VII	2.04±0.17 (439)	81.25±10.21 (4)	46.25±7.46 (4)	43.2±4.1 (4)
	VIII (male)	2.63±0.16 (273)	225.00±22.48 (4)	134.00±16.63 (4)	40.5±3.8 (4)
	VIII (female)	3.02±0.11 (423)	292.25±99.80 (4)	160.25±55.74 (4)	45.0±4.8 (4)
Metaconchoecia skogsbergi					
	III	0.40±0.03 (85)	2.05±0.19 (4)	1.25±0.19 (4)	38.9±7.9 (4)
	IV	0.51±0.04 (84)	4.83±1.06 (4)	2.00±0.53 (3)	60.8±2.4 (3)
	V	0.66±0.04 (140)	6.75±1.42 (4)	3.33±0.88 (4)	51.0±3.4 (4)
	VI	0.87±0.05 (207)	14.08±2.27 (4)	7.08±1.23 (4)	49.7±1.8 (4)
	VII	1.18±0.07 (248)	31.50±1.73 (4)	19.00±1.29 (4)	39.7±1.8 (4)
	VIII (male)	1.51±0.05 (143)	50.50±10.15 (4)	26.00±6.61 (4)	48.9±2.5 (4)
	VIII (female)	1.52±0.03 (317)	61.50±4.51 (4)	33.50±3.56 (4)	45.6±2.0 (4)

(Fig. 1): $DW = 1.20SL^{2.61}$ ($r^2 = 0.992$) and $AFDW = 1.16SL^{2.65}$ ($r^2 = 0.992$) for *D. pseudodiscophora*, $DW = 1.20SL^{2.53}$ ($r^2 = 0.996$) and $AFDW = 1.03SL^{2.36}$ ($r^2 = 0.995$) for *O. haddoni*, $DW = 1.31SL^{2.42}$ ($r^2 = 0.996$) and $AFDW = 1.03SL^{2.47}$ ($r^2 = $

0.995) for *M. skogsbergi*. The SL-DW relationships of *D. pseudodicophora* and *O. haddoni* did not differ significantly (ANCOVA $p > 0.85$) and so could be combined to give $DW = 1.20SL^{2.56}$ ($r^2 = 0.991$). Nor did the SL-AFDW relation-
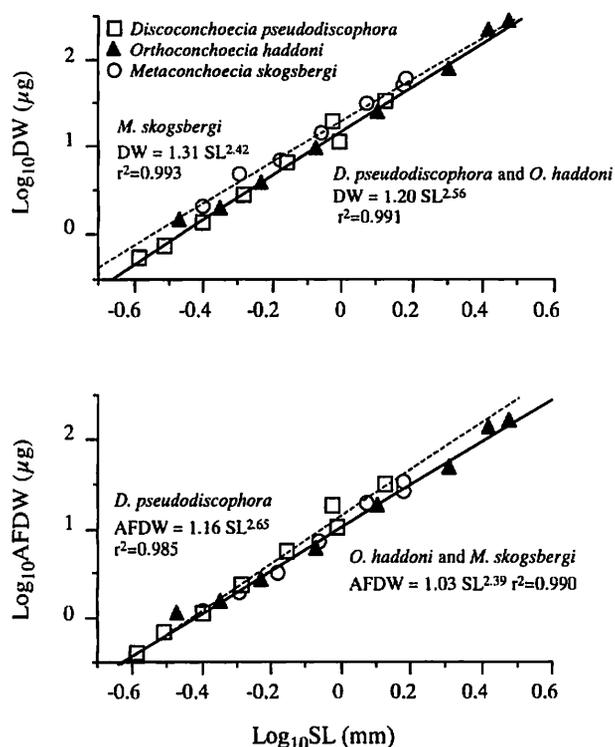
Fig. 1. The relationships between dry weight (DW) and shell length (SL) (top), and between ash-free dry weight (AFDW) and SL (bottom) of the three dominant ostracods in the Oyashio region.
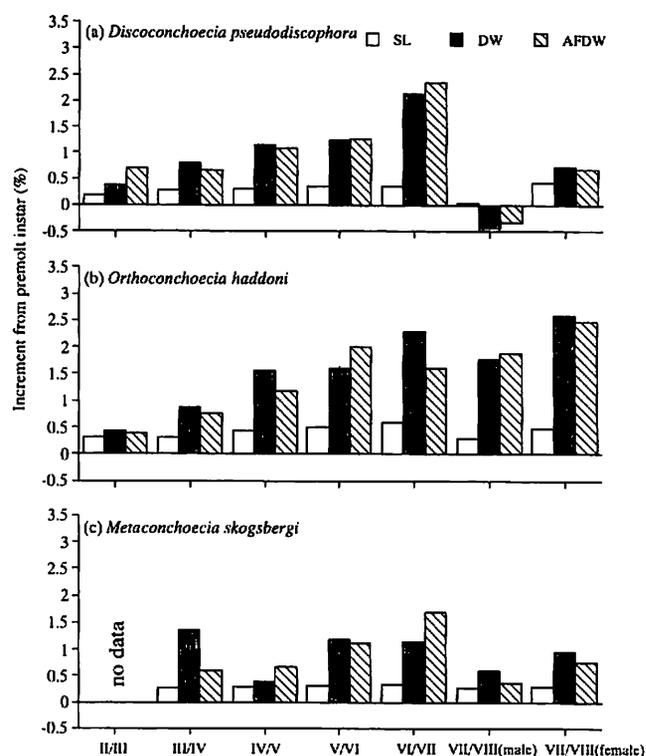

Fig. 2. Increments in shell length (SL), dry weight (DW) and ash-free dry weight (AFDW) between sequential instars in the development of (a) *D. pseudodiscophora*, (b) *O. haddoni* and (c) *M. skogsbergi* in the Oyashio region.

ships of *O. haddoni* and *M. skogsbergi* differ significantly (ANCOVA p>0.80) giving a combined result of $AFDW=1.03SL^{2.39}$ ($r^2=0.990$). We attribute the differences in DW-SL and AFDW-SL relationships to differential between-species accumulation patterns of ASH and AFDW in the body at each molt.

Between instars, ASH varied considerably ranging from 9.4 to 24.5% of DW in *D. pseudodiscophora*, from 19.0 to 45.0% of DW in *O. haddoni*, and from 38.9 to 60.8% of DW in *M. skogsbergi*. Regression analysis between instar number and ASH revealed that there is a steady increase in ASH with development in *O. haddoni* (r=0.921, p<0.001) but not in either *D. pseudodiscophora* (r=−0.680, p>0.05) or *M. skogsbergi* (r=−0.147, p>0.05). There were significant between-species differences in ASH averaged over all instars (*D. pseudodiscophora*, 14.2%; *O. haddoni*, 32.9%; and *M. skogsbergi*, 47.8%; Kruskal-Wallis test, p<0.001). This reveals that the deeper-living species exhibit higher ASH.

Increments in mass at each molt [(postmolt size−premolt size)/(premolt size)] were calculated for SL, DW and AFDW (Fig. 2). A pattern common to all three ostracods is that the between-instar increment values increase progressively up to instar VII (pre-adult); an exception to this pattern was the high incremental value for DW observed for the molt from instar III to instar IV in *M. skogsbergi*. The increment for the maturation molt (instar VII to VIII) varied greatly between the species and between sexes. There is a sharp reduction in the increment at

maturation in *D. pseudodiscophora*, especially in males, a moderate decrease in *M. skogsbergi*, but little or no reduction in *O. haddoni*. The negative increment at the maturation molt in male *D. pseudodiscophora* suggests that the adult males ceased feeding. Comparing the increments between instars expressed by SL, DW and AFDW, the increments in SL were the least for the three ostracods (the maximum SL increments are: 0.35 for instars V/VI for *D. pseudodiscophora*, 0.59 at instars VI/VII for *O. haddoni*, and 0.36 at instars VI/VII for *M. skogsbergi*). The increments of DW or AFDW are roughly comparable to each other; the maximum increments are for *D. pseudodiscophora* 2.34 in AFDW at instars VI/VII, for females of *O. haddoni* 2.60 in DW at instars VII/VIII, and for *M. skogsbergi* 1.68 in AFDW. The observed species-specific differences, both in magnitude and in pattern of accumulation of DW (=inorganic+organic matter) and AFDW (=organic matter) accompanied with development, are considered to reflect differences in physiological processes between the species.

There are no other comparable data for planktonic ostracods, but the instar incremental data (for DW) of marine copepods (mostly shallow-living species) compiled by Mauchline (1998) show a progressively increasing trend with development rising to a maximum value of around 2.0. For mesopelagic copepods in the Oyashio region, Yamaguchi & Ikeda (2000a, b) reported incremental values (for AFDW) for copepodid I through VI (adults) of <4.2 for *Heterorhabdus tanneri*, 0.8–1.5 for *Pleuromamma scutullata*, and −0.15–3.0

for *Gaidius variabilis*. The incremental values recorded in the present study for the three ostracod species fall somewhere between those of shallow-living copepods (Mauchline 1998) and two out of three meso-/bathypelagic copepods (Yamaguchi & Ikeda 2000 a, b). Interestingly enough, a recent study on the copepod, *Neocalanus cristatus*, which is primarily a herbivore, indicates an AFDW increment as high as 8.7 at the molt from C4 to C5 (Ikeda unpublished). The between-species differences in the increment patterns may be interpreted as a life history trait to cope with the temporal variability of the food supply; with species experiencing a relatively constant supply of food throughout their life cycle exhibiting lower maximum values. If this interpretation proves to be correct, then the between instar incremental data may be used as an indicator of the stability of the food supply in the environments that the crustacean plankters inhabit. To verify this hypothesis, more increment data will be needed on crustacean plankton from a wide variety of habitats in the ocean.

Acknowledgement

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