POPULATION STRUCTURE, SIZE DISTRIBUTION, AND SHELL GROWTH OF *DOSINIA LUPINUS* (L.) (BIVALVIA) IN RAUNEFJORDEN, WESTERN NORWAY, WITH BIOMETRICAL COMPARISON TO *DOSINIA EXOLETA* (L.)

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A total of 149 specimens of *D. lupinus* were obtained from 99 quantitative (0.2 m^2) substrate samples taken between Nov. 1975 and Oct. 1976, in the archipelago of Eggholmane near Bergen. The depth within the delimited area varied between 0.3 and 13.3. m. The sediment was rich in $CaCO_3$ and grain-size distribution varied from fine to very coarse sand.

Growth of the shell was described by an asymptotic curve (maximum shell length 36 mm). Maturation occurred at a length of 13–16 mm and 90 adult specimens consisted of 42 (46.7 %) males and 48 (53.3 %) females. Most individuals (40.3 %) were found in the deep (7.3–11.8 m) sub-area F (nine sub-areas), which had the finest sediment of the whole survey area (median grain diam. c. 0.35 mm). The density was estimated to 9.9 ind. per m^2 for the whole survey area and to 27.7 ind. per m^2 for sub-area F only. Corresponding values for the biomass (AFDW soft parts) were estimated to 2.07 g per m^2 and 5.70 g per m^2. The calculated biometrical relationships for *D. lupinus* and *D. exoleta* show significant differences between the two species, and the shells of both species grow allometrically.

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INTRODUCTION

The genus *Dosinia* SCOPOLI has a worldwide distribution. There are eight species in the Atlantic, five along the east side, and three along the east coasts of North and South America (FISHER-PIETTE 1967). There are two species in Norwegian waters, *Dosinia lupinus* (L.) and *Dosinia exoleta* (L.). *D. lupinus* has been found from Iceland to the Canary Islands. SARS (1878) found it at Bodö and Lofoten in northern Norway. It has also been recorded from Golfe du Lion in the Mediterranean (BUCQUOY & al. 1882–98). According to HAAS (1938) it is found in depths from 25 to 150 m (general figure for the whole distributional area). Both species were found in the study area, but they showed different patterns of distribution. Mostly the two species are also easy to distinguish, but varieties of *D. exoleta* can sometimes be similar to *D. lupinus*.

D. lupinus is a suspension feeder, and the apertures of the siphons are poorly developed, which indicates that it is a species adapted to life in clean, sandy, or gravelly bottoms (ANSELL 1961).

The study area and the quantitative distribution of the marcofaunal species found here have been described by TUNBERG (1981, 1982). The survey is part of a study on population dynamics of *D. exoleta* (TUNBERG 1979).

MATERIAL AND METHODS

The material was collected in a shallow (0.3–13.3 m), sandy area at Eggholmane, 60°15′36″ N, 5°13′ E (Department of Marine Biology Ref. numbers E 191–75 and E 298–76). The size of the delimited area was about 49 800 m^2, of which 11 200 m^2 (22 %) was land (islets and skerries) and 38 600 m^2 (78 %) water. This sampling area (Fig. 1), its division into nine sub-areas (Fig 2), the sampling technique, and sediment analyses are described in detail in TUNBERG (1981).

Quantitative fauna samples were collected 11 times with regular intervals from Nov. 1975 to Oct. 1976. On each occasion, one sample was taken in each sub-area (i.e. a total of 99 samples of 0.2 m^2, 16 cm deep, were collected. The locations of the substrate sampling points are shown in fig. 3 in TUNBERG (1981) and in Fig. 5.

Length, height, and width of all specimens were measured by means of vernier callipers, with an accuracy of ± 1/10 mm (Fig. 3). Individuals smaller than 15 mm were measured under a stereomicroscope. The volume of the bivalve was measured on living specimens only (weight of the water displaced when submerging it in fresh water).

Small samples of the gonads were taken and analysed under a microscope for sex-determination.

Dry weight (DW) and ash-free dry weight (AFDW) were calculated according to CRISP (1971). The shell was dried separately. The accuracy of the measurements was ± 0.1 mg.

Confidence limits (95 %) of the mean were calculated by using the equation $\pm t \sqrt{\frac{s^2}{n}}$. The method described by HØISÆTER & MATTHIESEN (1979:94–101) was used when calculating mean values and confidence limits of the density

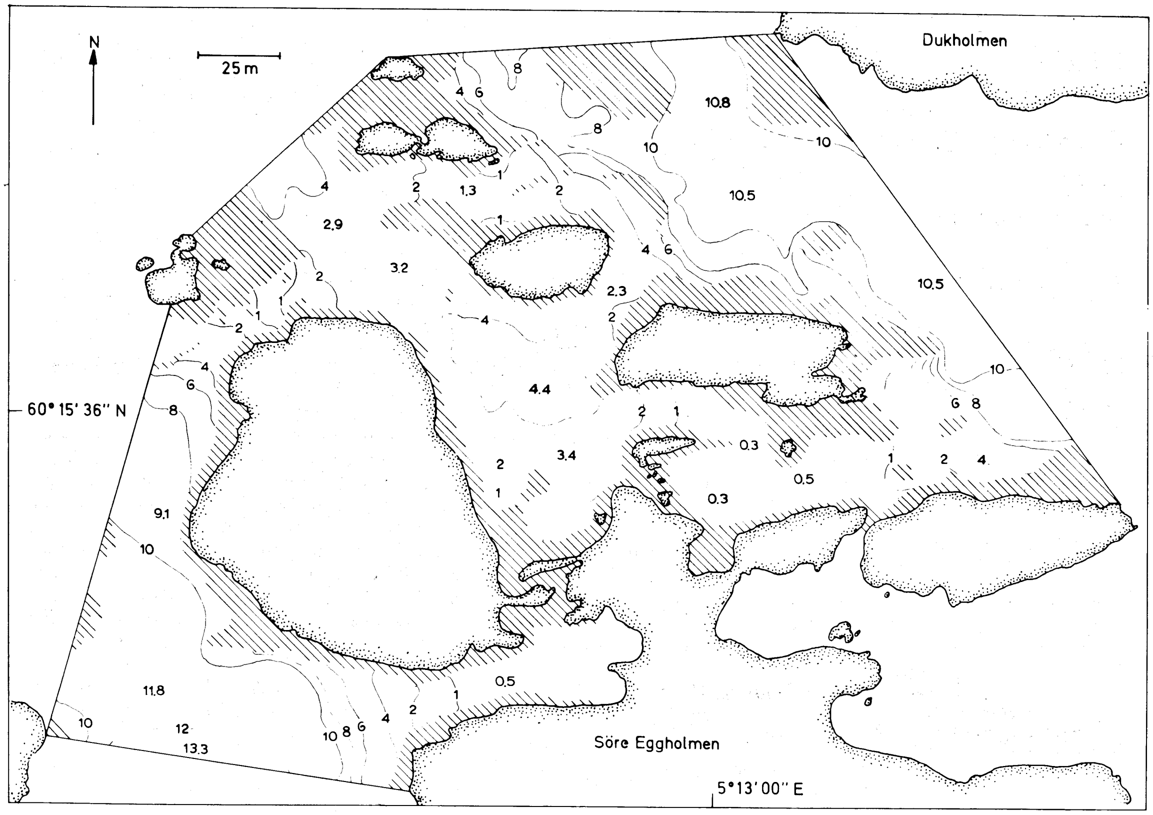


Fig. 1. Sampling area. Hatched parts indicate rock/pebble bottom. Some depths and isobates are shown for 1, 2, 4, 6, 8, 10, and 12 m depth. All depths have been corrected to LWS.

and the biomass of the whole survey area (primary area).

Four curves, linear, exponential, logarithmic, and power, were calculated for all sets of data points in order to find the best fit (the highest coefficient of determination). The program used applied the least square method, either to the original equations (straight line and logarithmic curve) or to the transformed equations (exponential curve and power curve). The program BMDP3R (DIXON 1975) was, however, used when calculating the power curves for *D. exoleta* (TUNBERG 1979).

RESULTS

Habitat

The differences concerning habitat preferences between *Dosinia lupinus* and *D. exoleta* have been briefly presented by TUNBERG (1981). Fig. 4 shows the percentage distribution of the two species within the nine sub-areas. They overlap in distribution, but are mainly found in different habitats. The sediment of areas A, B, C, and to a great extent also D and E, consisted of coarse and clean shell sand, while F–I consisted of finer and darker sand. Sediment analyses from the survey area are presented in fig. 4 in TUNBERG (1981). Even though a correlation analysis showed that there was a positive correlation (0.46) between depth and number of individuals of each sample, a corresponding analysis from the deep areas F–I only, showed no correlation at all (0.05). Sediment structure seems to be the most important factor concerning distribution, also within the four deep sub-areas. The sediment of areas F and G was much finer than that of areas H and I, with H coarser than I (see TUNBERG 1981).

Sub-area F, where most specimens were found, had the finest sediment (median grain diam. c. 0.35 mm). The depth of this area varied from 7.3 to 11.8 m.

Density and biomass

The number of individuals found in each of the 99 quantitative samples is shown in Fig. 5. Most specimens (12) were found in samples F10 and G3 (fig. 3 in TUNBERG 1981), with depths of 10.5 m and 10.3 m respectively.

The density of the whole survey area was calculated to 9.9 (± 2.9) ind. per m^2. The density of sub-area F only was calculated to 27.7 (± 10.9) ind. per m^2. The corresponding values of the biomass

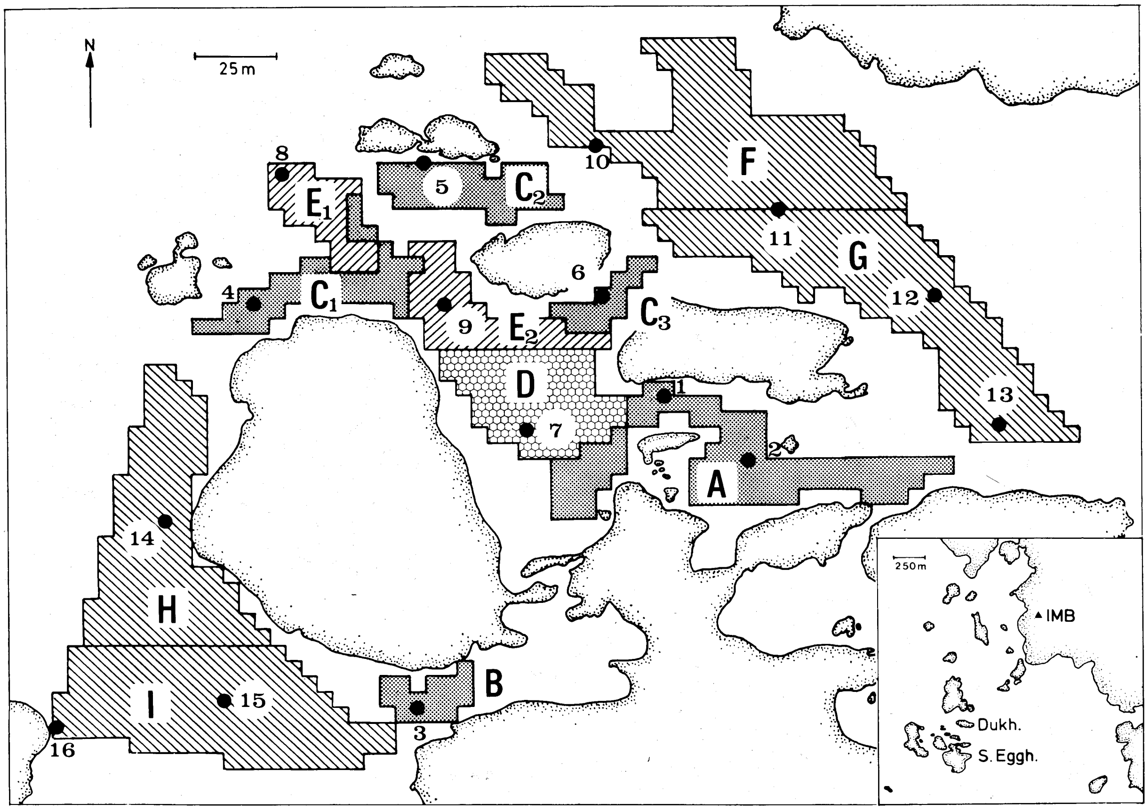


Fig. 2. The nine sub-areas, A–I, within the survey area. The dots show the 16 sediment-sampling points for grain-size and $CaCO_3$ analysis. IMB = Institute (now Department) of Marine Biology.

(**AFDW** soft parts) were calculated to 2.07 (± 0.81) g per m^2 and 5.70 (± 3.64) g per m^2.

Sex ratio

Of the 149 examined individuals, 59 (39.6 %) were either juveniles or impossible to determine to sex. The remaining 90 specimens consisted of 42 (46.7 %) males and 48 (53.3 %) females. In many cases the material was frozen for some time before treatment. This made it very hard to distinguish between males and females, since the sperm 'vanis-

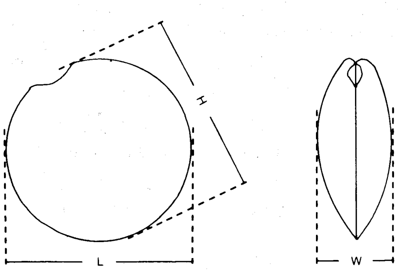


Fig. 3. View of the shell of *Dosinia lupinus* showing length (L), height (H), and width (W) measurements.

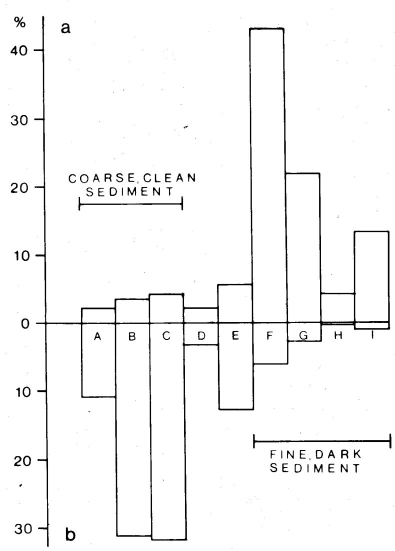


Fig. 4. Percentage distribution of *Dosinia lupinus* (a) (N = 149) and *D. exoleta* (b) (N = 428) in the nine sub-areas.

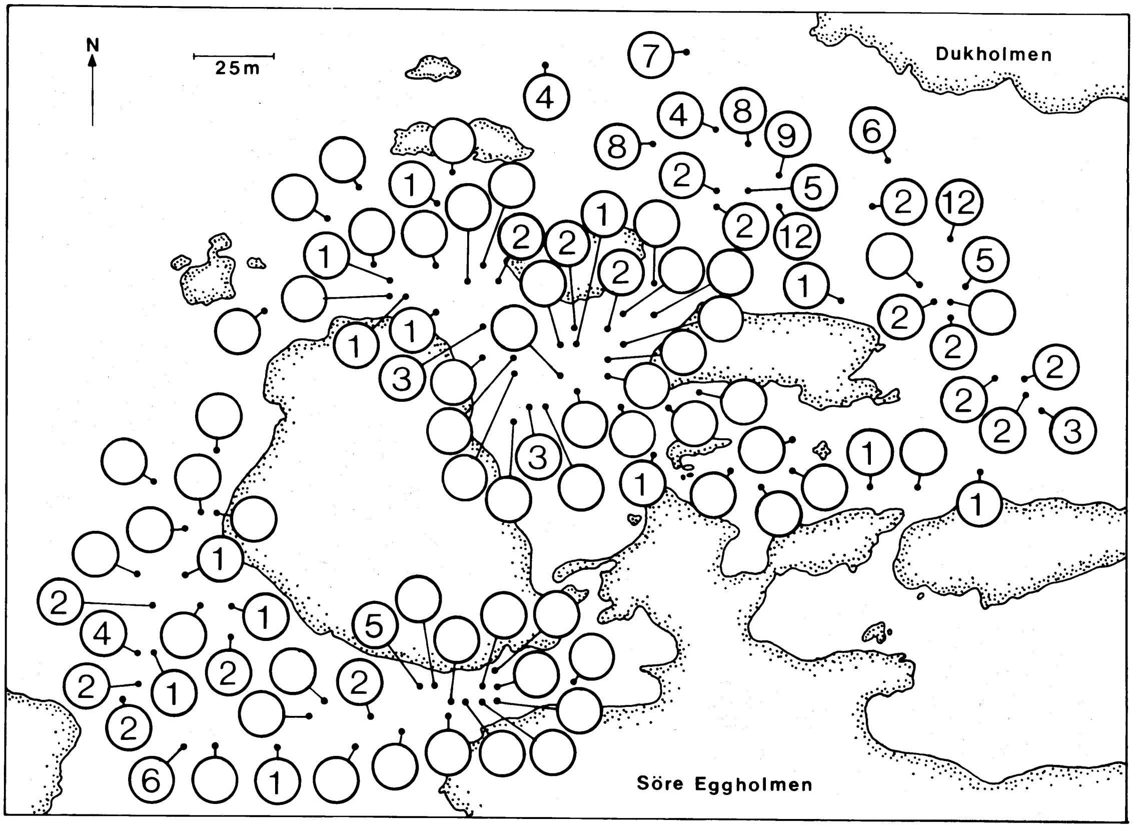


Fig. 5. Number of specimens of *Dosinia lupinus* found in the quantitative (0.2 m^2) samples.

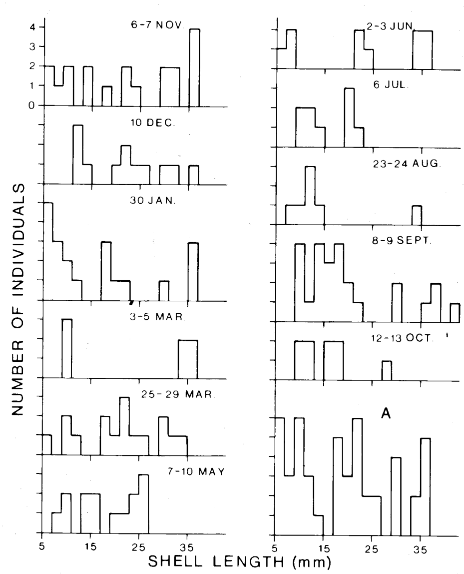


Fig. 6. Size-frequency histograms, Nov. 1975 to Oct. 1976. Histogram A shows size-frequency distribution of the winter samples 2–5 from areas F–I (see the text).

hed' when the bivalves were frozen. The eggs, however, remained intact.

The smallest male was 13.9 mm, the smallest female 13.2 mm, and the largest juvenile 14.1 mm long.

The data indicate that maturation occurs at a length of 13–16 mm. No observations were made on spawning but the heavy decline of soft parts (in relation to shell length) in July indicates that spawning occurs at this time of the year. Moore & Lopez (1970) found that the adults of *Dosinia elegans* Conrad (in Biscayne Bay, Florida) lost more than half their weight at spawning.

Size composition and growth

Fig. 6 shows the size-frequency distribution of the specimens collected at the 11 sampling occasions. At each occasion 9 samples were taken, as described earlier, i.e. the total area on each occasion was 1.8 m^2.

It was not possible to distinguish different year classes from this material. The size distribution of the winter samples 2–5 from the deep sub-areas, F–I, is presented in histogram A of Fig. 6. Since there was no growth during this period (TUNBERG 1979), this histogram should represent length distribution when the so-called winter rings are formed. The method described by HARDING (1949) and CASSIE (1954) was used in an attempt to separate year classes, but was not applicable. On 30 specimens of different sizes the dark 'growth bands' were also examined. These were hard to distinguish. CROZIER (1914) examined the dark bands of *Dosinia discus* (REEVE) and found no correlation between shell size and band number: 'It is possible the shells do not all grow at the same rate, or that the dark bands do not represent winter periods, or both'. However, the information achieved from the ring measurements on *D. lupinus*, together with the size-distribution data and the growth experiments of *D. exoleta* in the same area (TUNBERG 1979), made it possible to get a picture of shell growth of *D. lupinus*.

Asymptotic growth is usually described using the formula of von Bertalanffy (BEVERTON & HOLT 1957). The curve (Fig. 7, curve a) was calculated assuming a shell length of 11 mm after one year. The resultant equation reads as follows:

$$L_t = 36\,(1 - e^{-0.36t})$$

where L = length in mm, t = time in years.

The curves b and c of Fig. 7 were calculated from 13 and 9 mm length respectively, with resultant equations:

$$13\text{ mm:}\quad L_t = 36\,(1 - e^{-0.45t})$$
$$9\text{ mm:}\quad L_t = 36\,(1 - e^{-0.29t})$$

It is unlikely that the growth of the shell exceeds or falls below these equations. The idealized curve does not show the well known fact that growth varies during the year. The growth experiments carried out on *D. exoleta* in the same area showed that this species ceased to grow between Nov. and March (TUNBERG 1979).

According to the growth curve, *D. lupinus* reaches an age of at least 13–15 years.

Biometry

The relationships between length of the shell and eight variables are presented in Table 1. All these relations were expressed by means of power curves. The relationships between length and DW shell and between DW soft parts and AFDW soft parts were, however, expressed otherwise (see below).

Length/height is presented in Fig. 8a. The resultant power curve, very close to a straight line, has the best fit. The equation of the straight line ($Y = 0.9698\,X - 0.6319$), however, has an R^2 value only slightly lower (0.9960), than that of the power curve,

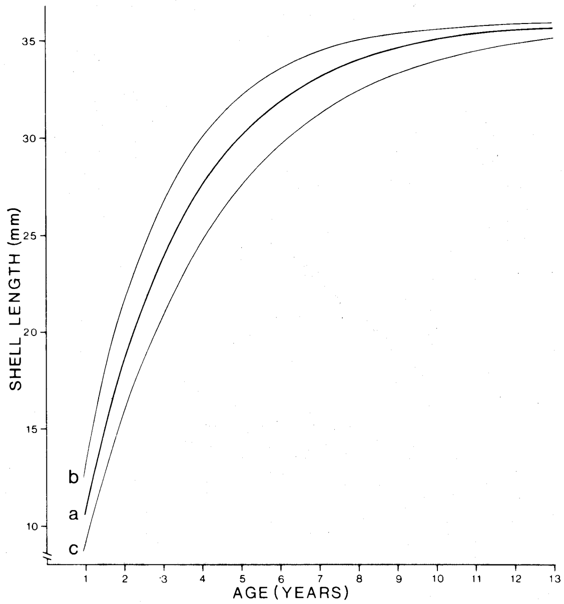


Fig. 7. Growth curves based on the von Bertalanffy equation. Curve a: shell length after one year = 11 mm, curve b: corresponding length = 13 mm, curve c: corresponding length = 9 mm.

but the latter crosses the Y-axis closer to the origin.

Length/width was expressed by means of two, significantly different (0.01 level) curves (Fig. 8b). When calculating these curves, all individuals smaller than 13 mm long were characterized as juveniles, and those longer than 16 mm were characterized as adults (corresponding lengths of *D. exoleta* were 18 and 21 mm).

Length/volume is presented in Fig. 8c.

Even though there is a good fit between length and DW soft parts (Fig 9a), the quantity of soft parts varied during the year. It was greatest in late spring, and low in July (after spawning) and during the winter (Nov. to Feb.).

The relationship between length and DW shell (Fig. 9b) was somewhat complicated. The power curve (Table 1) was not representative for older specimens. When all individuals smaller than 16 mm

Table 1. Regression equations (power curves) for length and eight variables of *Dosinia lupinus*.

Variable	n	a	b	R^2
Height	148	0.8813	1.0192	0.9968
Width (juv.)	47	0.5693	0.9506	0.9520
Width (adults)	81	−0.5417	0.6104	0.9672
Width (all ind.)	140	0.4834	1.0171	0.9876
Volume	64	1.26×10^{-4}	3.3179	0.9950
DW, soft parts	132	7.24×10^{-6}	3.2961	0.9822
AFDW, soft parts	117	7.34×10^{-6}	3.2477	0.9374
DW, shell	131	8.72×10^{-5}	3.1309	0.9938

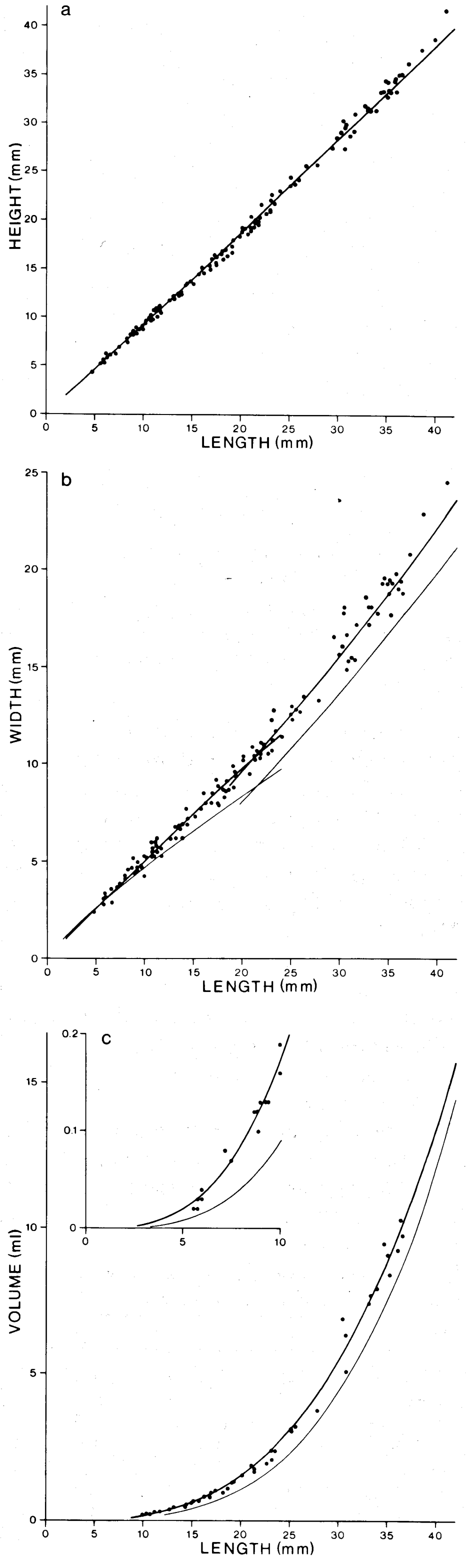


Table 2. Regression equations (power curves) for length and eight variables of *Dosinia exoleta.*

Variable	n	a	b	R^2
Height	432	0.7645	1.0561	0.9947
Width (juv.)	58	0.7116	0.8212	0.9373
Width (adults)	360	0.1710	1.2877	0.9369
Volume	204	2.82×10^{-5}	3.5165	0.9732
DW, soft parts	385	7.62×10^{-6}	3.1840	0.9124
AFDW, soft parts	365	8.40×10^{-6}	3.0975	0.8781
DW, shell (juv.)	49	9.98×10^{-5}	3.0590	0.9277
DW, shell (ad.)	326	3.79×10^{-6}	4.0283	0.9634

were excluded from the analyses (n = 72) an exponential curve ($Y = 0.0708\ e^{0.1295\ X}$) had the best fit ($R^2 = 0.9847$).

The relationship between DW soft parts and AFDW soft parts (Fig. 9c) was expressed by means of a straight line: $Y = 0.8190\ X + 1.16 \times 10^{-3}$, n = 117, $R^2 = 0.9992$ (the corresponding line for *D. exoleta* reads: $Y = 0.7842\ X - 1.00 \times 10^{-4}$, n = 366, $R^2 = 0.9890$).

The percentage amount of organic material in the soft parts (AFDW/DW × 100) was calculated separately for each individual (n = 117). The mean value was estimated to 82.0 % (s = 4.0 %). The biometrical relationships of *D. exoleta* are presented in Table 2.

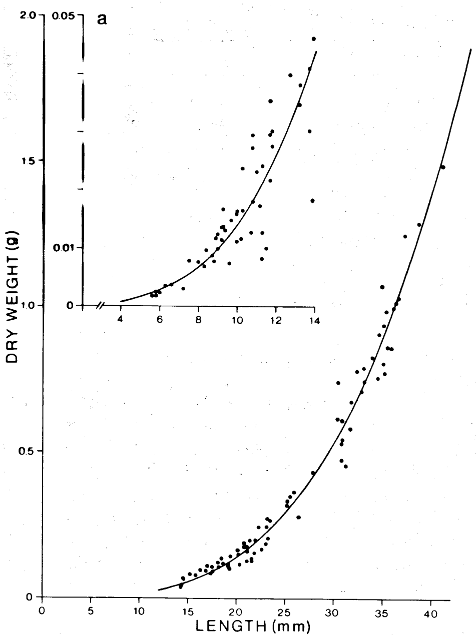
Analyses of covariance showed significant (0.01 level) differences between the two species concerning all relationships, except length/height (not sign. at the 0.05 level). The differences between the two species concerning length/AFDW) and length/DW shell were, however, not tested.

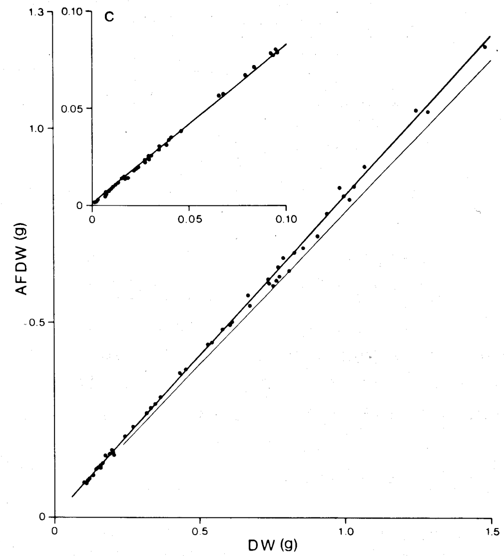
DISCUSSION

Dosinia lupinus was the fourth, and *D. exoleta* the second, most abundant bivalve species in this survey area (TUNBERG 1981). Both species were common also in other areas with similar substrate, in the Bergen area (pers. obs.). A study in progress, in a shell-sand area, at a depth of 12 m outside Gullmarsfjorden on the Swedish west coast, has shown that neither *D. lupinus* nor *D. exoleta* occur there. These species are probably polystenohaline, and therefore do not tolerate the fluctuating salinity of this area (influence of the Baltic Current). The fact that *D. exoleta* is (sporadically) found in deeper water further out in the archipelago (with higher and less fluctuating salinity) corroborates this presumption.

As shown in Fig. 8b, *D. lupinus* is wider, in relation to length, than *D. exoleta,* and growth is

Fig. 8. Biometry. The relationship between length/height (a), length/width (b), and length/volume (c). The thin curves in b and c represent *Dosinia exoleta.*





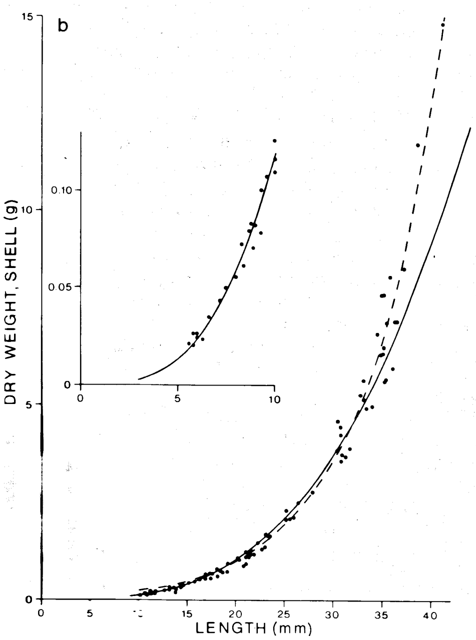


Fig. 9. The relationship between length/DW soft parts (a), length/DW shell (b), and DW soft parts/AFDW soft parts (c). The broken (exponential) curve in b represents adult specimens (see the text). The thin line in c represents *Dosinia exoleta.*

allometric in both species (more pronounced in *D. exoleta).* OHBA (1959) found higher W/L values in larger specimens of *Tapes japonica* DESHAYES than in smaller ones. In *Dosinia* this can possibly be an effective way to increase inner volume of the shell to give place to the gonads, which increase much in size in connection with maturation. In *Venerupis pullastra* (MONTAGU) there is an early change from round to oval shape, which is presumed to facilitate burrowing (QUAYLE 1952).

The thin shape of young specimens of *Dosinia* can possibly be explained in the same way. Adult specimens of *D. lupinus* and *D. exoleta* do not move around but are stationary (pers. obs.) and thus shape is of less importance.

D. lupinus and *D. exoleta* are in most cases easy to

Table 3. Some specific characteristics of *Dosinia lupinus* and *D. exoleta*.

Characteristics	*Dosinia lupinus*	*Dosinia exoleta*
Max. length	41.2 mm	57.3 mm
Dry shell	Glossy, dirty white	Dull, mostly straw-colored
Color markings	Never occur	Often red/red-brown blotches or striations or both
Lunule	Always white	Often brown in young individuals, yellowish white in older specimens
Umbo of young specimens < c. 7 mm	Often pink	Always white

distinguish from each other. Table 3 shows some characteristics, which may be of help when identifying especially small individuals of these species.

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