Growth and somatic production estimates of *Dosinia hepatica* (Lamark) (Mollusca: Bivalvia) in the Swartkops estuary, South Africa

N. Hanekom
Zoology Department, University of Port Elizabeth, Port Elizabeth

Regular and quantitative sampling for *Dosinia hepatica* was performed in the Swartkops estuary over a period of a year. The size of the *D. hepatica* recorded at LWMST was significantly ($P < 0{,}01$) larger than that sampled at 0,4 m above LWMST This appeared to be a result of a spatial separation of large and small individuals. Size frequency analyses of the populations sampled and growth ring lengths were used to construct a growth curve for *D. hepatica*. The calculated growth rate was slow, with *D. hepatica* reaching a shell length of approximately 16,3 mm and a dry tissue mass of *ca.* 44 mg after three years. The potential life span of the bivalve was estimated to be 8 – 9 years. The annual somatic production (per m^2) of the population sampled was calculated to be 0,58 g shell free dry mass or 8,63 kJ, while the production biomass (P/B) ratio was 0,3.
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Gereelde en kwantitatiewe monsters van *Dosinia hepatica* is oor 'n tydperk van 'n jaar in die Swartkops-getyrivier versamel. Die grootte van die *D. hepatica* opgeteken by 0,4 m bokant LWMSG was betekenisvol ($P < 0{,}01$) kleiner as die wat by LWMSG gevind was. Dit was blykbaar 'n gevolg van 'n ruimtelike skeiding van groot en klein diere. Groottefrekwensieontleding van die bevolking wat gemonster is en groeiringlengtes is gebruik om 'n groeikurwe vir *D. hepatica* te bepaal. Die berekende groeitempo was laag en *D. hepatica* het 'n skulplengte van naasteby 16,3 mm en 'n droë weefselmassa van *ca.* 44 mg na drie jaar bereik. Die moontlike lewensduur is geskat op 8 – 9 jaar. Die jaarlikse weefselproduksie (per m^2) van die gemonsterde bevolking was bereken op 0,58 g skulpvrye droë massa of 8,63 kJ, terwyl die produksie-biomassa (P/B)-verhouding 0,3 was.
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N. Hanekom
Present address: Tsitsikamma National Park, P.O. Storms River, 6308 Republic of South Africa

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Approximately eight species of burrowing bivalves are fairly common in the estuaries of southern Africa (Day 1981a). The population densities and biomasses of this group, with the exception of *Mactra lilacea* in the Langebaan lagoon, are, however, apparently small compared to those of the crustaceans (Day 1981a,b). Consequently, biological studies of these bivalves have been limited (McLachlan 1972, 1974; McLachlan & Erasmus 1974; Lucas 1979). This paper supplements the preliminary growth work of McLachlan (1974) and gives an estimate of the somatic production of the *Dosinia hepatica* (Lamark) population monitored within the Swartkops estuary.

D. hepatica is one of the smaller burrowing bivalves (shell length *ca.* 15 mm) found in the estuaries of southern Africa (Day 1969). Its distributional range stretches from approximately Morrumbene in the east to the Breede estuary in the west (Day 1981a).

In the Swartkops estuary, which is about 450 km east of the Breede River (Figure 1), the *D. hepatica* populations are relatively small and concentrated primarily in the middle reaches of the estuary (McLachlan & Grindley 1974; Hanekom, Baird & Erasmus 1986). It was in the above region that the study site was located. The topography and abiotic factors of the area have been discribed by MacNae (1957) and McLachlan & Grindley (1974) and sampling covered the period July 1975 to September 1976.

Methods

During the study period, the staff of the Port Elizabeth City Engineer took monthly readings of the surface water temperatures and salinities along the length of the Swartkops estuary. Measurements were done at spring low tide and the mean of the values recorded at Sites R – T (Figure 1) were used. Macrobenthic sampling was performed regularly (*ca.* every 6 weeks) at Site 1 (Figure 1). Duplicate samples, each covering 0,25 m^2, were taken at 0,0, 0,2 and 0,4 m above LWMST. The samples were dug to a depth of 15 cm, as McLachlan (1974) recorded *D. hepatica* almost exclusively in the upper 8 cm of the substrate. Samples were sieved through a 3-mm mesh. The *D. hepatica* were counted and measured to the nearest 0,1 mm using vernier calipers. The measurements were grouped into 1 mm size classes. Size frequency histograms were constructed for (i) the overall yearly samples taken at 0,0 and 0,4 m above LWMST, respectively and (ii) for each six weekly sample collected over the entire site. These histograms were respectively used to analyse the intertidal distribution of the population and the growth of the individual.

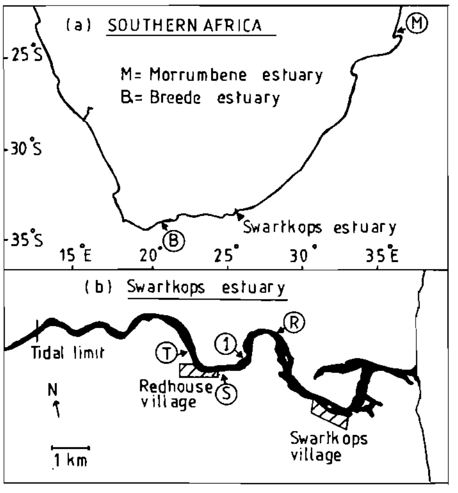

Figure 1 (a) A map of southern Africa, showing the geographical position of the Swartkops estuary and other areas mentioned in the text. (b) The Swartkops estuary and sampling sites for macrobenthos (1) and water analyses (R – T).

In the growth studies modal peaks were determined using probability paper (Cassie 1954) or in certain instances (marked by asterisks in Figure 6) by inspection. The progression of the modal mean was then plotted against time. These values were supplemented by growth ring data, as *D. hepatica* lays down fairly well-defined growth rings (McLachlan 1974). Ring lengths were measured on fifty *D. hepatica* having shells longer than 18 mm. The measurements were grouped into 1 mm size classes. Size frequency histograms were constructed and modal peaks determined. The latter values were plotted against time. McLachlan (1974) recorded relatively large numbers of *D. hepatica* spat in the Swartkops estuary during early autumn and spawning in this survey was assumed to be in mid summer (January).

The relationship between shell length and tissue dry mass of *D. hepatica* was determined from samples collected during winter (July – September, 1975). The bivalves were measured to the nearest 0,1 mm. The tissue portions were removed, individually oven dried at 90°C for 24 h and weighed to the nearest milligram. A regression line was fitted to the data. Quarterly collections of 30 – 60 *D. hepatica*, having shell lengths of 14 – 18 mm, were made for energy determinations. The tissue portions of the bivalves were freeze dried and bombed in an adiabatic bomb calorimeter. Duplicates were within 3% of each other.

Using the methods described by Crisp (1971), a survivorship plot and a somatic production estimate were determined for the *D. hepatica* population regularly sampled at Site 1. The population was dominated by one large modal peak (Figure 6) and in the calculations the entire population was treated as a single cohort. Furthermore, the recorded density and biomass values fluctuated and to smooth the survivorship curves (Figure 8) regression lines were fitted. The annual somatic production was determined using these regression values. The method was as follows: The differences in dry mass values between an individual having shell lengths equivalent to the modal means of consecutive samples were determined (e.g. $\Delta \bar{W}_1 = \bar{W}_2 - \bar{W}_1$). These values were then multiplied by the mean number of individuals present in the population over the sampling interval (e.g. $\bar{N}_1 \, \Delta \, \bar{W}_1$ ($\bar{N} = N_1 + N_2 \div 2$) and the product was multiplied by the mean energy content recorded for *D. hepatica* (see Table 1).

Results

The surface water salinity values recorded in the middle reaches of the estuary (Figure 2) were normally close to 30‰, except during September and October, 1975, when large freshwater flooding occurred. The recorded water temperatures showed a seasonal variation, ranging from 13°C in winter to 28°C in summer (Figure 2). Figure 3 illustrates the size composition of the *D. hepatica* population sampled in the lower and upper shores of Site 1. The mean size of the individuals sampled at LWMST ($\bar{X}$ = 15,7 ± 1,8 mm) was significantly (t = 7,4; $P < 0,01$) larger than that from the upper shores ($\bar{X}$ = 13,2 ± 2,4 mm). The smaller individuals were recorded almost exclusively in the upper shore (Figure 3).

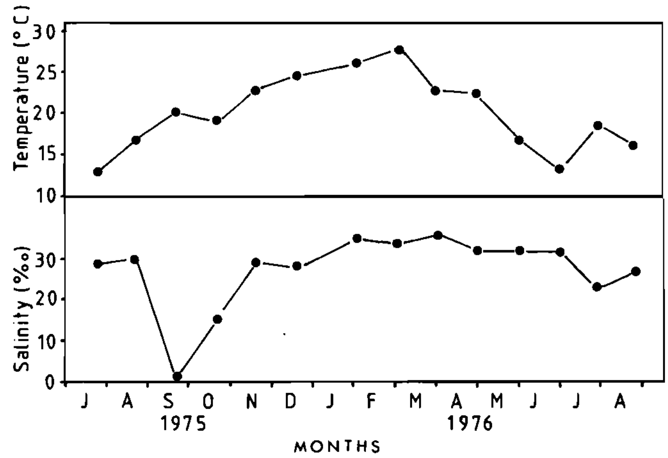

Figure 2 Mean monthly surface water temperature and salinity values recorded in the middle reaches of the Swartkops estuary during spring low tide (data obtained from the Port Elizabeth City Engineer).

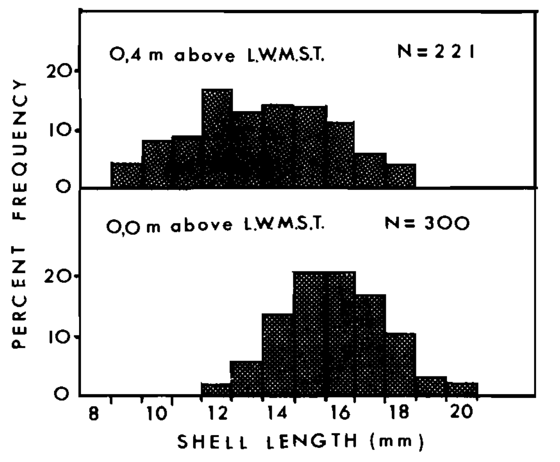

Figure 3 The size composition of all the *D. hepatica* sampled at 0 and 0,4 m above LWMST of Site 1 over the entire study period.

The size frequency histograms of the growth ring lengths are shown in Figure 4. The initial peak in the above histogram was relatively poorly defined and the modal mean of this group was taken at 6,5 mm. The peak values in the growth ring histogram were plotted a year apart in the form of a growth curve (Figure 5). Added to this growth curve were the modal means recorded in the size frequency histograms of the *D. heptica* population regularly sampled (see Figure 6). The latter population was dominated by a single modal peak,

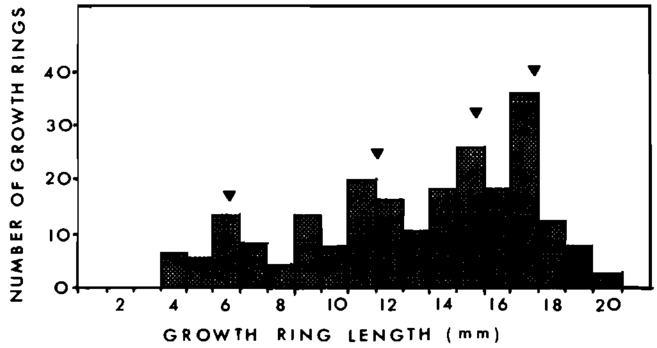

Figure 4 The size frequency of growth ring lengths measured on 50 *D. hepatica* shells, having lengths greater than 18 mm. Arrows indicate position of assessed modal means.

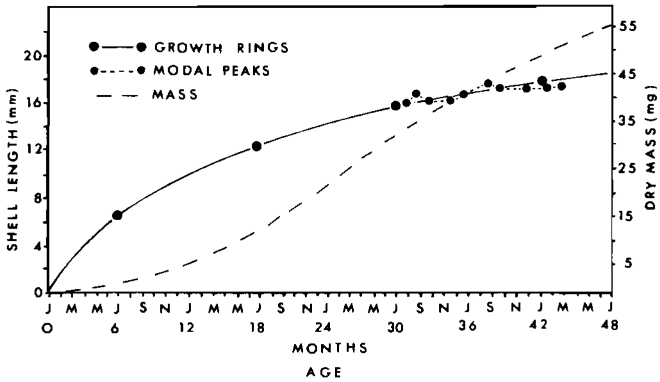

Figure 5 The growth curve (in terms of shell length) for *D. hepatica* plotted from size frequency peaks of growth ring lengths (large circles) and of populations sampled (small circles). Stippled line shows calculated growth in terms of shell free dry mass.

comprised of large individuals (*ca.* 15 mm shell length) and the progression of this peak over a period of a year corresponded to the size interval between the third and fourth growth ring peaks (Figure 5). The calculated growth in shell length was converted to dry mass (Figure 5), using the equation $y = 0{,}0010x^{3{,}8052}$, where y = shell free dry mass (mg) and x = shell length (mm) (see Figure 7).

A Walford (1946) plot of the consecutive growth ring peak values gave the equation $L(t + 1) = 8{,}049 + 0{,}613\ Lt$, where Lt and $L(t + 1)$ are shell lengths in mm at growth rings t and $t + 1$ respectively. From the above, the maximum theoretical shell length attainable (L_∞) was calculated to be 20,8 mm (Ricker 1968). This value was marginally smaller than the largest individual (21,3 mm) recorded in this survey and would suggest that the predicted growth rate in Figure 5 is probably slightly slower than that which occurs in nature. Through extrapolation of the growth curve shown, L_∞ was calculated to be attained between 8 – 9 years, while most of the individuals recorded during sampling (Figure 6) were estimated to be less than 6 years (i.e. 19,1 mm).

The survivorship plot of the *D. hepatica* population regularly sampled at Site 1 is shown in Figure 8. The regression lines fitted to the numbers and mean dry biomass values had significant ($P < 0{,}01$) regression coeffients (Figure 8). The values obtained from the regression lines and used to calculate the annual somatic production are shown in Table 1. The annual somatic production per m^2 was 0,58 g shell free dry mass or 8,63 kJ. The mean standing biomass ($\bar{B}$) of the population monitored was 1,89 g/m^2 and the production biomass (P/$\bar{B}$) ratio was therefore 0,3.

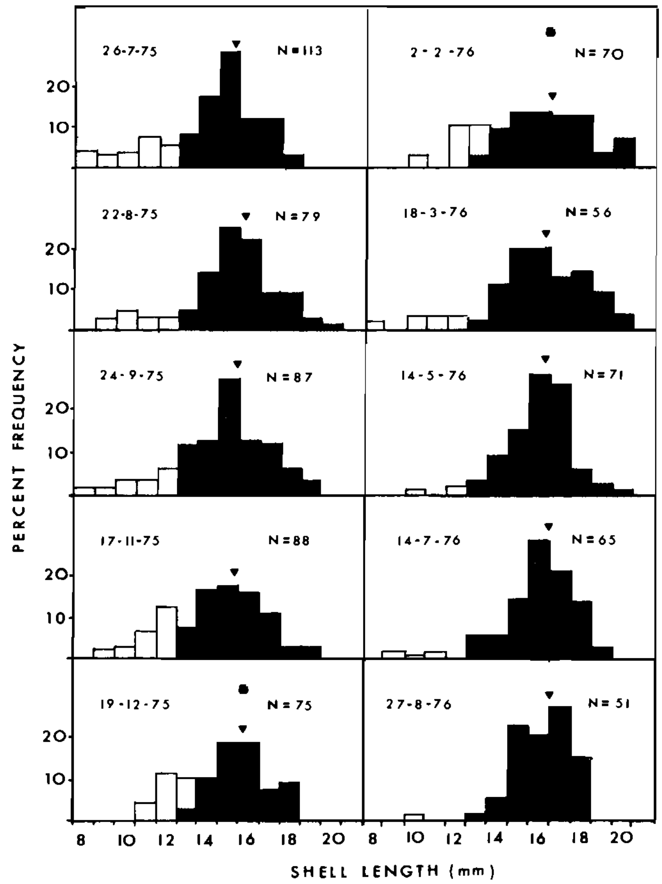

Figure 6 Size frequency composition of the *D. hepatica* population regularly sampled at Site 1. Shading and arrows respectively indicate modal peaks monitored and the position of the modal means, while asterisks show where modal peaks were determined by inspection.

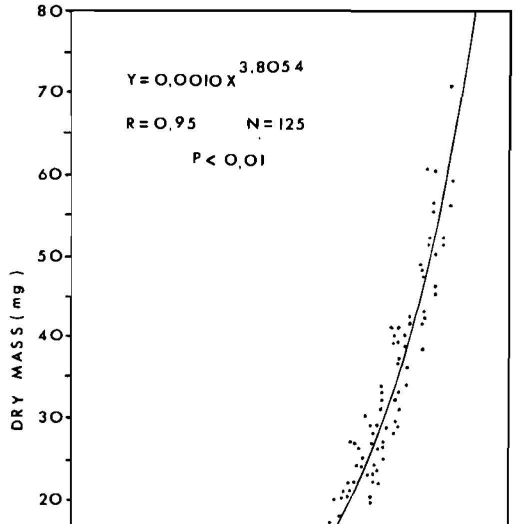

Figure 7 The relationship between shell length (mm) and dry tissue mass (mg) for *D. hepatica*.

Discussion

The mean size of the *D. hepatica* sampled at LWMST of

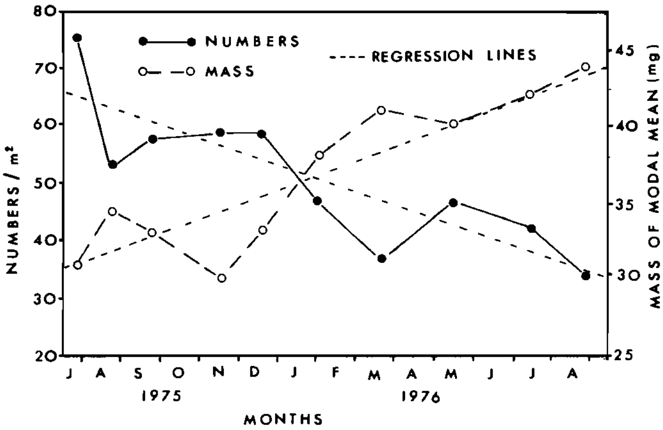

Figure 8 A survivorship plot of the *D. hepatica* population sampled at Site 1 between July 1975 and August 1976.
Equations of the regression lines are:
$N = 66{,}68 - 2{,}27\ X\ (n = 10,\ r = 0{,}71)$
$M = 30{,}04 - 0{,}98\ X\ (n = 10,\ r = 0{,}79)$
where N = numbers, M = dry mass (mg), X = time in months.

Site 1 ($\bar{X}$ = 15,7 mm) was significantly ($P < 0{,}01$) larger than that from the upper shore ($\bar{X}$ = 13,2 mm) (Figure 3). A similar phenomenon was recorded by McLachlan (1974) for both *D. hepatica* and *Macoma litoralis* within the Swartkops estuary. McLachlan (1974) related the pattern to decreases in the growth rates of the bivalves, as one proceeds up the tidal gradient. The results of this survey, however, seem to suggest that the above was due to a spatial separation of small and large *D. hepatica*, because individuals having shell lengths of less than 14 mm were recorded almost exclusively in the upper shore (Figure 3). Reading (1979) reported a similar distributional separation of small and large individuals of the bivalve, *Macoma balthica*. This species and *Scrobicularia plana* are apparently capable of migrating in a horizontal plane, by moving just below the surface of the substrate (Hughes 1970). It was therefore postulated that as the *D. hepatica* increased in size and burrowed deeper (McLachlan 1974), so they would probably migrate into the more turbulent lower shores, thus increasing their potential feeding time.

The initial peak in the growth ring histogram was relatively poorly defined and was apparently due to a spread in the size range values of the first ring class (Figure 4). Taylor & Venn (1978) recorded a similar phenomenon for *Chlamys opercularis* and related it to a protracted spawning season. They also noted that the spread in the size ranges decreased in the older ring classes. This was apparently due to the smaller individuals growing faster than the larger ones of the same ring class. The above would explain the form of the histogram recorded in this survey (Figure 4).

The slight discrepency recorded in Figure 5 between the population and growth ring values was probably due to the September – October 1975 flood (Figure 2). McLachlan (1974) found that in salinities below 14°/∞. *D. heptica* closes its valves tightly and can effectively isolate itself from the external environment for prolonged periods of time. The closure of the valves would, however, presumably curtail the feeding process and thereby decrease the growth rate of the bivalve. This could explain why the modal peak values for July and August 1976 of the population monitored were marginally smaller than that for the fourth growth ring peak (Figure 5).

Growth rings have been used to assess the growth of a number of bivalves, including *Chlamys opercularis* (Taylor & Venn 1978), *Cerastoderma edule* (Hibbert 1976; Jones 1979), *Mya arenaria* and *Macoma balthica* (Warwick & Price 1975) and *Scrobicularia plana* (Green 1957). The growth curve obtained in this survey was felt to be reasonable because the plot of growth ring peaks produced the expected von Bertalanffy type curve (Ricker 1968; Jones 1979); the progression of the modal mean from the population monitored over a period of a year corresponded to the size interval between two sets of growth ring peaks (Figure 5) and finally, the calculated maximum theoretical length attainable (L_∞) of 20,8 mm was close to the size of the largest individual (21,3 mm) recorded in this survey. The above growth curve (Figure 5) differed from that given by McLachlan (1974) for the same species. Its initial rate of growth was faster, while that for the fourth and fifth years was much slower. The estimated maximum potential life span of 8 – 9 years for *D. hepatica* corresponded to that (9 years) given by Jones (1979) for *Cerastoderma edule*, but was higher than the 6 – 7 years estimated for *Macoma balthica* (Warwick & Price 1975; Chambers & Milne 1975).

Excluding the effect of the flood, the progression of the modal mean from the sampled population suggested a seasonal growth pattern, with maximum growth occurring in spring and early summer (Figure 5). McLachlan (1974) recorded a similar phenomenon for *Solen corneus* and *Macoma litoralis* in the Swartkops estuary. Seasonal growth patterns have also been observed in bivalves, such as *Chlamys opercularis* and *Cerastoderma edule*, in the Northern Hemisphere. Although maximum growth in the above species occurs in spring and summer, the significance of water temperature on the growth processes remains vague, as food sources also apparently vary with seasons (Richardson, Taylor Venn 1982; Jones 1979).

The calculated annual somatic production (per m²) of the *D. hepatica* population monitored was 0,58 g shell free dry mass or 8,63 kJ (Table 1). The P/B ratio was 0,3 and was generally low compared to the ratio recorded for other burrowing bivalves (Table 2). The above was probably due to the fact that the population monitored in this survey consisted mainly of large individuals, whose high biomass would tend to depress the P/B ratio (Zaika 1972). The above dominance of a bivalve population by a single year class is

Table 1 The calculated annual somatic production of the *D. hepatica* population monitored in the Swartkops estuary. Dry mass was converted into kJ by multiplying mg by 0,0149 [the mean energy value recorded for *D. hepatica* sampled quarterly (SD = 0,0004)]

Date	Numbers per m² N	Dry mass of individual equivalent to modal mean (mg) $\bar{W}$	Production: Dry mass (mg/m²) $\bar{N}\Delta\bar{W}$	Production: Energy (kJ/m²) $\bar{N}\Delta\bar{W} \times 0{,}0149$
Aug. 1975	63	32		
Sept. 1975	60	33	62	0,924
Nov. 1975	56	35	116	1,728
Dec. 1975	54	36	55	0,820
Feb. 1976	51	37	53	0,790
Mar. 1976	47	38	49	0,730
May 1976	43	40	90	1,341
July 1976	38	42	81	1,207
Aug. 1976	35	44	73	1,088
Total			579	8,628

Table 2 Biomass (B), production (P) and production biomass (P/B) ratios recorded for a number of small burrowing bivalves. The values were expressed as grams ash free dry mass/m² or grams dry mass/m²*. The data come from work performed in the Northern Hemisphere, except that of this survey

Species	B	P	P/B	Reference
Cerastoderma edule	18 – 65	29 – 71	1,1 – 2,6	Hibbert (1976)
Macoma balthica	1,3*	1,9*	1,5	Burke & Mann (1974)
Macoma balthica	4,8*	10,1*	2,1	Chambers & Milne (1975)
Macoma balthica	0,3	0,3	0,9	Warwick & Price (1975)
Mercenaria mercenaria	8 – 50	4 – 14	0,2 – 0,5	Hibbert (1976)
Mya arenaria	4,6*	11,6*	2,5	Burke & Mann (1974)
Mya arenaria	5,5	2,7	0,5	Warwick & Price (1975)
Scrobicularia plana	2,1	0,5	0,2	Warwick & Price (1975)
Venerupis pullastra	135	20	0,2	Johannessen (1973)
Dosinia hepatica	1,89	0,61	0,3	This study

apparently fairly common and appears to be related to the wide fluctuations that occur in the success of juvenile recruitment (Hughes 1970 and Jones 1979). Furthermore, the findings of Warwick & Price (1975) would suggest that bivalve spat are very sensitive to environmental conditions and that mass mortalities are not uncommon.

If the P/B ratio in Table 1 was applied to the estimated standing biomass value [908 kg shell free dry mass, the organic content of the tissue = 71 ± 4% (n = 4)] for the entire *D. hepatica* populations (sub- and intertidal) of the Swartkops estuary (Hanekom, Baird & Erasmus 1986) the total annual somatic production would approximate 272 kg dry mass or 4×10^6 kJ. This is small compared to those (*ca.* 1115×10^6 kJ and 192×10^6 kJ) of the respective thalassinid prawn populations of *Upogebia africana* and *Callianassa kraussi* in the Swartkops estuary (Hanekom, Erasmus & Baird unpublished). It would thus seem that *D. hepatica* with its relatively small size and growth rate contributes little towards the overall macrobenthic production of the Swartkops estuary.

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References

BURKE, M.V. & MANN, K.H. 1974. Productivity and production: Biomass ratios of bivalve and gastropod populations in an eastern Canadian estuary. *J. Fish. Res. Bd Can.* 31(2): 167 – 177.

CASSIE, R.M. 1954. Some uses of probability paper in the analysis of size frequency distribution. *Aust. J. Mar. Freshwater Res.* 5: 513 – 522.

CHAMBERS, M.R. & MILNE, H. 1975. The production of *Macoma balthica* (L) in the Ythan Estuary. *Estuarine Coastal Mar. Sci.* 3: 443 – 455.

CRISP, D.J. 1971. Energy flow measurements. In: Methods for the study of marine benthos. IBP Handbook No. 16. (Eds.) Holme, N.A.M. & McIntyre, A.D. pp. 196 – 297. Blackwell Scientific Publications, Oxford.

DAY, J.H. 1969. A guide to marine life on South African shores. 289 pp. A.A. Balkema Publishers, Cape Town.

DAY, J.H. 1981a. The estuarine fauna. In: Estuarine ecology with particular reference to southern Africa. (Ed.) Day, J.H. pp. 147 – 179. A.A. Balkema Publishers, Cape Town.

DAY, J.H. 1981b. Summaries of current knowledge of 43 estuaries in southern Africa. In: Estuarine ecology with particular reference to southern Africa. (Ed.) Day, J.H. pp. 251 – 331. A.A. Balkema Publishers, Cape Town.

GREEN, J. 1957. The growth of *Scrobicularia plana* (Da Costa) in the Gwendraeth estuary. *J. Mar. Biol. Ass. U.K.* 36: 41 – 47.

HANEKOM, N., BAIRD, D. & ERASMUS, T. 1986. A quantitative study to assess standing biomasses of macrobenthos in soft substrata of Swartkops estuary. *S. Afr. J. Mar. Sci.* 6.

HIBBERT, C.J. 1976. Biomass and production of a bivalve community on an intertidal mud-flat. *J. Exp. Mar. Biol. Ecol.* 25: 249 – 261.

HUGHES, R.N. 1970. Population dynamics of the bivalve *Scrobicularia plana* (Da Costa) on an intertidal mud-flat in North Wales. *J. Anim. Ecol.* 39: 333 – 356.

JOHANNESSEN, O.H. 1973. Length and weight relationship and the potential production of the bivalve, *Venerupis pullastra* (Montagu) on a sheltered beach in western Norway. *Sarsia.* 53: 41 – 48.

JONES, A.M. 1979. Structure and growth of a high level population of *Cerastoderma edule* (Lamellibranchiata). *J. Mar. Biol. Ass. U.K.* 59: 277 – 287.

LUCAS, M.I. 1979. Growth and metabolism of *Mactra lilacea*. Abstract, 4th (S. Afr) Natl. Oceanog. Symp., Cape Town. July, 1979. C.S.I.R. Pretoria.

MACNAE, W., 1957. The ecology of the plants and animals in the intertidal regions of the Swartkops near Port Elizabeth, South Africa. Part 1. *J. Ecol.* 45: 113 – 131.

MCLACHLAN, A. 1972. Studies on burrowing bivalves in the Swartkops estuary. M.Sc. thesis, University of Port Elizabeth, R.S.A.

MCLACHLAN, A. 1974. Notes on the biology of some estuarine bivalves. *Zool. Afr.* 9(1): 15 – 34.

MCLACHLAN, A. & ERASMUS, T. 1974. Temperature tolerance and osmoregulation in some estuarine bivalves. *Zool. Afr.* 9(1): 1 – 13.

MCLACHLAN, A. & GRINDLEY, J.R. 1974. Distribution of macrobenthic fauna of soft substrata in Swartkops estuary, with observations on the effects of flood. *Zool. Afr.* 9(2): 211 – 233.

READING, C.J. 1979. Changes in the downshore distribution of *Macoma balthica* (L) in relationship to shell length. *Estuarine Coastal Mar. Sci.* 8: 1 – 13.

RICHARDSON, C.A., TAYLOR, A.C. & VENN, J.C. 1982. Growth of the queen scallop, *Chlamys opercularis* in suspended cages in the firth of Clyde. *J. Mar. Biol. Ass. U.K.* 62: 157 – 169.

RICKER, W.E. (ed.) 1968. Methods for assessment of fish production in freshwater. IBP Handbook No. 3. 313 pp. Blackwell Scientific Publications, Oxford.

TAYLOR, A.C. & VENN, T.J. 1978. Growth of the queen scallop, *Chlamys opercularis*, from the Clyde Sea area: *J. Mar. Biol. Ass. U.K.* 58: 687 – 700.

WALFORD, L.A. 1946. A new graphic way of describing growth of an animal. *Biol. Bull.* 90(2): 141 – 147.

WARWICK, R.M. & PRICE, R. 1975. Macrofauna production in an estuarine mud-flat. *J. Mar. Biol. Ass. U.K.* 55: 1–18.

ZAIKA, V.E. 1972. Specific production of aquatic invertebrates. Nankova Duma Kiev. (In Russian). Translated in 1973 by Israel Program for Scientific Translations Ltd Distributors. (Ed.) Golleck, D., 154 pp. Halsted Press: a division of John Wiley and Sons Inc., New York.