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Growth and production of the amphipod *Parhyale basrensis* (Talitridae) in the Shatt al-Arab region

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ABSTRACT: Life history data for the intertidal amphipod *Parhyale basrensis* Salman was collected, from April 1983 to September 1984, from an area near the Al-Chibassy tributary of the Shatt al-Arab River at Basrah, Iraq. Population density in the Shatt al-Arab region ranged from 928 to 12 512 m^{-2} and mean annual density was 3842 m^{-2} Growth rate of the generation which survived only the summer was 0.027 mm d^{-1} for males and 0.026 mm d^{-1} for females, and of the over-wintered generation was 0.024 and 0.019 mm d^{-1} for males and females respectively. Mortality rate was higher amongst the over-wintering generation (0.200 yr^{-1}) than the summer generation (0.048 yr^{-1}). Mean annual biomass of the population was 1.82 g dwt m^{-2}, annual production was 5.58 g dwt m^{-2} and P:B ratio was 3.06.

INTRODUCTION

The intertidal talitrid amphipod *Parhyale basrensis* Salman is widely distributed in the Shatt al-Arab River, Iraq. The River in this region contains oligohaline brackish water, characterized by few species of however high population density (McLusky 1971). In recent years the amphipod was noticed to occur in much higher densities than before which suggested an unusually high productivity. This led to a program for investigating the biological significance and role of the species in the Shatt al-Arab River.

Since its original description (Salman 1986) the species has been under intensive study. In an earlier study (Ali & Salman 1986) it was found that *Parhyale basrensis* has a semi-annual life history extending from May of one year to June of the next year, giving a maximum life span of 13 to 14 mo. The breeding season extends from late November or December with recruitment starting at the beginning of May. The objective of the present study was to estimate the growth and production of *P. basrensis*.

MATERIALS AND METHODS

This study is based on samples collected monthly from the intertidal zone in the period between April 1983 and September 1984. The sampling site was near Al-Chibassy tributary of the Shatt al-Arab River, Iraq (Fig. 1), just opposite the Silo of Basrah. Two quadrats (25 × 25 cm) were taken on each occasion. After killing and preserving in 4 % formalin, amphipods *Parhyale basrensis* were sorted through a 0.425 mm mesh-sized sieve. This mesh-size was found to be small enough to retain all stages of the amphipod. The amphipods were then grouped into 1 mm total length size classes and different cohorts separated by probability paper plotting (Harding 1949, Cassie 1954). Density and growth were determined by following the change in numbers and mean lengths of each generation over successive sampling periods.

To estimate monthly mean biomass and mean weight increments, the mean lengths of the amphipods were converted to mean weight using an empirical length-weight regression equation. For this purpose live amphipods of different sizes, ranging between 1.5 and 12 mm, were collected in May 1986. Each individual was anaesthetized, measured for length from cephalon to telson to the nearest 1 mm and the dry weight determined after oven-heating at 60 °C for 24 h. Weights of the amphipods were measured to the nearest 0.01 mg by a Sartorius-type balance. Instantaneous mortality rate Z was calculated from the slope of the regression $\log_{10}N$ against time, and annual mortality rate was estimated as $1-e^{-Z}$ (Crisp 1984).

Annual mean biomass was calculated from the monthly means of biomass and used for computing the production-biomass ratio (P:B). The production of each generation and the total annual production were esti-

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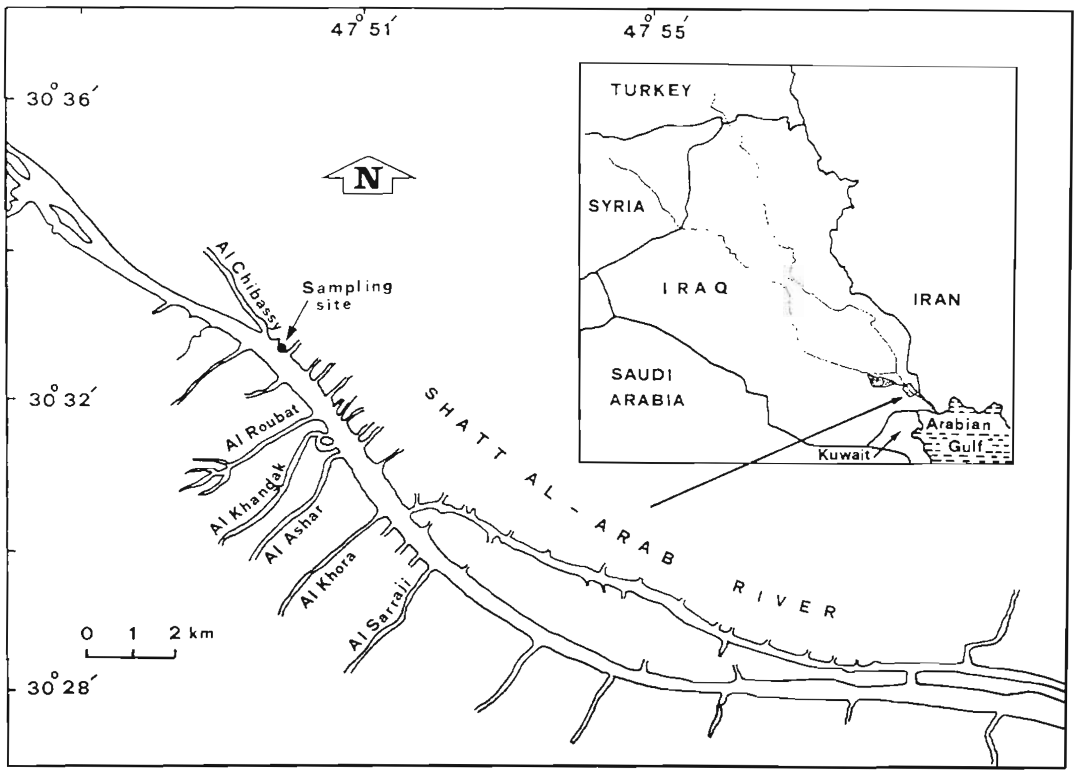

Fig. 1. Shatt al-Arab River, Iraq, showing the sampling site

mated by measuring the survivorships and mean weight increments of each generation separately using the expression of Crisp (1984):

$$P = \sum_{t=0}^{t=n} \frac{\overline{N}_t + \overline{N}_{t+1}}{2} \overline{W} \tag{1}$$

where $\overline{N}$ = mean population density at times t and t + 1; $\overline{W}$ = the mean weight increment between successive samples.

RESULTS

Length-weight relation

The length-weight relation for *Parhyale basrensis* was obtained from data on 120 specimens (Fig. 2) and expressed in the form of the following exponential equation:

$$\text{Log(dry weight)} = 2.7217\log(\text{length}) - 2.1919, \quad r = 0.9723 \tag{2}$$

Density

The population density of *Parhyale basrensis* reached a peak of 12 512 m^{-2} in July 1983 (Fig. 3), declined steadily towards October, and sharply thereafter. The lowest total value of 928 m^{-2} was attained in January and March 1984. A gradual increase occurred in April to June and a peak (9104 m^{-2}) was found in July 1984 (i.e. lower than for the same month in 1983).

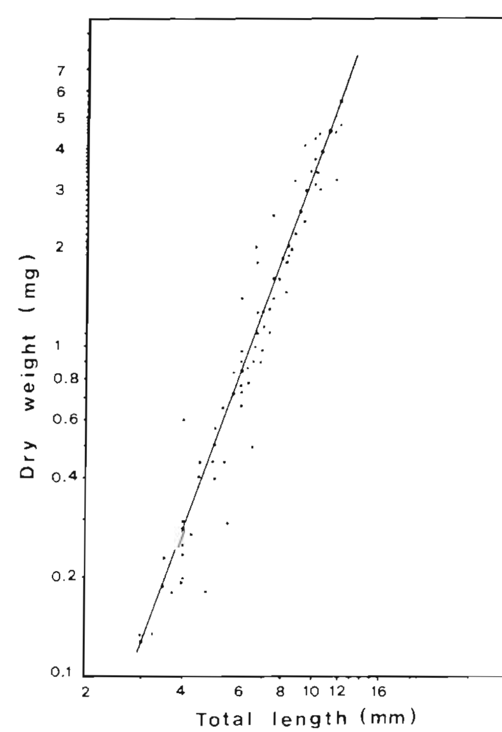

Fig. 2. *Parhyale basrensis*. Length-weight relation

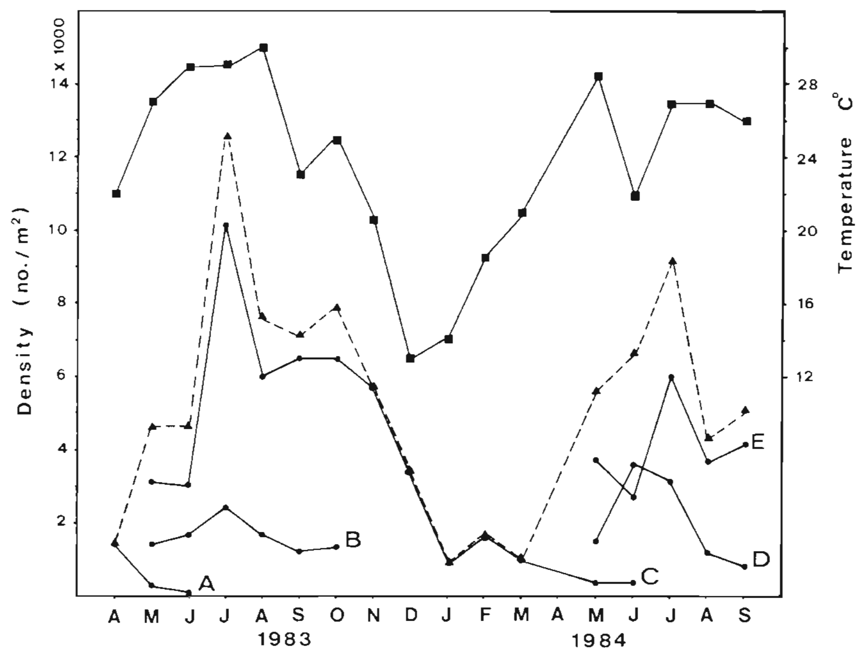

Fig. 3. *Parhyale basrensis.* Population density in the Shatt al-Arab region, from April 1983 to September 1984 (▲---▲), with the density of each Generation A to E. Water temperature (■——■) is given at the top of figure

Fig. 3 reveals considerable annual variations in population density. It is apparent that the rise in population density follows the gradual increase in water temperature. The peak of density was reached in July of both years 1983 and 1984 when water temperatures were 29 and 27 °C respectively. Conversely the minimum population density of January 1984 was attained when the water temperature dropped to 14 °C. The relation between the population density of *P. basrensis* and water temperature was found to be linear and highly significant ($r = 0.843$), indicating that temperature may be the predominant factor regulating the population density of this species.

Growth

Growth trends based on mean length increments and the standard deviation of each generation during successive months are shown in Fig. 4. Members of the new generation (B), which was released after 11 Apr 1983, grew from the hatching size of 1.5 mm total length to 5.1 mm for males and 5 mm for females by 11 May 1983. Average growth rate for males in this period was 0.17 mm d^{-1} and for females was 0.166 mm d^{-1}. During May–June 1983 the growth rate of Generation B was much slower than during the previous month. The life span of Generation B was found to be about

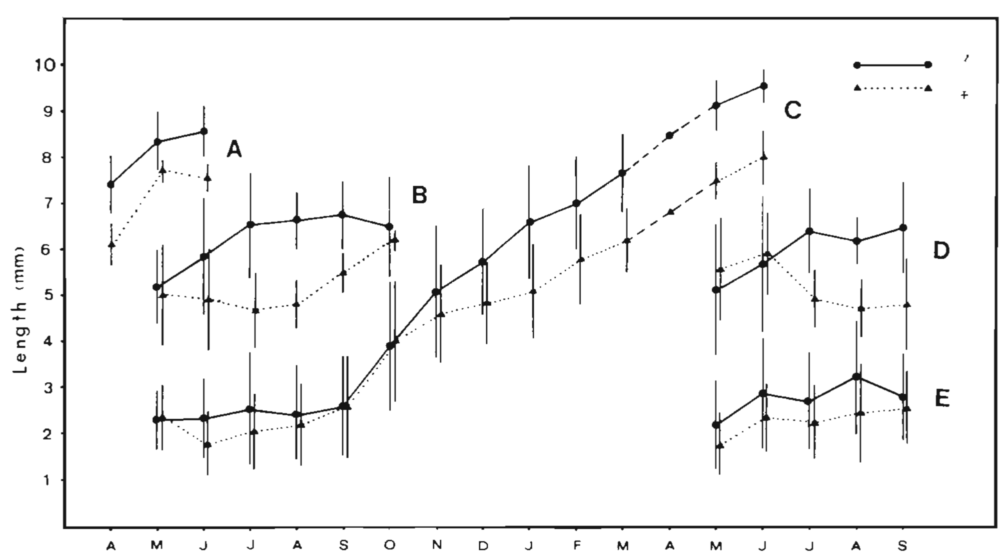

Fig. 4. *Parhyale basrensis.* Mean lengths and standard deviation of each generation in the Shatt al-Arab region for the period April 1983 to September 1984

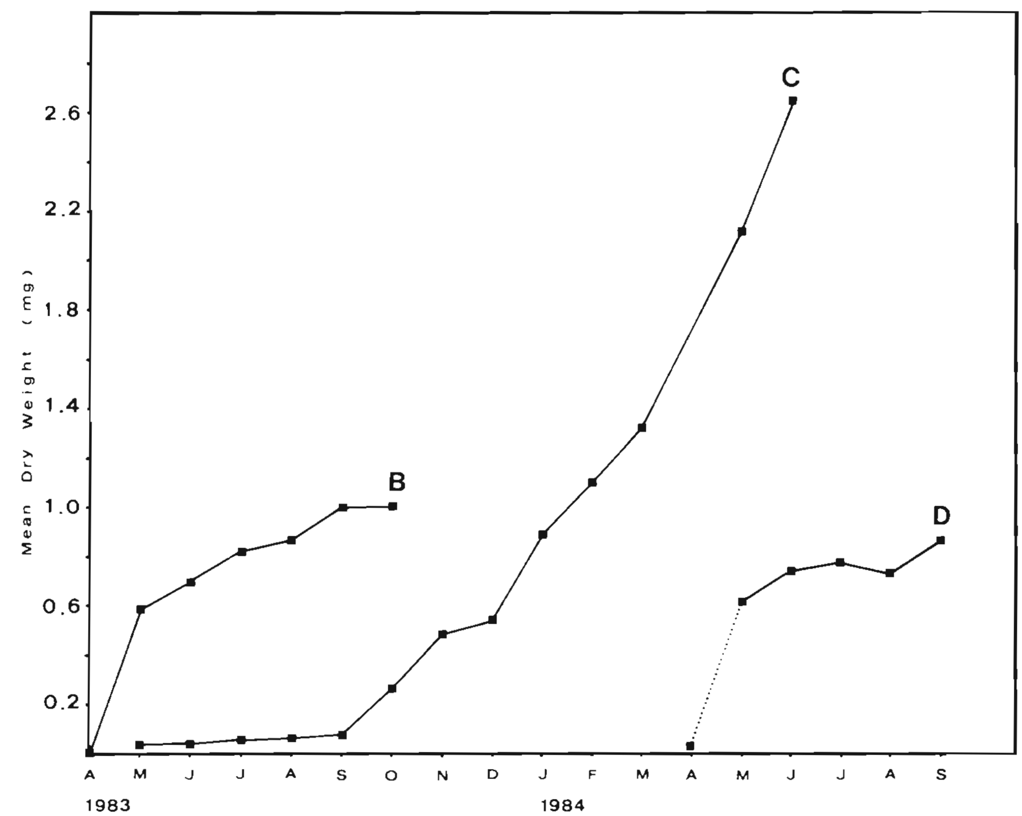

Fig. 5. *Parhyale basrensis.* Mean dry weight of Generations B, C and D in the Shatt al-Arab region over the sampling period

6 mo and the growth rate averaged throughout its life span was estimated to be 0.027 mm d^{-1} for males and 0.026 mm d^{-1} for females. Generation C which was released at the beginning of May 1983, persisted to June 1984. Growth rate of Generation C was low at the beginning of its life, from May to September 1983, but faster growth occurred from September to November 1983, when the estimated growth rate was about 0.040 mm d^{-1} for males and 0.033 mm d^{-1} for females. The growth rate of this generation for the period from August 1983 to June 1984 was 0.024 and 0.019 mm d^{-1} for males and females respectively.

Mean weight increments between successive sampling periods for Generations B, C and D, as estimated from length-weight expressions, are given in Fig. 5. The rates of dry weight growth averaged throughout the lives of Generation B and C was estimated to be 0.0056 mg d^{-1} and 0.0095 mg d^{-1} respectively.

Life-history table and mortality

A life-history table for the *Parhyale basrensis* population was constructed by following the survivorship of Generations B and C combined. Due to the problem of continuous breeding only a segment of these generations, starting from July 1983 and continuing to June 1984, was taken. The initial recruitment of Generation C was assumed to be equal to that of Generation B (8000 m^{-2}, see 'Discussion'). Intervals of 2 mo were taken for the survivorship estimates. The data on the survivorship obtained (Table 1) was in the form of an inverse hyperbola, which is a usual curve for most

Table 1 *Parhyale basrensis.* Life-history table of the population in the Shatt al-Arab River. x: age class (2 mo intervals); n_x: number entering age class; l_x: number surviving at start of age interval x; d_x: number dying during age interval x to x + 1; q_x: rate of mortality during the age interval x to x + 1 (multiply by 100 to convert to percentage mortality); L_x: average number of individuals alive during the age interval x to x + 1; e_x: mean life expectation for individuals alive at start of age x (units of 2 mo)

Age group	n_x	l_x	d_x	q_x	L_x	e_x
0	16 000	1.000	5904	0.369	13 048	2.0495
1	10 096	0.631	2312	0.229	8 940	1.9556
2	7 784	0.487	3192	0.410	6 188	1.3880
3	4 592	0.287	3304	0.719	2 940	1.0052
4	1 288	0.081	640	0.497	968	1.3012
5	648	0.041	264	0.407	516	1.092
6	384	0.024	384	1.000	192	0.500

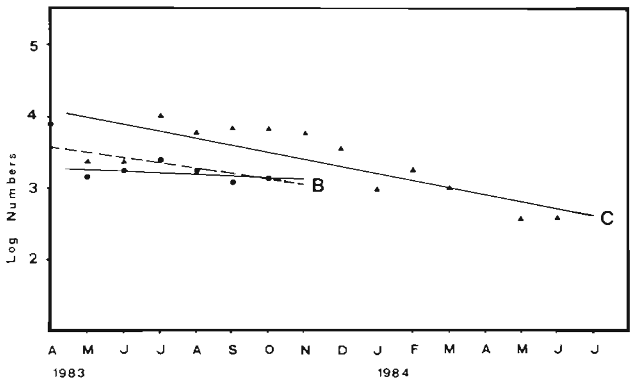

Fig. 6. *Parhyale basrensis.* Survivorship curves for Generations B and C at the Shatt al-Arab River during 1983/84. Broken line indicates curve of Generation B when initial calculated value of hatchlings (8000 m^{-2}) in April was considered

invertebrates. The mortality rate of the 0-age group was about 37 % $(2\ mo)^{-1}$, and the peak of mortality, 72 % $(2\ mo)^{-1}$, occurred in November–December.

Mortality rates of Generations B and C are shown in Fig. 6. Age-specific mortality rate Z for Generation B = 0.049 yr^{-1} and for Generation C = 0.224 yr^{-1}. Annual mortality rate was 0.048 and 0.200 yr^{-1} for Generations B and C respectively.

Biomass and production

The mean monthly biomass of the population showed 2 peaks in 1983 (Fig. 7), the first in July and the second in October. In 1984 a peak was reached in June. The estimated biomass in each of these 3 mo was 2.7, 3.0 and 3.9 g dwt m^{-2}, respectively. The biomass of each generation may be estimated from the mean monthly weight and the density of the generation (Table 2). The annual mean biomass of the population was 1.82 g m^{-2} inclusive of all generations. The mean biomass of Generations B and C was 0.78 and 1.04 g m^{-2} respectively. A comparison between the density curves (Fig. 3) and the biomass curves (Fig. 7) showed that the biomass peaks follow the density peaks.

The annual production, biomass and P : B ratio of the population and of each generation are given in Table 2. The overwintering generation (C) was more productive (5.04 g m^{-2} yr^{-1}) than the summer generation (B) (0.73 g m^{-2} yr^{-1}). Most of the population production accumulated in October and November (1.25 and 1.33 g m^{-2} respectively). Overall annual production was 5.58 g m^{-2}. Turnover ratio, P : B, of Generation C was 5.1 times greater than that of Generation B. Overall annual turnover ratio was 3.06.

In calculating maximum potential production (Table 2) the following assumptions were made: for Generation B sampled in May 1983, it was supposed that the entire generation recruited immediately after sampling on 11 Apr 1983. The length of these recruits was assumed to be the same as that of newly released juveniles of this species. Although no sampling was done in April 1984, the density curve of Generation D was constructed on the basis that, since the numbers of juveniles of this generation in May 1984 were almost equal to those of Generation B of May 1983, then they may have had the same density at the time of recruitment. It was further considered that Generation D lived

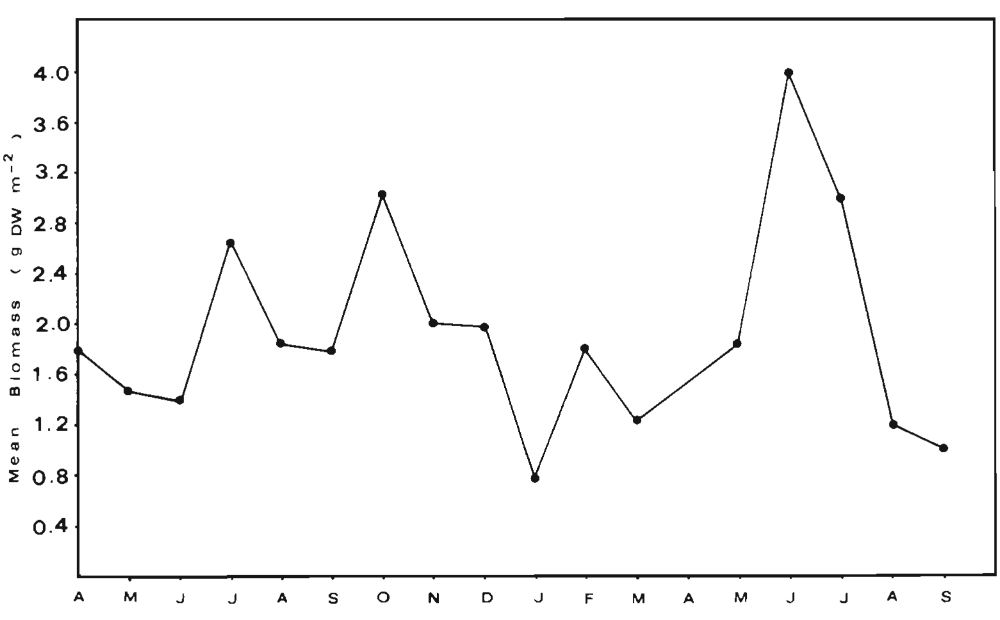

Fig. 7. *Parhyale basrensis.* Mean monthly biomass in the Shatt al-Arab region for the period April 1983 to September 1984

Table 2. *Parhyale basrensis*. Summary of production data in the Shatt al-Arab River. Figures in parentheses represent maximum potential values

Mean annual biomass ($\bar{B}$) (g dwt m^{-2})	Annual production (P) (g dwt m^{-2} yr^{-1})	Annual P : B	Generation	Data by generation		
				$\bar{B}$	P	P : B
1.82 (1.68)	5.58 (8.24)	3.06 (4.9)	B	0.78 (0.679)	0.732 (3.403)	0.94 (5.01)
			C	1.04 (1.0)	5.04 (5.044)	4.85 (5.04)
			D	(0.687)	(3.396)	(4.94)

for the same period as Generation B of the previous year and the maximum lengths attained by this generation were similar to those of Generation B. A density estimation for Generation D in October 1984 was determined by plotting $\log_{10}N$ of this generation against time which gave a straight line from which the value of N (630 m^{-2}) was calculated (Crisp 1984). Results calculated as biomass and production are given in brackets in Table 2.

DISCUSSION

Parhyale basrensis, in the Shatt al-Arab River, has a high annual mean density (3842 m^{-2}) when compared with amphipod species from other areas (Table 3). The peak of abundance of this species in early summer (12 512 m^{-2}) was due to the presence of 3 generations at the same time. Generation B was produced by Generation A, whereas Generation C was due to the breeding activities of Generation B (Ali & Salman 1986). The reduction of growth rate of Generation B during May and June 1983 was due to its attainment of the reproductive state and production of Generation C. Generation C exhibited very slow growth during the period May to September 1983. This is probably an artifact of analysis caused by the presence of several overlapping cohorts of Generations B and C at the same time and the failure of the method of cohort analysis to separate

Table 3. A comparison of population density and production of different species of amphipods from different localities

Species	Locality	Density (ind m^{-2})	Production (g dwt m^{-2} yr^{-1})	P : B	Source
Ampelisca agassizi	Georges Bank, USA		2.24	1.5	Collie (1985)
A. araucana	Coast of Chile		5.8	1.9	Carrasco & Arcos (1984)
A. brevicornis	North Sea		1.0	4.0	Klein et al. (1975)
A. brevicornis	Isle of Man, UK		1.3–1.7	2.5–3.2	Hastings (1981)
A. spinipes	Coast of Brittany, France		0.2	2.4	Glemarec & Menesguen (1980)
A. tenuicornis	North Sea		0.2	3.4	Sheader (1977)
Corophium robustum	Lower Dnieper, USSR	1–12250	5.3–101.5	0.8–3.0	Bortkevitch et al. (1984)
C. volutator	Swedish coast		2.0–4.0	3.0–4.0	Birklund (1977)
C. volutator	German Wadden Sea	5–20000			Linke (1939)
C. volutator	Swedish West coast	8–45000	1.5–30	5.1–11.3	Møller & Rosenberg (1982)
C. volutator	Danish East coast	7000			Muss (1967)
C. volutator	Danish Wadden Sea	3000			Smidt (1944)
Ericthonius fasciatus	Georges Bank, USA		2.28	4.4	Collie (1985)
Eogammarus confervicolus	British Columbia	3603 & 6233	6.4 & 21.5		Stanhope & Levings (1985)
Crangonyx richmondensis occidentalis	Marion Lake, British Columbia	283	1.64		Mathias (1971)
Gammarus pseudolimnaeus	Valley Creek, USA		27.1		Waters & Hokenstrom (1980)
Gammarus pulex	Danish Spring	880–5440	3.8	2.03	Iversen & Jessen (1977)
Hyale barbicornis	Tokyo Harbour, Japan	13400–368800			Hiwatari & Kajihara (1984)
Hyalella azteca	Marion Lake, British Columbia	75 & 1952	0.83–1.74		Mathias (1971)
Talorchestia capensis	Eastern Cape, South Africa	52–1313	2.9–7.2	2.25	van Senus & McLachlan (1986)
T. margaritae	Venezuela	5692–39047			Venables (1981)
T. quoyana	New Zealand	256			Fincham (1977)
Orchestia tuberculata	Chile	1000			Duarte (1974)
Parhyale basrensis	Basrah, Iraq	928–12512	5.58	3.06	Present study
Pontoporeia affinis	Baltic Sea		3.2	1.9	Cederwall (1977)
P. femorata	Baltic Sea		3.0	1.4	Cederwall (1977)
P. femorata	Nova Scotia		2.8–3.5	3.6–4.8	Wildish & Peer (1981)
Unciola inermis	Georges Bank, USA		2.79	2.5	Collie (1985)

them. The rise in growth rate of Generation C during September to November 1983 may indicate the absence of the interference of cohorts of new releases. Hence it may represent a good estimate of growth rate.

There were no appreciable differences in growth rates of Generations B and C taken over their whole life span, as growth rates were 0.027 and 0.026 mm d^{-1} for males and females of the former generation and 0.024 and 0.019 mm d^{-1} for males and females of the latter. Individuals of the short-lived Generation B did not attain the maximum size for this species, while individuals of the long-lived Generation C reached a relatively large size. On the other hand the daily growth rate in terms of dry weight of Generation C was higher (0.0095 against 0.0056 mg d^{-1}). This is because growth in weight is not isometric with growth in length and individuals of Generation C reached larger sizes than those of Generation B. This also results in a higher mean annual biomass of Generation C (1.04 g m^{-2}) than that of Generation B (0.78 g m^{-2}). The mortality rates of Generation B derived from Fig. 6 are most certainly an underestimate. This is due to the fact that the peak of release of juveniles of this generation in April 1983 was overlooked and the time-lag between the samples of 11 Apr and 11 May 1983 was quite enough for these hatchlings to achieve maturity. The recruitment of this generation was therefore determined by multiplying the density of mature females (over 4 mm total length) in April 1983 by the brood number of the average-sized females (Wildish & Peer 1981). Using fecundity data previously reported (Ali & Salman 1986), the density of hatchlings was estimated to be 8000 m^{-2}. This implies that about 77 % of the deaths of this generation occurred between 11 Apr and 11 May 1983. Moreover the instantaneous mortality rate will then be 0.205 yr^{-1} and the annual mortality rate 0.185 yr^{-1}, which are quite comparable with the values obtained for Generation C.

In contrast the mortality among Generation C was very low at the beginning of its life. A mortality peak occurred in October to December 1983 when about 78 % of the individuals died.

Available data from the literature on amphipod productivity from different localities (Table 3) shows that *Parhyale basrensis* is one of the most highly productive species. It ranks next to *Corophium robustum* of the Lower Dnieper, USSR (Bortkevitch et al. 1984), *Gammarus pseudolimnaeus* of Valley Creek, USA (Waters & Hokenstrom 1980), *Eogammarus confervicolus* of British Columbia (Stanhope & Levings 1985) and *Corophium volutator* of the Swedish west coast (Møller & Rosenberg 1982). Furthermore, *P. basrensis* is a multivoltine species and the data obtained here agree very much with the conclusion of Rigler & Downing (1984) that multivoltine species have higher rates of production than do univoltine species.

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