Reproduction and Population Dynamics of Grandidierella japonica in Upper Newport Bay

Grandidierella japonica (Amphipoda: Gammaridea) is a common amphipod in the sandy intertidal and sub-tidal sediments of Newport Bay. It was introduced to California from Japan (Chapman and Dorman 1975) and was first reported in Newport Bay in 1979 (MBC and SCCWRP 1980). Short-term (10 d) and long-term (28 d) sediment toxicity tests with *G. japonica* were developed at SCCWRP (Nipper *et al*. 1989) and the short-term test methods were published by the American Society for Testing and Materials (ASTM 1991). *Grandidierella japonica* was used to assess the toxicity of sediments on the mainland shelf off Southern California (Anderson *et al*. 1988), and to monitor temporal and spatial changes in sediment toxicity after sludge discharge ended in Santa Monica Bay (SCCWRP 1992).

In the long-term tests, 3-7 d old juveniles are added to the sediment. The juveniles are obtained from gravid females, which are collected in the field and held in petri dishes in the laboratory until the young are released. Females generally release 10-40 young (average about 25). During an experiment in March 1992, females released as many as 150 offspring (average about 40) (SCCWRP, unpublished data). At the same time, SCCWRP was developing a 35-day life-cycle test with the number of offspring as an endpoint. Questions arose about the determinants of brood size in the natural population and whether brood size could be affected by controlling this factor in laboratory experiments.

The objective of this study was to determine the abundance and fecundity (=brood size) of *Grandidierella japonica* in Newport Bay. These data were compared to weekly measurements of water quality to identify relations between fecundity and environmental characteristics.

Analyzing data in the toxicology laboratory.

MATERIALS AND METHODS

Sediment and water samples were collected between July 1993 and June 1994 from Upper Newport Bay on the south shore of Shellmaker Island west of the Newport Dunes Aquatic Park boat launching ramp. Water samples were collected weekly from the bottom in approximately 1 m of water with a 3 L Van Dorn bottle. Temperature was measured with a thermometer. Water samples were returned to the lab where salinity was determined from conductivity measurements performed with an Orion 122 Conductivity Meter and a salinity conversion program.

Three sediment cores were taken monthly in approximately 1 m of water with a 78 mm diameter stainless steel hand core. The cores were packaged separately and returned to the laboratory where they were screened through a 0.3 mm sieve within 24 h. *Grandidierella japonica* were counted and scored as male, ovigerous female, non-ovigerous female, and immature (sex could not be determined by eye).

Samples of surface sediments were collected monthly in approximately 1 m of water with a shovel and sieved through a 1 mm screen in the field. Material retained on the screen was returned to the lab. The first 65 gravid females encountered were sorted from the animals collected on the screen; during some months, fewer than 65 females were collected. Each gravid female was placed in a separate 60 x 15 mm petri dish with seawater. The dishes were checked daily until all juveniles were released (within 7 d) and the offspring were collected and counted. A subset of about 15 females was preserved in alcohol for length measurements. All of the juveniles from a subset of about five of these females were preserved for length measurements.

Amphipods were measured by projecting them on a Nikon Shadowgraph at a 10X magnification and tracing along the mid-line between the tip of the rostrum and the end of the telson. The tracings were digitized and converted to millimeters with a Basic computer program.

Descriptive statistics were calculated for all replicate data. Juvenile size was tested for temporal variation by analysis of variance (ANOVA) and Tukey's test (Wilkinson 1990). The number of juveniles released by an average size female each month was predicted from linear regressions of the number of juveniles released versus female size for each month (Zar 1984). Day length data were generated by a computer program called Sunny 2000 written by Lou Moccia.

RESULTS

The bottom water temperature in Upper Newport Bay was high from June through September and declined in October to a low in December (Figure 1). Salinity remained fairly constant at about 30 g/kg except for a few declines following periods of rain. The pattern of day length was similar to temperature.

The mean number of *G. japonica* in the cores varied by two orders of magnitude during the year (Figure 2). The abundance decreased dramatically in October and remained low through the following April. The average number of juveniles released per female was lowest from October through January (Figure 3).

The number of young released was correlated to female length ($r=0.69$, $p=<0.05$, $n=199$) (Figure 4). The relationship was different for females collected from October through January compared to the rest of the year. To separate the effects of female size from the effects of seasonality, the release data were normalized by calculating the predicted number of juveniles that would be released by the average size female (5.58 mm, SD=0.87, n=199). The number of juveniles released was lowest from October through February and in June (Figure 5).

The average size of the juveniles released was lowest in July, December, and January (Figure 6). Animals released in January were significantly smaller than animals released in all other months except July ($F=10.83$, $p<0.05$).

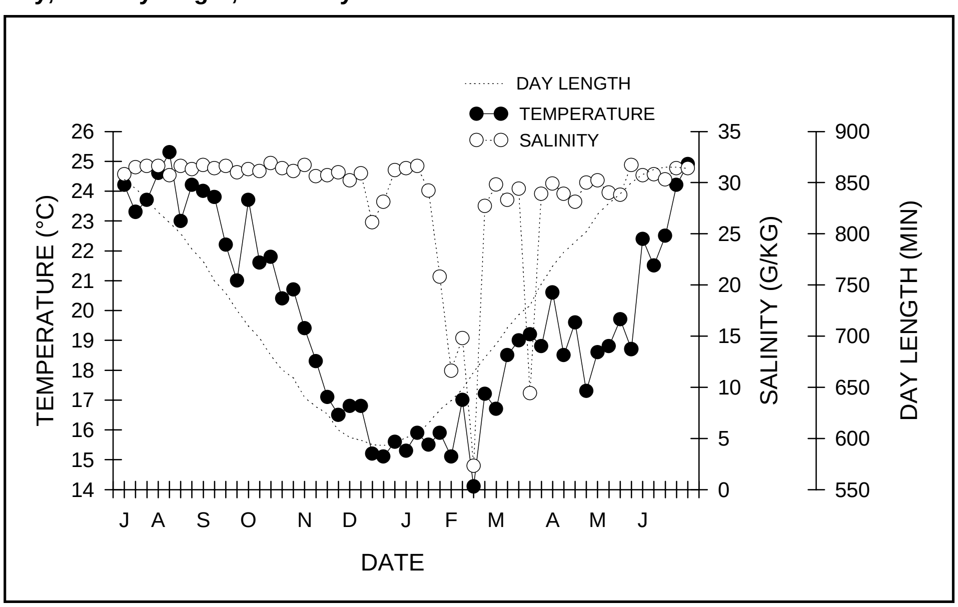
DISCUSSION

The abundance of *Grandidierella japonica* in cores collected from Upper Newport Bay was high throughout the summer, declined in the fall to a low in winter, and recovered the following spring (Figure 2). A similar pattern was observed by MBC and SCCWRP (1980). In that study, *G. japonica* were collected at most stations in November, December, and July, but were rarely collected in January and March. The high variability of the abundance data in the present study suggested that the animals were patchily distributed. A power analysis on the first two months of core data indicated that more than 20 cores per month would have been necessary to achieve reasonable power (ß=0.80) of detecting a 50% change in population size.

Gravid females were collected each month during the present study (Figure 3) indicating that *G. japonica* reproduced throughout the year in Upper Newport Bay. However, brood size (Figures 4 and 5) and size of the offspring (Figure 6) decreased during the winter. The smallest gravid females collected in June were larger than the smallest gravid females in the other months. This resulted in a steeper slope for the regression and a lower predicted brood size. While sampling bias cannot be ruled out, females may have been maturing at a larger size in June. There is no explanation for the small juvenile size in July.

The annual patterns of abundance and fecundity in *G. japonica* parallel the annual patterns of temperature and photoperiod in Upper Newport Bay. Unfortunately, there is no information available on the life history of *G. japonica*. The initiation of reproduction in the beach flea, *Orchestia gammarellus*, is affected by temperature, but not by changes in photoperiod or salinity (Morritt and

FIGURE 1. Weekly bottom water temperature and salinity in Upper Newport Bay, and day length, from July 1993 to June 1994.



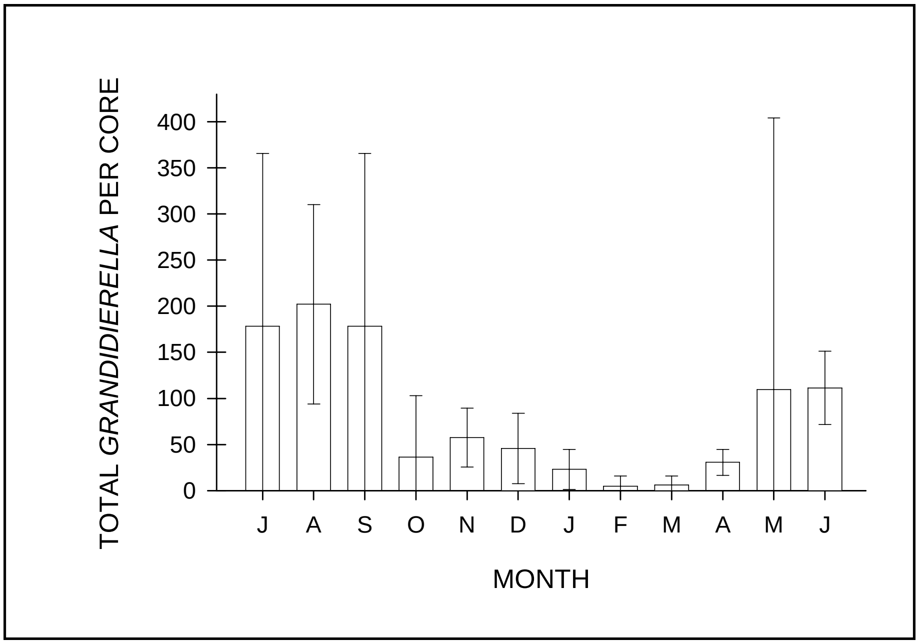


FIGURE 2. Number of *Grandidierella japonica* collected in cores (78 mm diameter core) in Upper Newport Bay from July 1993 to June 1994 (n=3; mean ± 95% CI).

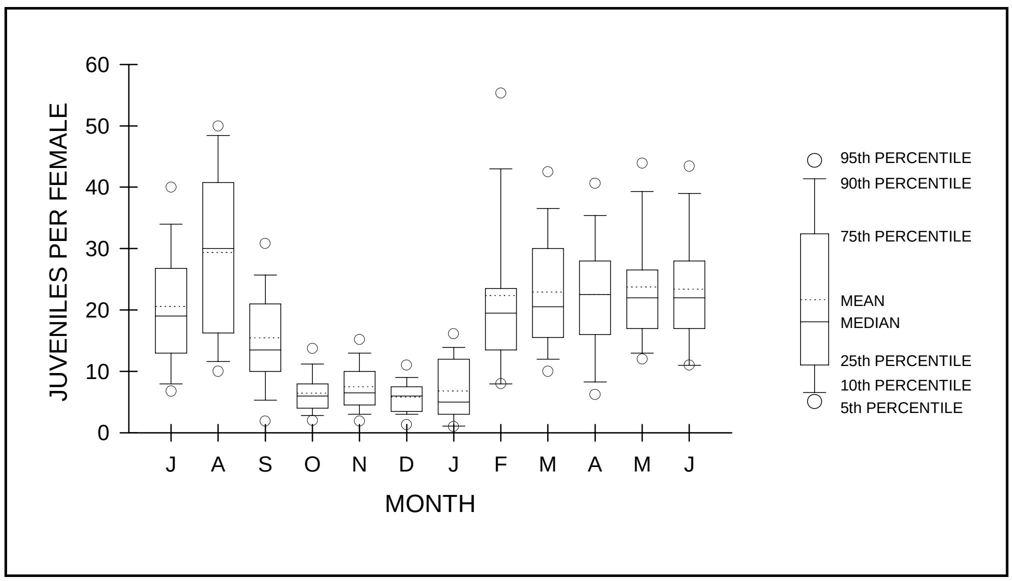


FIGURE 3. Number of offspring released by female *Grandidierella japonica* collected in Upper Newport Bay from July 1993 to June 1994 (16≤ n≤ 72 females per month).

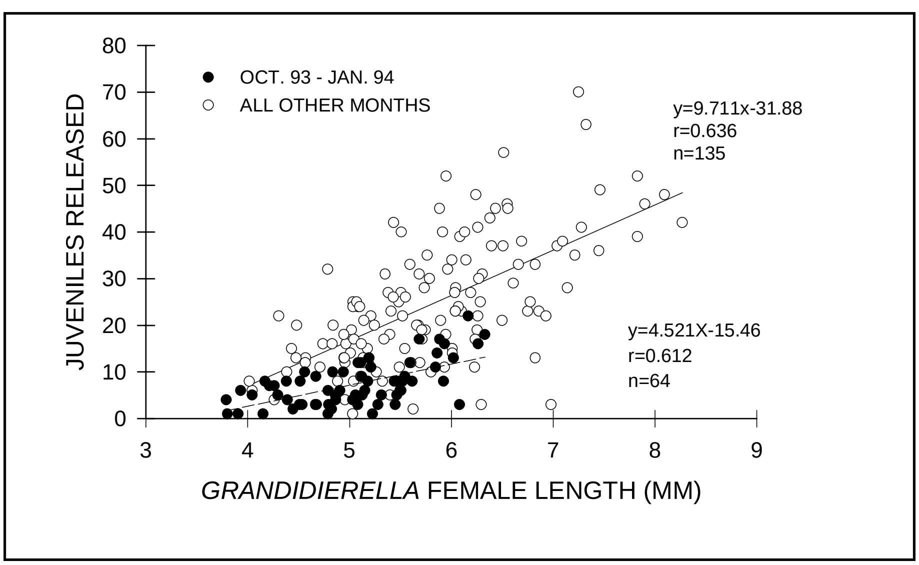
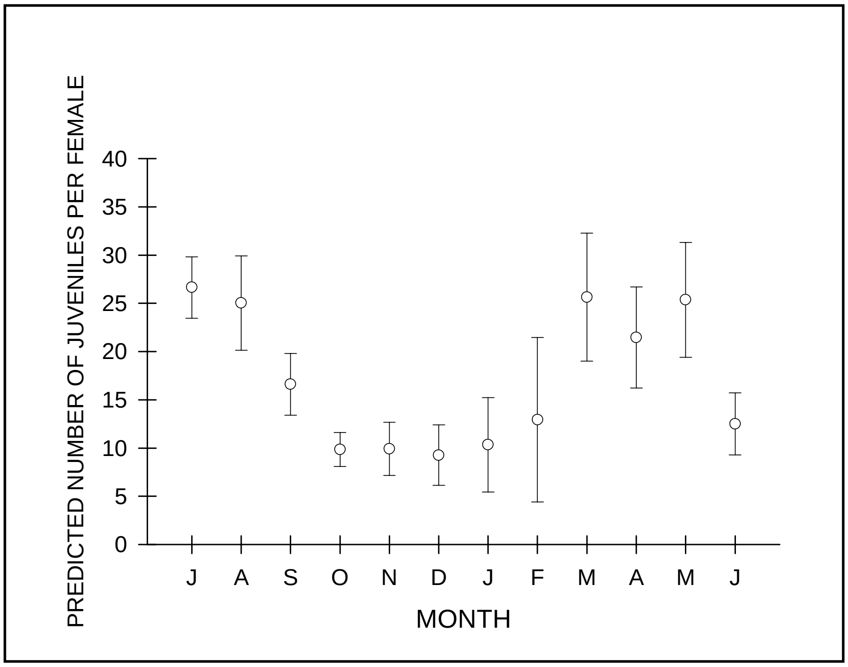


FIGURE 4. Number of offspring released versus female length for *Grandidierella japonica* collected in Upper Newport Bay from October 1993 through January 1994 and for all other months.

FIGURE 5. Number of offspring predicted (± 95% CI) for the average size female *Grandidierella japonica* collected in Upper Newport Bay from October 1993 through January 1994. Predictions were based on regressions of offspring against female size for monthly data. The average size of all females collected during the study was 5.58 mm.



Stevenson 1993). The initiation and cessation of reproduction in the freshwater amphipod *Hyalella azteca* is affected by photoperiod, but temperature affects the rate at which they occur (De March 1977).

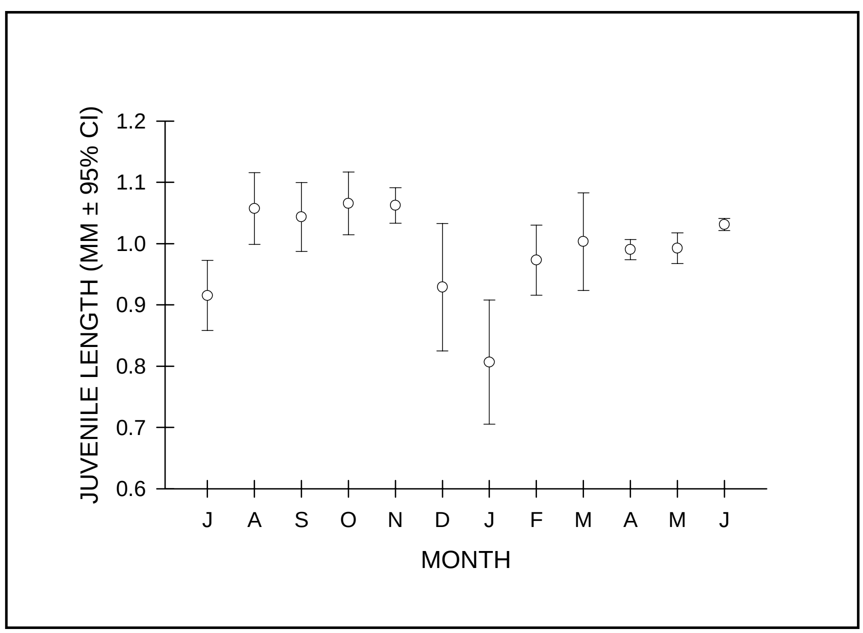
While temperature and photoperiod could directly affect reproduction of *G. japonica*, they probably also affect the availability of food such as algae. Brood size started to decrease before water temperatures began to drop (Figures 1 and 2) indicating that either photoperiod or food supply could be important. The decrease in brood size during the winter, and the decrease in juvenile size in December and January, indicate that less energy was expended on reproduction, perhaps because of reduced food availability. The clutch size of *Gammarus duebeni* also declines toward the end of breeding season (McCabe and Dunn 1994).

A reduction in food supplies coupled with lower water temperature and reduced salinity (due to freshwater runoff from storms) could decrease juvenile production and increase adult and juvenile mortality. The survival of *G. japonica* in the laboratory decreased by more than 10% at a salinity of 10 g/kg during a 10-day test (SCCWRP, unpublished data).

In Upper Newport Bay in the fall, there was a lag between the decrease in fecundity and the decrease in abundance; in the spring, there was a lag between the increase in fecundity and the increase in abundance (Figures 2 and 3). While the decrease in fecundity was about four fold, the decrease in abundance was about 10 fold suggesting that mortality increased, and that other factors, such as predation, may play a role. The abundance of fish in the littoral zone in Newport Bay is quite high from summer through fall (Allen 1982) and many of these fish prey on amphipods (Horn and Allen 1985).

The monthly changes in brood size observed in this study have important implications for development of life cycle bioassays with *Grandidierella japonica*. Currently, long-term tests with this species are performed at 20°C and a photoperiod of 12:12 h (light:dark). If temperature and/or photoperiod affect brood size, then higher temperatures and/or longer photoperiods during bioassays should increase the number of offspring obtained from healthy females. A higher number of offspring in controls could increase the sensitivity of the bioassay making it easier to detect changes in production of offspring.

FIGURE 6. Length of offspring released from *Grandidierella japonica* females collected in Upper Newport Bay from October 1993 through January 1994 (n=4-7 females per month; mean ± 95% CI).



CONCLUSIONS

The abundance of *Grandidierella japonica* in Upper Newport Bay was high in the summer, declined in the fall to a low in winter, and recovered the following spring. Female brood size was highest in the summer and lowest in the winter. Decreases in abundance and brood size were related to declines in water temperature and reduced photoperiod. However, food availability and predation, which were not measured in this study, may have also played a role. The annual cycle of fecundity should be considered in developing a life-cycle bioassay for *G. japonica*, but more laboratory work is needed to determine the factors that regulate changes in brood size.

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