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The Distribution and Biology of *Patiriella vivipara* (Echinodermata: Asteroidea: Asterinidae) a Sea Star Endemic to Southeast Tasmania

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ABSTRACT. The asterinid sea star *Patiriella vivipara* is endemic to southeast Tasmania and has a highly restricted distribution, being only known from four locations. It has an unusual pattern of viviparous reproduction, giving birth to juveniles. In this study the birth rate, growth rate, size and age at commencement of reproduction of *P. vivipara* was examined in aquaria for a period of six years. The population of *P. vivipara* at Pittwater was also monitored through monthly examination of a permanent $1m^2$ quadrat in which the number of adults and juveniles were counted and recorded. These counts were made over an eight-year period. *Patiriella vivipara* gives birth to juveniles through the year with a period of enhanced reproduction from November to January. Records of water salinity and temperature were taken at Pittwater, as were air temperatures and exposure times during low tide.

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Patiriella vivipara (Dartnall 1969) (Asterinidae) is a small 5 armed asterinid sea star that incubates its young in the gonads (Dartnall 1969; Byrne 1991, 1996). When first described (Dartnall, 1969) it was the only known species of sea star to exhibit viviparity. Three other viviparous asteroids were subsequently found and these are also asterinids. They are *Asterina pseudoexigua pacifica*, (Hayashi, 1977) from Japan, *Patiriella parvivipara*, (Keough & Dartnall, 1978) from South Australia and *P. pseudoexigua* from Queensland, (Byrne, pers. comm.). *Patiriella vivipara* is a simultaneous hermaphrodite and most of the gonads are ovotestes, thereby creating the potential for self fertilisation (Byrne, 1996). The juveniles emerge through the gonopores which are located on the aboral surface. It is not known whether self, cross fertilisation or both takes place. An unusual feature of *P. vivipara* and *P. parvivipara* is that intragonadal cannibalism supports post-metamorphic growth to an advanced size (Byrne, 1996).

Patiriella vivipara is endemic to southeast Tasmania, and has a highly restricted distribution. In the original survey (Dartnall, 1968) this species was recorded from only three localities, Pittwater, Roches Beach and Eagle Hawk Neck. In 1990 another colony was found on the southern shore of Fortescue Bay (Fig. 1). *Patiriella vivipara* is a uniform orange/yellow orally and aborally, has a maximum radius (R) of 15 mm and the average adult size is approximately 10.00 mm R.

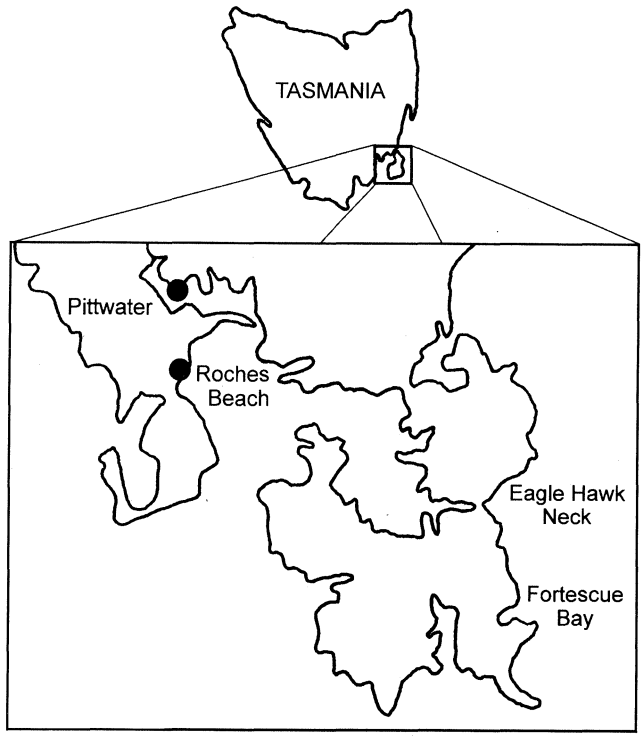

Figure 1. Locality map for *Patiriella vivipara* in south-east Tasmania.

Viviparity in *P. vivipara* represents the most derived life history pattern in the Asteroidea, and provides important insights into the evolution of development (Byrne, 1996; Byrne & Cerra, 1996). *Patiriella* is a specious genus in Australia (Dartnall, 1970) and their divergence was associated with developmental change (Byrne, 1995; Byrne & Cerra, 1996; Hart, *et al.*, 1997). Considering the highly restricted distribution of *P. vivipara*, its non-dispersive life history and its scientific importance, this study provides essential information for the conservation biology of this unique sea star.

Methods

In this study reproduction and growth of *Patiriella vivipara* was documented in aquarium and field observations spanning a eight-year period from 1975 to 1983. The population of *P. vivipara* on the shore was also monitored at Pittwater (42°48'S 147°32'E), Eagle Hawk Neck (43°01'S 147°55'E) and Roches Beach (42°54'S 147°30'E). The length of shoreline at all sites occupied by this asteroid was estimated by noting the presence of the asteroids while measuring the distance walked along the shore. During 1995 the population on the southern shore of Fortescue Bay (42°08'S 147°57'E) was examined, and the length of shoreline occupied by *P. vivipara* was also measured. Emphasis was placed on the Pittwater site because this has the largest known population of *P. vivipara*.

The population of *Patiriella vivipara* at Pittwater was examined on the shore and in aquaria. From 1976 to 1982 specimens were maintained in glass aquaria to determine growth rate, size at first reproduction, birth rate and potential for reproduction in isolation. The sea stars fed on an algal film that formed on the walls of the aquaria. For the growth rate study, five juvenile *P. vivipara* (radii 1.25–2.25 mm), were followed for up to six years. They were placed in aquaria in isolation and periodically removed to measure their radius (R) from the centre of the disc to the end of the arm. These sea stars were also used to determine the potential for reproduction in isolation, and the aquaria were monitored for the appearance of new juveniles. The size at which these *P. vivipara* produced their first young was recorded. For the reproductive output study, six adults (R = 9.0 mm) were placed in each of two aquaria and the number of juvenile births recorded.

The population of *Patiriella vivipara* at Pittwater was censused at approximately monthly intervals from 1976–1983. Each month the number of individuals in a fixed 1 m^2 quadrat was counted and their radii measured. The quadrat was sited at the base of the rockfill along the southern side of the eastern causeway and was marked by rocks on a gently sloping area of the rockfill.

Several environmental parameters were measured at the area in Pittwater occupied by *P. vivipara*. These included air and sea temperature and water salinity. Water salinity and temperature were recorded on a monthly basis approximately 1.5 hrs before or after high tide, using a salinity/temperature meter. *Patiriella vivipara* can be emersed for several hours at low tide and so the air temperature was recorded from a thermometer set up at my home. The length of time that the sea stars were emersed during the low tide was recorded by noting the time with a watch.

Day and night feeding activity of *P. vivipara* at Midway Point in the Pittwater area was also examined. This involved documentation of the position of the sea stars on top of or under rocks, and whether they had their stomachs extruded.

Results

Distribution and habitats

The sites where *Patiriella vivipara* occurred are shown in Fig. 1. At each site *P. vivipara* was found only in the upper area of the intertidal zone. At Pittwater this sea star was found among or under loose rock on a gently sloping sandstone shelf (Figs. 2a–c), and at a maximum depth of 1.5 m at H.W.S. The shore in Upper Pittwater where the main concentration of *P. vivipara* occurred (Fig. 1) consisted of approximately 50% sand or sandy mud and 50% sandstone shelf. Lower Pittwater was mostly sand or sandy mud, except for a small area of sandstone on the southern end of Midway Point where *P. vivipara* could be found (Figs. 2a–c). Two causeways, approximately 1 km long, link Midway Point to the western and eastern shores of Pittwater respectively. Just below high water, *P. vivipara*

occurred in a narrow band on the sandstone and basalt rocks used to construct the causeways. Pittwater is a sheltered bay opening to the open sea by a narrow channel at the south-east corner. Pittwater had the largest population of *P. vivipara*, comprised of several thousand specimens. At this site *P. vivipara* inhabited approximately 5 km of the shoreline.

At Roches Beach (Fig. 1) the population of *P. vivipara* was limited to a sandstone shelf approximately 100 m^2 that protrudes out from the middle of a sandy beach. Although Roches Beach is a relatively sheltered site, the rock shelf can be subjected to considerable wave action at times, dependent upon the wind direction. There was a good cover of loose rocks where *P. vivipara* could shelter. Here *P. vivipara* only inhabited the inshore northern quarter of the rock shelf in an area roughly 35 m^2. In 1983 the population was estimated to be comprised of approximately 400 animals.

The Eagle Hawk Neck (Fig. 1) site differs from the other two locations in being a large platform of sedimentary rock on the open (eastern) coast where it is exposed to Tasman Sea conditions. A well known tourist attraction (*The Tessellated Pavement*), the site has an estimated population of 1500 *P. vivipara* sheltered amongst carpets of the small mussel *Xenostrobus pulex*. During calm sea conditions in the summer months specimens were occasionally found in the open in pools on the pavement. At Eagle Hawk Neck a second population of *P. vivipara* is located about half a kilometre to the north of *The Tessellated Pavement*. Here *P. vivipara* were found on the rock platform under rocks. Their numbers were difficult to estimate due to the size and placement of the rocks. The combined length of shoreline inhabited by *P. vivipara* at Eagle Hawk Neck was approximately 300 m.

In 1995 a survey of the population of *P. vivipara* at Fortescue Bay (Fig. 1) was undertaken. At this location *P. vivipara* inhabited the southern shore well in from the entrance to the bay. On this rocky shore *P. vivipara* occupied a narrow band just below high water mark and was found well down into the rocks. This last survey estimated the number of animals at this site to be approximately 50. The approximate length of shoreline inhabited at Fortescue Bay by *P. vivipara* was 200 m.

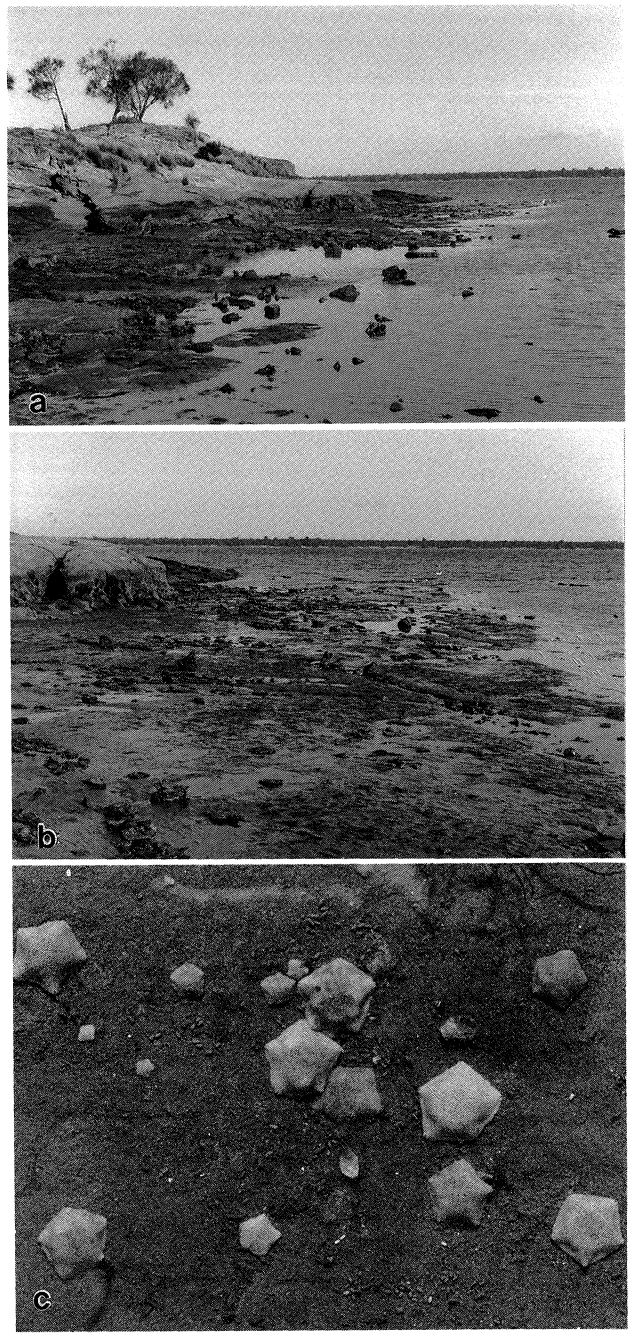

Figure 2. **a**, A sandstone substrate with loose littered rocks; type locality for *Patiriella vivipara* at Midway Point, Pittwater, Tasmania, 42°49'S 147°31'E. **b**, Type locality, Pittwater, low tide. **c**, Adult and juvenile *P. vivipara* at Pittwater on the under surface of a rock (×0.6).

Environmental conditions at Pittwater

Sea water salinity and temperature and air temperature were measured monthly at Pittwater from 1979 to 1983. At this site, *P. vivipara* contended with a wide range of climatic conditions. When exposed during spring tide, they were out of water for as long as 7 hrs. During this time air temperature extremes ranged from -3°C in winter to 40°C in summer. *Patiriella vivipara* also tolerated rainfall during low tide. Sea water temperature also varied considerably throughout the year, with the minimum 3.5°C recorded in July 1982 and the maximum 34°C recorded in February 1977 and February 1982.

The salinity at Pittwater averaged 32‰, but varied depending upon rainfall. The main sources of fresh water were from five small creeks or rivers, run off from surrounding hills, and drainage from the townships of Sorell, Midway Point and Lewisham.

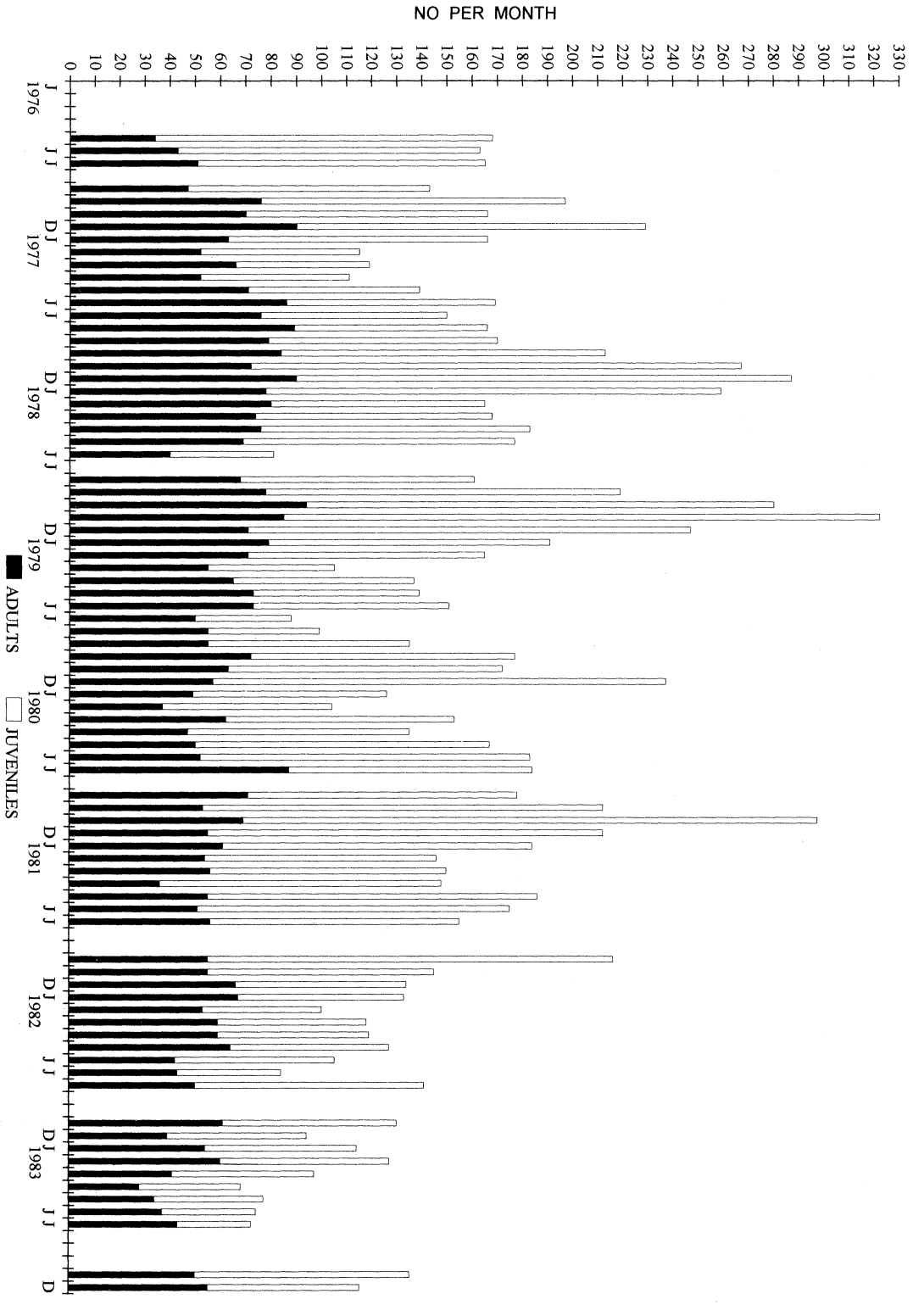

Figure 3. Population count for *Patiriella vivipara* at Pittwater, 1976 to 1983.

Pittwater population

Although sandy mud dominated the shore at Pittwater, *P. vivipara* was rarely seen on this substratum. The sea stars could not attach their tube feet to this material, nor could they right themselves if placed with their aboral surface on the sandy mud. Adult *P. vivipara* adhered strongly to the top or underside of rocks located on the sandy mud. Juvenile *P. vivipara* were rarely seen on the top of rocks, and when present were readily dislodged by disturbance.

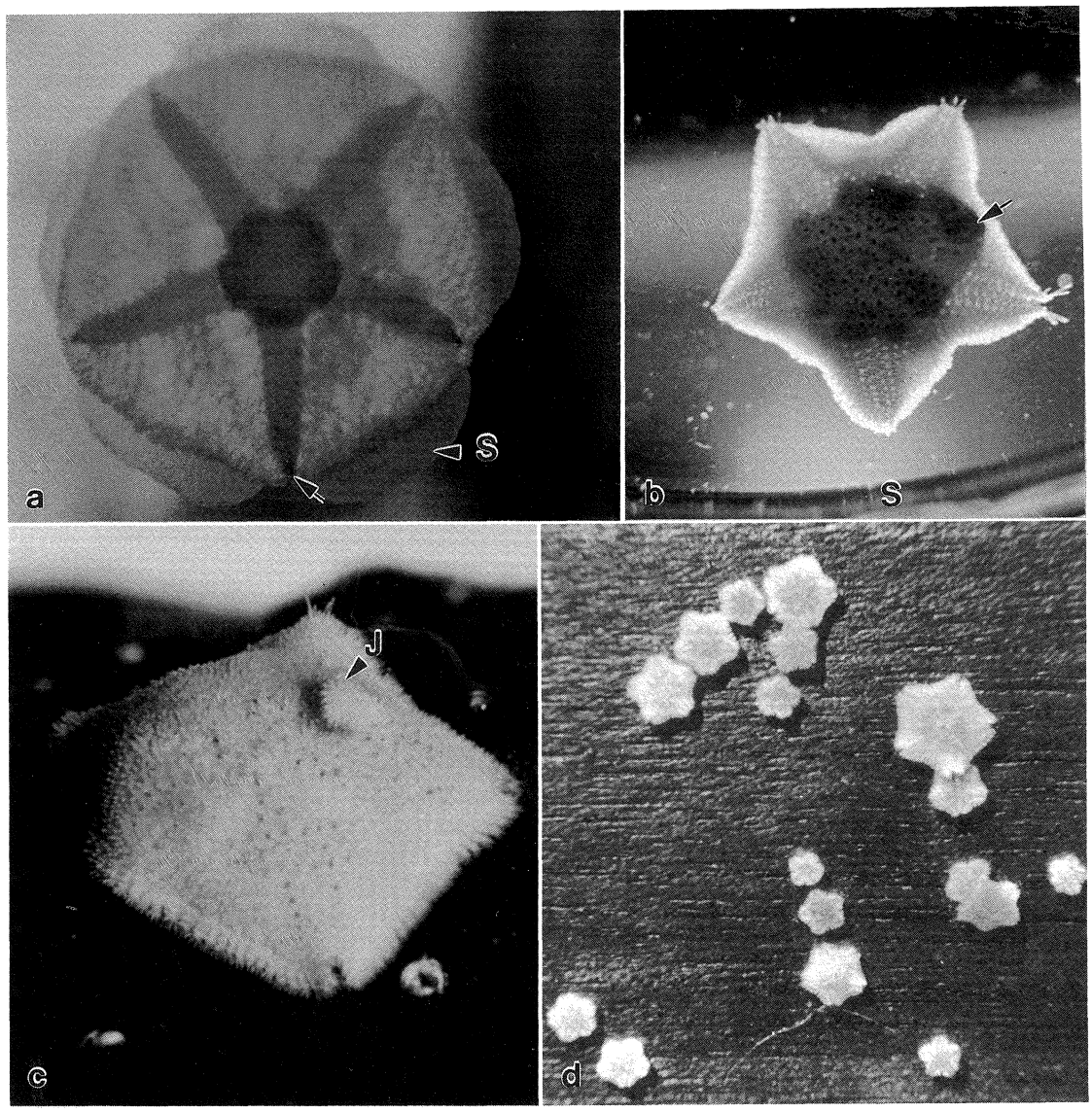

Figure 4. **a**, Adult *Patiriella vivipara* feeding on an algal film on the aquarium wall, showing the stomach (s) everted beyond its body, retaining a grip with the outermost pairs of tube feet (arrow) (×3.5). **b**, A back lit adult. The central dark area is the stomach. Arrow points to a well-developed gonad (×2.5). **c**, Adult in the process of giving birth. The juvenile (J) is about halfway out of the gonopore (×3). **d**, A selection of juveniles, born in aquaria, ranging in arm radius from 1.00–4.00 mm (×2).

Figure 3 shows the number of adults and juveniles counted in the selected 1 m^2 area on the eastern causeway from May 1976 to December 1983. In this figure sea stars R<5.0 mm are classed as juveniles because 5 mm is the minimum size of parents observed to give birth.

Feeding activity

Patiriella vivipara fed on the algal film and associated micro-organisms that grew in the aquaria and on the rocks on the shore (Fig. 4a).

On the shore, feeding activity was influenced by weather and tidal conditions, with most activity taking place between dusk and dawn. Feeding also occurred during the day providing the weather was dull, at which time *P. vivipara* came on to the top of the rocks to feed. Juveniles (R<5.0 mm) were rarely seen feeding on top of rocks.

In aquaria, feeding seemed to be a continuous process, especially during the summer. In colder months feeding activity was reduced, and on very cold days, virtually ceased.

Growth rate

The growth of six juveniles was followed from 1976 to 1981. In 1976 the radius of the juveniles were measured

when put into the aquarium on 1 January and again at the end of December. At the beginning of these growth trials the juveniles had a mean radius of 1.96 mm (SE = 0.03, range 1.0–2.5 mm, n = 6). Subsequent measurements were taken on 31 December of each year, depending on their survival. The growth recorded for the juveniles ranged between 2.75–6.50 mm for year 1 (X = 5.3, SE = 0.56, n = 6); 0.25–3.25 mm for year 2 (X = 1.6, SE = 0.45, n = 6); 0.00–0.75 mm for year 3 (X = 0.5, SE = 0.18, n = 4). In years 4–5 there was only one surviving specimen and it grew 0.25 mm in year 4, 1.00 mm in year 5 and 0.00 mm in year 6. During the first 12 months *P. vivipara* juveniles exhibited a faster rate of growth compared to later years.

The growth of an additional four juveniles was monitored from November 1978 to December 1980. At the start they had a radius of 1.50 mm (n = 4), and at the end of two years they had a mean radius of 6.125 mm (SE = 0.36, n = 4).

The life span of *P. vivipara* is not known. Four specimens lived six years in the aquaria before dying as the result of a heat wave. When collected they were estimated to be two years old, making them eight years old when they died. Just prior to the heating event, they were still healthy and reproducing.

Reproduction

During the years 1976 to 1983, a total of 4429 adult and 7517 juvenile *P. vivipara* were counted in the 1 m^2 quadrat located on the eastern causeway, a ratio of 1.7 juveniles per adult (Fig. 3). Juvenile births could not be followed in detail and so the actual number of births is not known. *Patiriella vivipara* reproduced throughout the year, with the greatest number of juveniles appearing in spring and summer (October to January), in most summers monitored (Fig. 3). The high number of juveniles obtained in June and July of some years suggest that there may also be a mid-year release period.

Six sea stars, having an average radius of 9 mm, were placed in each of two aquaria and records of juvenile births were kept until all adults had died. One aquarium operated from January 1976 to July 1979, producing a total of 119 juveniles, an average of five juveniles per adult per year. The second aquarium operated from February 1976 to March 1981 producing 333 juveniles, an average of nine juveniles per adult per year. Adults maintained in aquaria for up to eight years continued to produce juveniles.

Patiriella vivipara has 10 sets of gonads situated interradially in pairs. It is possible to hold a sexually mature specimen up to a bright light and—through the oral surface—see and count sets of gonads containing developing juveniles (Fig. 4b). These will be visible as a dark orange dot. As the juvenile develops, a small dark orange bump appears on the aboral surface of the parent over the developing set of gonads (Figs. 2c, 4b). When birth is imminent, the centre of the bump changes from dark orange to white. Initially it was thought that the skin above the juvenile split at birth, but it is now known that the juveniles emerge through the gonopores (Byrne, 1996).

During birth which can take as little as 2 hrs or as long as 48 hrs, the juvenile emerges without any apparent assistance from the parent (Fig. 4c), which moves around the aquarium normally. Stillborn juveniles have been recorded so the parent must have some means to expel moribund progeny. Once the juvenile is free, it either walks or rolls down the aboral surface of the parent. If the parent is on the side of the aquarium or upside down under a rock, the juvenile drops gently to the bottom. If the juvenile lands upside down, it rights itself, immediately taking up an independent life. At birth the juveniles ranged in size from 0.30 mm to 5.0 mm R with 1–8 pairs of tube feet (Fig. 4d). The majority of newly emergent juveniles were approximately 1.50 mm R with 4–5 pairs of tube feet.

Patiriella vivipara is capable of reproduction in isolation, the time before the first births took place ranged from 14–42 months and the average was 22 months. Whether self fertilisation or parthenogenesis took place is not known. The minimum size of the parent giving birth was 5.00 mm R. Some sea stars did not produce juveniles until they had attained a radius of 7.00 mm. Four juveniles born in November/December 1978 were placed in an aquarium on 1 January 1979 to determine if juveniles from an isolated parent would reproduce. The first juveniles were born in February 1981, approximately 27 months after the birth of their parents.

Occasionally adults were observed to suddenly give birth to a number of juveniles in a very short period. This happened during a time of stress when the water temperature increased to 30°C and above during a sudden onset of hot weather, and was possibly associated with decreased oxygen levels. High or low salinity extremes, can also cause "stress births". The highest number of juveniles born to a single adult was 15 in 24 hrs, and from an aquarium containing six adults, was 23 in 24 hrs. All these juveniles were sufficiently developed to survive, and ranged in radius from 0.75–2.00 mm. Although the maximum number of juveniles born in a short time from a single aquarium-held adult was 15, dissection of several adults indicated that this number could be higher. The specimen, (R = 9.5 mm), illustrated in (Fig. 5) contained 66 juveniles, the majority of which could survive if born at this stage in sheltered conditions on the shore.

A diseased sea star (see below) will also "stress birth" especially if the disease is terminal. The juveniles born under these circumstances are mostly premature, and do not survive long. However, the first 3–4 born are generally large enough to survive.

Morphological variation

Morphological variation in *Patiriella vivipara* is common, with 3-, 4- or 6-arm sea stars present on the shore (Fig. 6a). Juveniles having these arm numbers were also born in aquaria. At reproduction these individuals in turn give rise to progeny with a similar number of arms, or the normal complement of five arms. The percentage of morphological variations to the number of births is low. Out of 452 juveniles born in the aquaria, one had two arms, 12 had three arms, 18

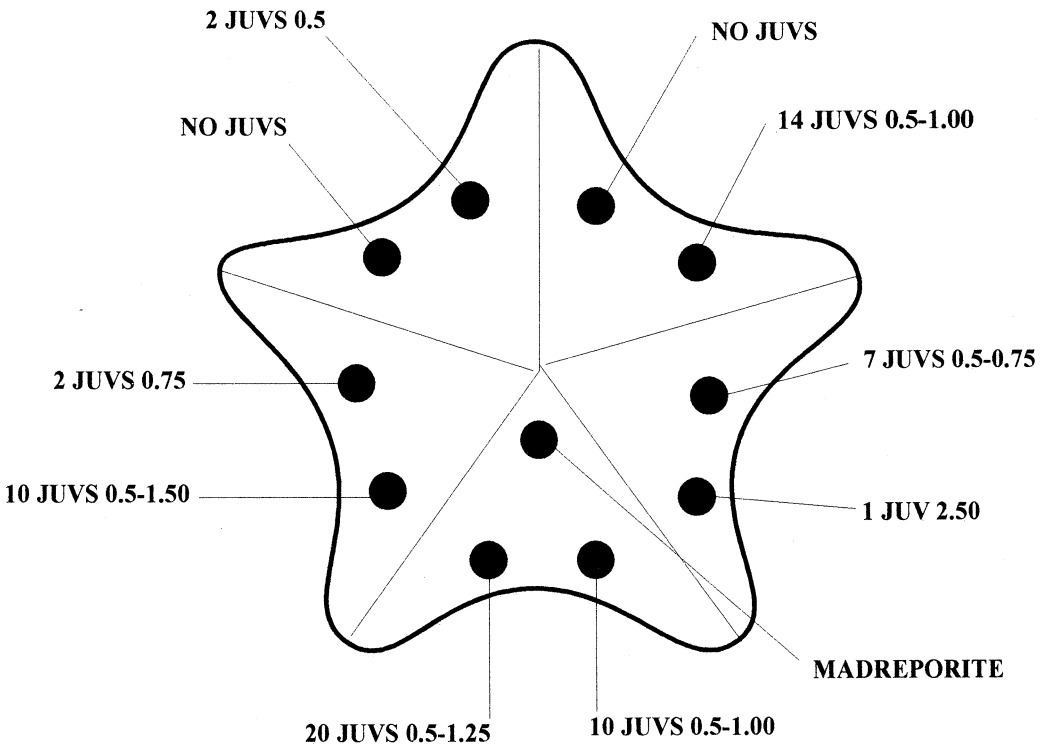

Figure 5. Diagrammatic view of a dissection of an adult *Patiriella vivipara* showing the number of recognisable juveniles in each gonad.

had four arms and four had six arms. These non-pentamerous juveniles were 7.08% of the total births. On the shore the percentage is lower, about 2.5% (n = 188).

A two-armed juvenile born in an aquarium survived for five months (Fig. 6b). At birth it was 2.25×11.50 mm along the major axes, and could move around in a fashion. For the most part it rocked in place, and when it did advance it followed a zigzag path. Although it was able to feed on the algal film, it had difficulty in everting its stomach. When it died, it measured 3.50×2.50 mm along the respective axes.

Disease

Patiriella vivipara is commonly affected by "brown spot" disease (Figs. 6c–d). Brown spot disease may or may not be fatal to the sea star, depending upon its severity. In specimens with this disease, small brown areas are evident on the aboral surface and occasionally on the oral surface. This disease (Figs. 6a,c) was seen on numerous specimens on the shore and in aquaria and at all times of the year over the eight years of study. It can be one small spot that clears in a few days, or it can remain for two to three months. In mild cases this disease clears without leaving a scar. During a moderate attack, several spots of varying sizes can appear. Some of these, especially the larger ones can cause a small amount of necrosis of the tissue, which heals, leaving a scar (Fig. 6d). In severe cases, necrosis progressed until the sea star dies. This is a slow death, taking up to four weeks.

Discussion

Patiriella vivipara along with *P. exigua, P. pseudoexigua* and *P. parvivipara* belong to the "*exigua*" group proposed by Dartnall (1970). The diagnostic characters of the group include the presence of five rays, single oral intermediate spines, and aboral spines on the centre of the disc being 0.2–0.3 mm long. The arm length of these species is seldom greater than 15.00 mm R (Dartnall, 1970). *Patiriella vivipara* is an extra-oral feeder on micro-algal surface films and can evert its stomach to a diameter larger than that of its body while feeding. This method of feeding has also been reported for *P. exigua* (Branch & Branch, 1980; Arrantes & Underwood, 1991), *P. parvivipara* (Byrne, pers. comm.) and the closely related species *Asterina gibbosa* (Crump & Emson, 1978). Like *P. vivipara, A. gibbosa* comes out from under the rocks at night to feed on the upper surfaces (Crump & Emson, 1978). *Patiriella exigua* differs from *P. vivipara* in that its distribution is not restricted to rock shelter. This species was abundant on intertidal rock platforms where its feeding activity was observed to occur through the day. Neither *P. vivipara* nor *P. exigua* completely remove the algal growth that they feed on. *Patiriella vivipara* does not leave a mucus web behind it while feeding as reported for *P. exigua* (Branch & Branch, 1980). *Patiriella vivipara* does not feed upon macro-algae as does *A. gibbosa*. Macro-algae does not grow in the habitat of *P. vivipara*.

Patiriella vivipara is the largest and longest-lived of the three viviparous sea stars that have been investigated,

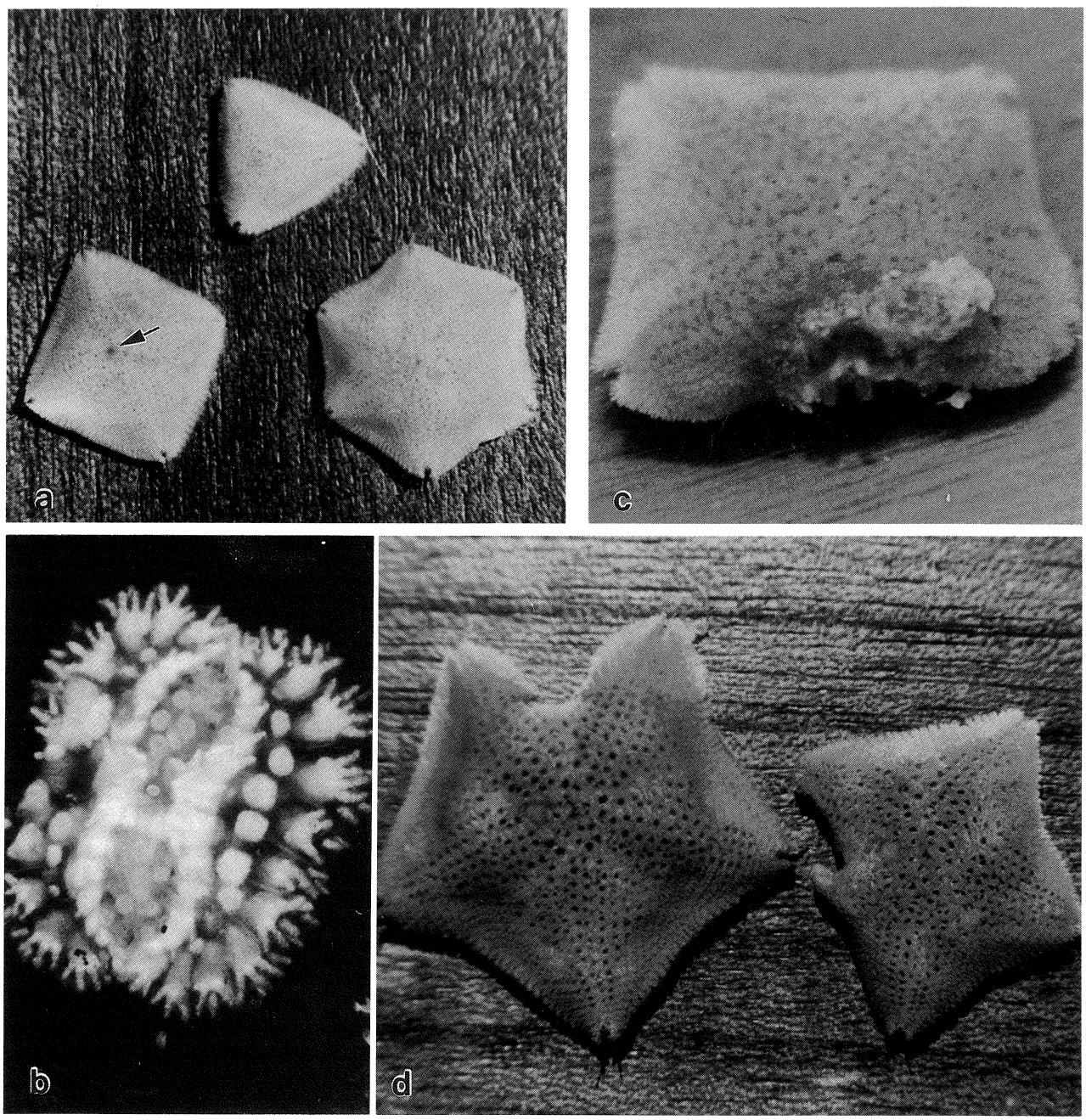

Figure 6. **a**, 3, 4 and 6 armed *Patiriella vivipara* raised in aquaria. The dark spot almost in the centre of the 4–arm specimen (arrow) is a small area of the "brown spot disease" (×2). **b**, The oral surface of the two-armed juvenile 5 months old, about 1 week before it died (×16). **c**, Necrosis caused by a severe attack of "brown spot disease". The sea star was affected interradially, and died about 2 weeks later (×4). **d**, Scars left by a non-fatal attack of the "brown spot disease" (×3).

attaining a maximum radius of 15 mm, and living for 8–10 years. In comparison *Asterina pseudoexigua pacifica* grows to a maximum radius of 10 mm R, and lives for 2–3 years (Komatsu, pers. comm.). *Patiriella parvivipara* is the smallest of these sea stars, growing to a maximum 4.70 mm R, and based on aquarium observations is suggested to live for approximately one year (Keough & Dartnall, 1978).

Although the main period for birth of juvenile *P. vivipara* appeared to be December to February, this was not consistent over the eight years of study. *Patiriella vivipara* is capable of reproducing throughout the year. In aquaria, an average of five juveniles per year were born to each adult, while the average in the quadrat was about two. The quadrat average may be an underestimation, as the sea stars in the quadrat were not restricted in their movement

as were the ones in the aquaria. Juvenile *P. vivipara* leave the parent at an advanced size, ranging in radius from 0.50–5.00 mm. Its smaller congener—*P. parvivipara*—which has a maximum radius of 5 mm, gives rise to juveniles of 2.00–2.50 mm diameter (Keough & Dartnall, 1978; Byrne, 1996). The largest newly emergent *P. vivipara* were 38% of the adults diameter, similar to that reported for *P. parvivipara*. In their first year after birth the juveniles exhibited a rapid growth rate in aquaria with a mean increase in radius of 2.85 mm. The first year of growth in *P. vivipara* is comparable to that recorded for *Asterina gibbosa* which increased in radius by 3.4–3.8 mm (Emson & Crump, 1978). *Patiriella parvivipara* gives birth to only a few juveniles in the summer months December to February, and the adult appears to die after the juveniles emerge. This species appears to live for only 12 months, thus the juvenile born one year becomes a parent the next year and has only has one season of reproduction (Keough & Dartnall, 1978).

In contrast to *P. vivipara, P. pseudoexigua* and *Asterina pseudoexigua pacifica* release a large number of small (R = 0.45 mm) young (Komatsu, *et al.*, 1990; Byrne, pers. comm.). *Asterina pseudoexigua pacifica* is capable of giving birth to 1000 or more juveniles in four weeks (Komatsu, *et al.*, 1990). At a radius of 0.45 mm, they are 4.5% of the adults diameter and are considerably smaller than newly released *P. vivipara* and *P. parvivipara*. The main period for development and birth of *A. pseudoexigua pacifica* is from mid-June to mid-July in the northern hemisphere summer (Komatsu, *et al.*, 1990). In Queensland, *P. pseudoexigua* releases young from September to November (Byrne, pers. comm.). At birth *A. pseudoexigua pacifica* and *P. pseudoexigua* have two pairs of tube feet, as do similarly sized juvenile *P. vivipara*. In comparison, *P. vivipara* emerge at a radius of up to 2.50 mm and with seven pairs of tube feet per arm. This advanced size is attained through intragonadal cannibalism (Byrne, 1996) and undoubtedly enhances their chance of survival. One year after birth *A. pseudoexigua pacifica* has six or seven pairs of tube feet per arm. *Patiriella vivipara* have 13–15 pairs of tube feet per arm at a radius of 7.00–8.00 mm one year after birth.

All four of these viviparous sea stars inhabit the intertidal zone. *Patiriella vivipara* usually occurs under rocks, and occasionally in rock pools. *Patiriella parvivipara* is found in rock pools, and as far as I can ascertain, *A. pseudoexigua pacifica* is also found under rocks. *Patiriella pseudoexigua* also occurs under rocks (Byrne, pers. comm.). Like *P. vivipara, P. parvivipara* and *P. exigua* experiences high summer temperatures, with the water in the pools reaching 30°C at low tide (Keough & Dartnall, 1978; Byrne, 1992). For *P. parvivipara*, tidal flushing made little difference to the temperature encountered by this sea star. *Patiriella vivipara* encounters a broad range of air temperatures, and for a relatively short period, water temperatures of up to 33°C while the tide initially comes in. Once the water reaches 0.3 m depth, the temperature starts to drop to whatever the deeper water temperature is at the time.

Since the initial surveys in the 1970's and 1980's, the populations of *P. vivipara* at Pittwater, Eagle Hawk Neck and Roches Beach have declined. Recent reconnaisance revealed that *P. vivipara* is not present along the Pittwater causeways in the numbers recorded in 1979. Several large colonies have almost disappeared from the south western shore of Upper Pittwater, and the remaining populations have decreased. The main population of *P. vivipara* at Pittwater is now found on the western shore of Midway Point.

Factors potentially influencing the decline of *P. vivipara* at Pittwater include the decrease in water quality associated with the discharge of effluent from sewerage treatment plants into Pittwater, seepage from areas serviced by septic tanks and from storm water runoff. The nutrients from these discharges can cause a heavy growth of epiphytes, and are thought to have contributed to the loss of sea-grass beds in Pittwater (Prestedge, 1996). Pittwater has experienced increased siltation since the early surveys and spaces between and under rocks previously occupied by *P. vivipara* have been filled by a combination of sediment and *Pyura stolonifera*. Storm water run off affects *Patiriella vivipara* populations located near drain outlets, and appears to cause a necrotic disease that kills some of the sea stars.

The population of *P. vivipara* on *The Tessellated Pavement* at Eagle Hawk Neck has decreased in association with the decline of the carpets of the small mussels *Brachidontes rostratus* and *Xenostrobus pulex* which they sheltered in. A drain carrying waste water has discharged just above the mussel zone for many years and may have contributed to the mussel die-off and the resulting decline of *P. vivipara*. In a survey conducted during February 1998, only 60 *P. vivipara* were found at this site.

The population of *P. vivipara* at Roches Beach has also decreased, but there is no obvious perturbation in the vicinity. A survey at this site during February 1998, the number of *P. vivipara* was estimated to be approximately 100.

The situation at Fortescue Bay is tenuous as the population is limited and the habitat does not appear suitable for an increase in the population of *P. vivipara*. At the present time there is very little pressure from human activity at this site.

In 1997 *P. vivipara* was found at Peppermint Bay, Woodbridge (Materia, pers. comm.). The presence of this species at this site appears to be due to release of adults from a nearby aquarium centre.

The decline in *P. vivipara* indicates that this sea star may be in danger of extinction. *Patiriella vivipara* was listed in July 1998 under the Tasmanian Threatened Species Protection Act, 1995, as follows: "*Patiriella vivipara* (viviparous seastar): Approved for listing on Schedule 3, Part 1—Endangered taxa of flora and fauna—Extant." Its limited distribution and low dispersive life history make it highly vulnerable to local perturbation. Considering its apparent decline since the original population census in 1976 and the scientific importance of this unusual species, some thought should be given to protection of *P. vivipara* and its habitat.

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