

peared to be a very favorable location for any type of field work on the South American sea lion. The colony contained about 300 animals, the beach was easily accessible, and the area was situated in sheltered waters.

The bioacoustics phase of Cruise 70-3 ended on June 18, 1970, as *Hero* neared Valparaíso, Chile. We are grateful for the assistance given us by Dr. Raymond M. Gilmore (senior scientist), Dr. Joseph R. Jehl, Jr. (ornithologist), and Mr. Steven L. Bowen (research assistant), all from the San Diego Natural History Museum. *Hero's* Master, Robert Carrow, and the crew did a splendid job of manning the ship and providing support, often under severe conditions. The work was supported by NSF grant AG-217.

The general ecology of the antarctic limpet *Patinigera polaris*

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Studies begun under the direction of Dr. Joel W. Hedgpeth during the austral summer of 1969-1970 (Stout and Shabica, 1970) of the life cycle of the intertidally occurring limpet *Patinigera polaris* were continued at Palmer Station through the austral winter. Field observations by scuba diving complemented extensive experimentation in the biological laboratory. The data will be used to gain a greater understanding of population dynamics in what appears to be one of the most simple and undisturbed of ecological communities.

Meter-square samples of *P. polaris* were collected monthly from six levels of the littoral zone: 0.0, 1.5, 3.0, 6.0 to 7.4, 10.5 to 12.0, and 15.0 m. To determine population size, age structure, and recruitment, a size distribution analysis was performed. Length, width, and height of each specimen were measured. The height of the limpet appears to be an important parameter, as the height to width-length ratio decreases as depth increases. Perhaps the higher shell, which allows greater exposure in the supralittoral, is being selected naturally. As in some temperate species, the higher shell presumably allows greater water retention.

Each animal was sexed and its gonad examined. Since the reproductive period was unknown, gonadal growth and state were investigated to allow predictions regarding spawning. Shell epiphytes and their relative concentrations were noted, for marked differences in shell surface morphology are associated with such growths. Variation of the shell surface appears to be related to depth, and the epiphytes may well be responsible. Other possible causes are bacterial action on the shell or differential shell solution, both being re-

lated to depth. The shells of the limpets were dried and weighed. Generally, shell thickness and thus weight appear to reduce with increasing depth. The thick, heavy shells of the limpets above 3.0 m and especially of those occurring in the supralittoral suggest natural selection for greater resistance to the abrasion and crushing caused by ice in shallow water.

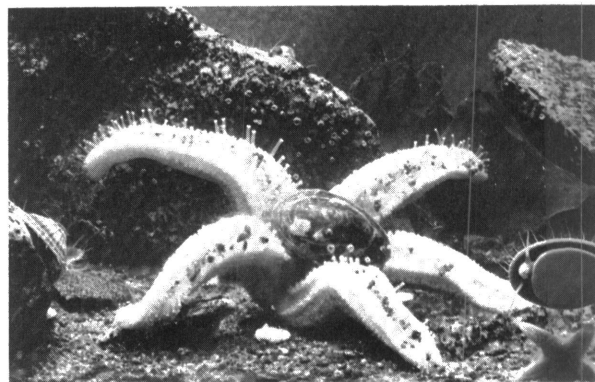
Marked limpets released in March 1970 were collected again in February and March 1971 and remeasured. Animals included in the study ranged in length from 10 to 65 mm. The data have not been completely analyzed, but growth rates are high in the smaller limpets and negligible in the larger ones. A growth of 1 to 3 mm during the year's study was not unusual in the smaller animals.

Observations showed the following animals to be predators of *P. polaris*, in decreasing order: the kelp gull, *Larus dominicanus*, which swallows the limpets at the water's edge and then regurgitates them in gull middens (fig. 1); an asteroid (fig. 2); the sheath bill, *Chionis alba*; the fish *Notothenia coriiceps*; the pycnogonids *Colossendeis robusta* and *C. megalonyx*; the echinoid *Sterechinus neumayeri*; and the pycnogonid *Pentanympheon* sp. The observations were made dur-



Figure 1. Common gull midden of *Larus dominicanus*.

Figure 2. Sea star (turned on dorsal surface artificially) feeding on *Patinigera polaris*.



ing scuba dives, from the Palmer Station live tanks, and in the Arthur Harbor region.

To determine the food preference of *P. polaris*, specimens were collected from 0.0, 6.1, 12.2, and 18.3 m. At each level, collections were made from three existing substrate types: rock, algae, and mud. Slides were prepared of the gut contents, and a 200-point count was made. Generally, regardless of substrate type, diatom fragments made up the greatest percentage of total gut content. Algal filaments and fragments made up the next greatest percentage, followed closely by inorganic or mineral fragments. Apparently, *P. polaris* is nonselective in its feeding habits. The mean water content of the soft tissue of the limpet was found to be 83 percent of total body weight.

Shell regeneration is quite rapid despite the low water temperatures. In all cases examined, $\frac{1}{16}$ -inch holes drilled through the shells were sealed internally by a hard pearly white substance after a maximum of 9 months. The protective value of this rapid regeneration is obvious: animals whose shells are either slightly crushed by ice or damaged by a predatory bird (pecking fractures) would be more vulnerable to other types of predators if the shell remained unsealed.

P. polaris is dioecious, and fertilization takes place externally. Maturation can occur in limpets larger than 2.2 cm; no upper size limit of fecundity was observed. Spawning is probably related to water temperature. Observations in the wild and in the live tanks at Palmer Station—as well as observations made by Eric Twelves, British Antarctic Survey (personal communication), at Signy Island—support this. From 2 to 3 weeks of above -1.40°C . water temperature seem to be required to initiate maturation of gametes. Experiments show that, prior to the water's warming trend, placing eggs and sperm together artificially does not result in fertilization. However, after 3 weeks of warming (water temperature reaching -0.65°C .), fertilization can be induced artificially. There is a definite time lag between the spawning of the deep and shallow water limpets.

The embryological development of fertilized eggs was followed to the trochophore stage (fig. 3).

Live-tank observations of spawning indicate that the release of eggs by the female is perhaps responsible for the emission of semen by the male (fig. 4), an unknown substance released with the eggs stimulating the males. Very ripe males and females have been observed to spawn separately with mechanical—differential pressure—stimulation.

Breeding appears to occur in two separate periods: early November and early December. This could be the result of differential growth and maturation, the existence of two distinct populations of the same species or of two different species that are morphologically similar but genetically different, or a long, indistinct breeding season. Histological examination of the gon-

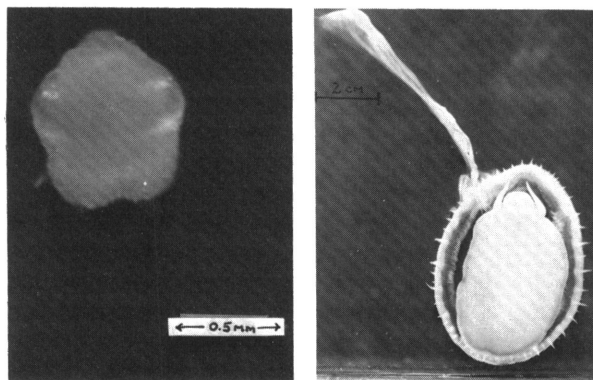
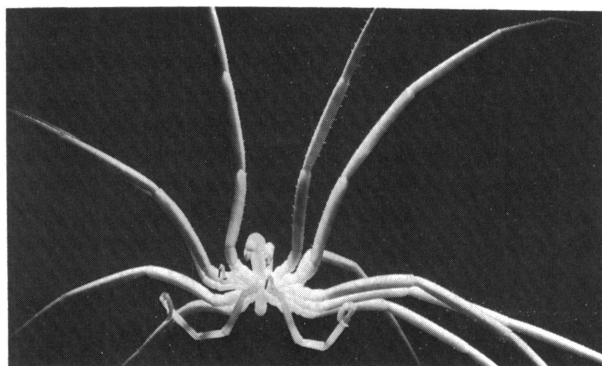


Figure 3 (left). Trochophore stage of *Patinigera polaris*.

Figure 4 (right). Semen release by *Patinigera polaris*.

Figure 5. Twelve-legged pycnogonid *Dodecalopoda mawsoni*.

Photos: S. Shabica



ads will be carried out at Oregon State University and should clarify this phenomenon.

Experimental work performed during the winter shows that (1) *P. polaris* demonstrates positive phototaxis, (2) it exhibits no thermal preferendum in the -1.0° to $+10.1^{\circ}\text{C}$. range, (3) it can tolerate 0-percent normal sea water for 16 hours and 225-percent normal sea water for 14 hours (in conjunction, it exhibits osmoregulatory behavior as measured by weight gain or loss), and (4) it can tolerate $+17.0^{\circ}\text{C}$. water temperature for 2 hours and -8.0°C . for 12 hours. The animals were tested from -13.5° to $+22.0^{\circ}\text{C}$.

Closed respirometry studies were performed on over 800 individuals.

The vertical limit of distribution of *P. polaris* appears to be shallower the farther south the animal is observed. At Signy Island ($60^{\circ}43'\text{S}$. $45^{\circ}38'\text{W}$.) Michael Robbins (personal communication) states that its vertical limit is at a depth of 31.8 m. In Arthur Harbor ($64^{\circ}46'\text{S}$. $64^{\circ}04'\text{W}$.), its limit is 20.5 m. At the Argentine base Almirante Brown ($64^{\circ}53'\text{S}$. $62^{\circ}53'\text{W}$.), its limit is 15.4 m. All observations were from similar substrates.

In other work, the first perfect specimen of the rare 12-legged pycnogonid *Dodecalopoda mawsoni* (fig. 5)

was collected while trawling from R/V *Hero* near the Melchior Islands (64°19'S. 62°57'W.). This was the fourth specimen of *Dodecalopoda* ever collected.

This work is supported by National Science Foundation grant GA-18348.

Reference

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Effects of temperature on carbon dioxide compensation points of the moss *Drepanocladus uncinatus*

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Photosynthetic and respiratory rates as influenced by temperature and light intensity have been reported for antarctic mosses (Gannutz, 1970; Rastorfer, 1970). However, to the author's knowledge carbon dioxide compensation points (concentrations) have not been ascertained previously for an antarctic moss species. The determination of this physiological parameter is important in understanding the biology of antarctic mosses. Plants with relatively high CO₂ compensation points indicate that they may have a

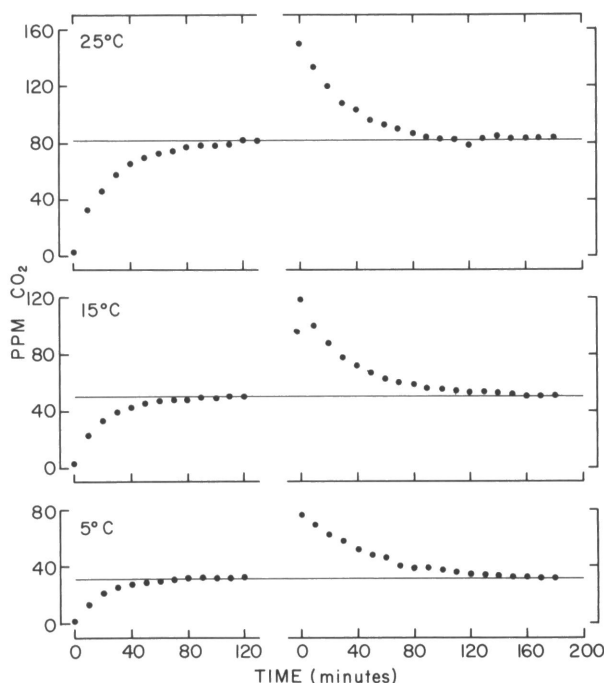
light-dependent CO₂ releasing mechanism that differs from dark respiration (Jackson and Volk, 1970). In this study, CO₂ compensation points were determined at three different temperatures for gametophytes of *Drepanocladus uncinatus* (Hedw.) Warnst.—of west antarctic origin but cultured under controlled conditions.

Materials and Methods. Experimental plant tissues consisted of new gametophytic shoots of *D. uncinatus* produced by regeneration from parent materials collected on the easternmost island of the Corner Islands, Argentine Islands, Antarctica. Plants were cultured on vermiculite in plastic trays having drainage holes and a clear plastic fitted lid. This tray was kept in a growth chamber with temperatures, at plant level, ranging from 0.5° ± 0.5°C. during the dark period to 12.5° ± 0.5°C. during the light period. The light period was 14 hours per 24 hours from fluorescent lamps providing a light intensity, at plant level, of 2.5 milliwatts per sq cm (Δλ 400–750 nanometers). In addition, the culture was supplied weekly with a 0.1 concentration of Hoagland solution.

Carbon dioxide compensation points were determined in a closed system employing a Beckman model 215 infrared gas analyzer. The test shoots were sealed in a Plexiglas chamber, which was submerged in a water bath and connected to the closed system. Temperatures of the water bath were adjusted to maintain the specified experimental temperatures of 5°, 15°, and 25°C. inside the plant chamber. The light intensity, at plant level, was 5.84 mw per sq cm (Δλ 400–750 nm) from incandescent reflector lamps. Although the results of only one sample consisting of 1.02 g (dry weight) of shoots are presented in this report, tests of a duplicate sample give similar results.

Results and discussion. Carbon dioxide compensation points increased with increasing temperatures (see fig.). The CO₂ compensation values were 32, 50, and 82 parts per million at 5°, 15°, and 25°C. respectively. This temperature response in affecting CO₂ compensation points is consistent with those reported for vascular plants (Joliffe and Tregunna, 1968; Heath, 1969).

In general, higher plant species can be divided into two categories—those with high CO₂ compensation points and those with low compensation points amounting to approximately 5 ppm or less (Jackson and Volk, 1970). Among the former species, CO₂ compensation points, in moderately bright light and between 20° and 30°C., usually range from 32 to 122 ppm (Heath, 1969; Goldsworthy and Day, 1970). The moss *Bryum argenteum* is reported to have a CO₂ compensation point of 58 ppm at 20.5°C. (Rastorfer, 1970). The CO₂ compensation values for *D. uncinatus* may be higher than normal, as caused by reduced photosynthetic activities resulting from low chlorophyll (*a* + *b*) contents. Tissue samples taken



Carbon dioxide compensation points as affected by temperature for *Drepanocladus uncinatus* gametophytes.