

First Report of the Enigmatic Echinoderm *Xyloplax* from the North Pacific

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*More than 100 specimens of the rare and enigmatic echinoderm *Xyloplax*, a deep-sea wood-fall specialist described as the new class Concentricycloidea on the basis of nine specimens from New Zealand (1), were recently collected from a depth of 2675 m in the North Pacific. These first submersible-collected specimens of *Xyloplax* from the Pacific contrast with the submersible-collected specimens of the Atlantic's *X. turnerae* in developmental mode. Embryos of the Pacific specimens—including those from New Zealand—undergo extended development in the ovary; members of the Atlantic species apparently release small embryos or eggs. In what may be an associated difference, females appear to dominate the North Pacific population in numbers and exceed males in individual size. In addition, the marginal spines of North Pacific specimens show a nonlinear relationship to body diameter on an ln-ln plot; relatively rapid growth of marginal spines in small individuals may enhance dispersal on near-bottom currents. In the Atlantic species, the sexes are equally represented (although sexual size dimorphism exists), and marginal spines grow at a constant rate. The increased biomass of females among North Pacific specimens may reflect their increased investment in each offspring.*

Animals specialized to live on deep-sea wood falls remain little known, both taxonomically and biologically. Nine specimens from five New Zealand wood falls collected at depths from 1057 to 1208 m were assigned to the genus *Xyloplax*, which has been interpreted as composing a new class of echinoderms, the Concentricycloidea (1) and, alternatively, as a highly derived genus of the Asteroidea (2 and references therein). Detailed anatomical study of the genus (3), and a brief report of population parameters (4) were based on more than 200 specimens collected from an ex-

perimental wood deployment at 2066 m off the Bahamas. The recent collection of more than 100 specimens of the genus from an experimental wood deployment in the North Pacific provides a contrast between this viviparous species and the Atlantic species with its shorter embryonic development. Despite distinct reproductive strategies, both species exploit the rare and unpredictable habitat provided by deep-sea wood falls.

This study reports the population composition and growth patterns of specimens of the undescribed North Pacific species. The specimens probably represent the original population accurately because the deployments were recovered inside a closed box on the Deep Submergence Vehicle *Alvin*. C. Mah, University of Illinois at Urbana-Champaign, is describing the new species represented by these specimens.

The wood from which the specimens were collected had been deployed on 28 July 2002. The deployment consisted of a mesh diver's bag containing one 45.7-cm-long piece of machine-cut, bark-free, green 10.1-cm-square Douglas fir (*Pseudotsuga* sp.) and an identical piece of oak (*Quercus* sp.); cable ties secured the bag. The Remotely Operated Vehicle *Tiburion* (Monterey Bay Aquarium Research Institute) placed the bag at 2675 m near 42° 45.2'N 126° 42.5' W. The habitat was basalt talus within a few feet of widely scattered tubeworms of *Ridgeia piscesae*; the long, thin morphology of the tubeworms is typically associated with low concentrations of sulfide (5). Down-slope and to the south was the GR-14, or SeaCliff hydrothermal vent field, an off-axis vent field located on a west-facing slope (6) that, at least during the recovery dive, was characterized by exceptionally strong bottom currents.

On 31 August 2004, the DSV *Alvin* recovered the deployment by grasping the wood through the bag with its manipulator arm and placing the bag inside a lidded box on the submersible. The box lid was then closed and secured

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with an elasticized band. No elevated temperatures associated with hydrothermal activity could be found in the area. Five hours later, the submarine was recovered and the wood was removed from the collection box and placed into cold seawater.

The bag containing the wood was opened and animals visible to the naked eye (Fig. 1) were removed from the wood by hand. Because the partially anoxic wood had been inside the closed recovery box for more than 5 h, the animals' positions on the wood could not be considered to accurately reflect normal life positions. The wood was rinsed in cold seawater and later sectioned with an electric saw. All water that had contact with the wood, including water from the recovery box on *Alvin's* basket, water into which the wood was placed after recovery, and rinse water, was sieved with a 250- μm mesh. All material retained in the sieve was preserved in 95% ethanol and later sorted under a dissecting microscope. The specimens are catalogued at The Field Museum, Chicago, Illinois, as FMNH 12458, 12459, 12460, and 12461.

The tube feet in one sector of the body were counted and multiplied by five to generate a total count, after verifying in about half of the specimens that the sectors were invariant. The diameter, including the spines, was measured for all individuals collected, except one that was badly damaged. Developing embryos visible through the adult's oral surface were used to identify gravid females; developing embryos were counted. Cygnoid spines, said to identify males of both known species (3), could not be seen in these specimens at

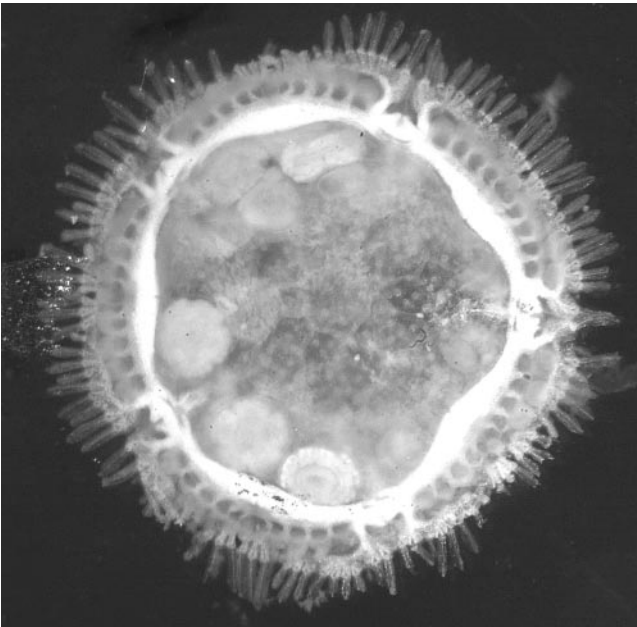


Figure 1. Digital still image of a fresh-collected female of *Xyloplax* with a diameter of about 10 mm. Developing embryos can be seen through the body, which is covered by erect spines and encircled by marginal spines. (Photo courtesy of T. Haney.)

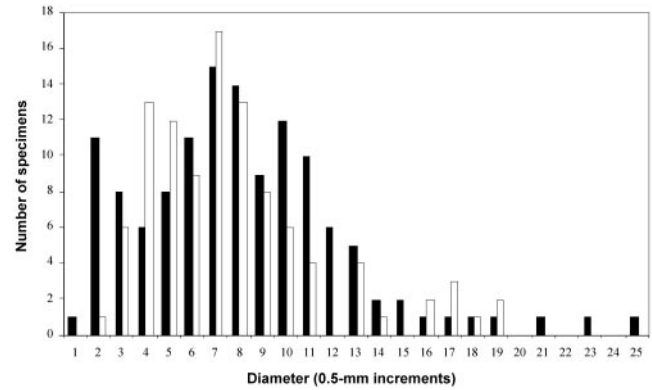


Figure 2. The diameters of the North Pacific specimens are indicated by open columns ($n = 98$) and those of *Xyloplax turnerae* by solid columns ($n = 136$); data for the latter from (3). Each increment is 0.5 mm, beginning with zero. The size distribution does not significantly differ (KS test; $P = 0.414$).

the magnifications used. On the basis of a previous report that in *Xyloplax* the testes are kidney-shaped (3) and the observation of kidney-shaped gonads in some specimens, this character was used to identify potential males. Specimens with neither apparent developing embryos nor kidney-shaped gonads were considered to be juveniles. To test whether growth of marginal spines, which appear very large in small individuals, was non-allometric—that is, departs from the power law relationship of being linear on a plot of natural logarithms—marginal spine length and body diameter (exclusive of the spines) were measured from camera lucida drawings. To document growth, the data were transformed to natural logarithms (7). The size distribution of these specimens was compared, using a histogram, to that of *X. turnerae* reported by Rowe (4); the presence of significant differences was tested with a KS test.

The size range of the specimens was from 0.75 to 9 mm (Fig. 2); largest were 14 gravid females with diameters of from 6 to 9.5 mm and a total of 55 to 65 tube feet. Only four individuals, ranging in diameter from 3.75 to 5 mm, were considered to be males on the basis of their kidney-shaped gonads. Diameters of juveniles overlapped those of males. Males had 40 to 45 tube feet; juvenile specimens had between 25 and 45 tube feet.

Individual females contained between 7 and 16 embryos in various stages of development. The most mature embryos appeared to be very similar to the smallest (0.75-mm-diameter) free-living specimen recovered. One mite was attached to each of four preserved individuals, all of which were under 2 mm in diameter and had been recovered from the sieve; that is, they had fallen off the wood, as had nearly all the smaller specimens. A free mite was also found in the sieve residue and in the vial of 74 specimens of *Xyloplax* that had been removed directly from the wood. The mites

have been sent to I. Bartsch of the Forschungsinstitut Senckenberg, Germany, for study.

Close examination of the preserved specimens revealed that in many, the marginal spines were angled relative to the plane of the body, minimizing their apparent length. Rather than risk damaging the specimens by removing the spines, specimens with detectably angled spines were eliminated from consideration, leaving only 18 individuals. Even with this reduced sample, nonlinear growth of the marginal spines was clear (Fig. 3). The spines lengthened at a consistent rate as body diameter expanded to about 2.75 mm. Beyond that point, lengthening of the roughly 0.74-mm-long spines was limited to less than 0.1 mm, even though body diameter tripled.

The wood contained very few small claims of *Xylophaga* sp. on or near its surface, but several larger claims had bored deep inside. This deployment had conspicuously fewer claims than did comparable ones from which predatory taxa such as *Xyloplax* and turbellarian flatworms were absent (unpub. data).

This report offers the first data from a Pacific population of the enigmatic genus *Xyloplax*. The other Pacific species, *X. medusififormis*, is known only from 9 specimens pulled from five pieces of wood collected at depths from 1057 to 1208 m around the islands of New Zealand. Judging from the notation that they were removed from molluscan borings (3), these animals were probably trawl-collected. More than 200 specimens of *Xyloplax turnerae* were collected on experimental wood deployments off Andros Island, Bahamas, at 2066 m. The deployments had been in place for 18 and 24 months when the recoveries were apparently performed by *Alvin* (possibly during dives 751–755, 800, 851–

853, a conclusion based on the dates and position (3) and *Alvin* dive log: http://www.whoi.edu/marops/vehicles/alvin/alvin_dive_log.html). The morphology and aspects of the population biology of this species described in published reports (3, 4) contrast with those of the present species in that the Atlantic species is larger (Fig. 2; diameters of females of up to 12 mm, and of males up to 7.2 mm), has more tube feet (up to 110 compared to 65), and has a stomach. The Atlantic species has a very nearly equal sex ratio, female-biased sexual size dimorphism, and linear growth of the marginal spines. Embryos contained in Atlantic females have all been smaller than 180 μm (3).

In the New Zealand *X. medusififormis*, embryos develop to a near-juvenile stage inside the ovary (3), as they appear to do in the North Pacific species. The North Pacific specimens contrast with Atlantic specimens in apparently having a strongly female-skewed sex ratio; however, the two species share a female-biased sexual size dimorphism, which is common in deep-sea animals (8). The increased female investment in each individual offspring may be associated with greater increase in female biomass in the North Pacific population.

Differences in the species' dispersal strategies may be expressed in morphological differences. *Xyloplax* has been suggested to disperse by a parachute-like mode of locomotion, apparently in reference to passively floating (1) or *via* a more active, medusoid method of locomotion driven by pulsations of the oral surface (3). The relatively large spines of young North Pacific specimens of *Xyloplax* increase the animal's surface area by nearly 50% while only minimally affecting weight. The discovery that the spines of most preserved specimens are angled supports the hypothesis that muscles control spine movements. The large, mobile marginal spines of small individuals (Fig. 1) would enhance either parachuting or medusoid locomotion. In the Atlantic *X. turnerae*, marginal spines show negatively allometric growth relative to body diameter through life, meaning that the spines are relatively longest in the smallest animals. They would therefore also enhance dispersal potential, despite being shorter than those of the Pacific species, in all but the very largest females (Fig. 1).

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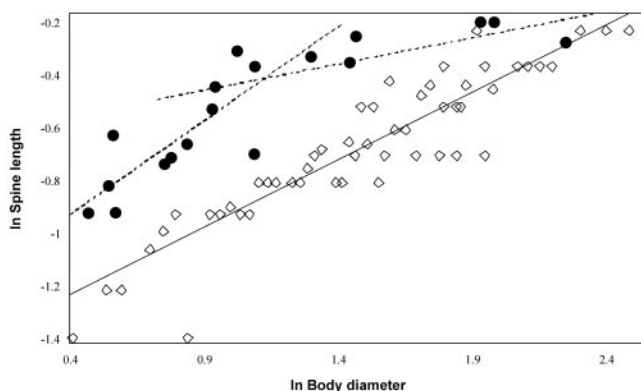


Figure 3. Natural log of marginal spine length plotted versus natural log of body diameter for 18 North Pacific specimens of *Xyloplax* (solid circles) and for 53 Atlantic specimens of *X. turnerae* (open diamonds). The lower end of the plot, showing only specimens of *X. turnerae*, has been truncated to emphasize the inter-specific contrast. Although scatter exists, especially among the smaller individuals, spine lengthening is nonlinear relative to increases in body diameter in the North Pacific specimens; the Atlantic specimens show a uniform increase. The spines of both species reach the same length (0.82 mm) in the largest females.

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