



Photographic identification guide to larvae at hydrothermal vents

by Susan W. Mills, Stace E. Beaulieu and Lauren S. Mullineaux
Woods Hole Oceanographic Institution

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June 2009

Technical Report

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Department of Biology

Table of Contents

Foreward	2	Unknown neomphalid W.	55
Acknowledgements	2	<i>Melanodrymia aurantiaca</i>	57
Introduction.	3	Unknown ?neomphalid 290µm	59
Methods.	3	<i>Rhynchopelta concentrica</i>	61
Using This Guide.	5	<i>Ctenopelta porifera</i>	63
Terminology.	6	<i>Bathymargarites symplector</i>	65
Gastropoda	9	<i>Laeviphitus</i> sp.	67
<i>Gorgoleptis spiralis</i>	9	<i>Phymorhynchus</i> sp.	69
“Pointy apex”	11	Bivalvia	71
Unknown benthic sp. A.	13	<i>Bathymodiolus thermophilus</i>	71
Unknown neomphalid 5	15	<i>Bathypecten vulcani</i>	73
<i>Lepetodrilus</i> spp.	17	Polychaeta	75
<i>Clypeosectus delectus</i>	19	<i>Amphisamytha galapagensis</i>	75
<i>Gorgoleptis emarginatus</i>	21	<i>Archinome rosacea</i>	77
<i>Gorgoleptis</i> sp. 3.	23	“Chaetosphaerids”	79
Unknown 7.	25	<i>Glycera</i> sp.	81
<i>Lepetodrilus</i> -like protoconchs	27	Nectochaetes.	83
Unknown 8.	29	<i>Nereis</i> sp.	85
Unknown 9.	31	<i>Ophryotrocha</i> sp.	87
<i>Echinopelta fistulosa</i>	33	Polynoids.	89
<i>Peltospira</i> spp.	35	Unknown polychaete A.	91
<i>Lirapex granularis</i>	37	Unknown polychaete B.	93
Unknown peltospirid 240µm	39	Crustacea	95
Unknown neomphalid B.	41	Barnacle cyprids.	95
<i>Cyathermia naticoides</i>	43	<i>Bythograea microps</i>	97
<i>Neomphalus fretterae</i>	45	<i>Bythograea thermydron</i>	99
<i>Melanodrymia ?galeronae</i>	47	Foraminifera	101
<i>Neolepetopsis</i> spp.	49	? <i>Tretomphalus</i> sp.	101
<i>Pachydermia laevis</i>	51	Literature Cited	102
<i>Eulepetopsis vitrea</i>	53	Taxonomic Index	104

Foreward

The purpose of this guide is to assist researchers in the identification of larvae of benthic invertebrates at hydrothermal vents. Our work is based on plankton sampling at the East Pacific Rise 9-10°N vent field from 1991-2007, supplemented by benthic collections of juveniles. In addition to images and descriptions of the species, we included frequency data from large-volume plankton pump samples taken between 1998 and 2004 and time-series sediment trap samples from 2004-2005.

This guide is divided into five sections: Gastropoda, Bivalvia, Polychaeta, Arthropoda and other miscellaneous taxa. All except the gastropods are in alphabetical order within a section. Since size is an important characteristic in species determinations in gastropod protoconchs, we have put them in order of ascending size. An alphabetical index is included at the end of the guide. Except where otherwise stated, light microscope

pictures were taken by Stace Beaulieu and SEM's by Susan Mills and Diane Adams.

Although our own samples are limited to the EPR 9-10°N site, we would like to expand this guide by including additional species from other areas. This guide is also available online at:

<http://www.whoi.edu/vent-larval-id/>

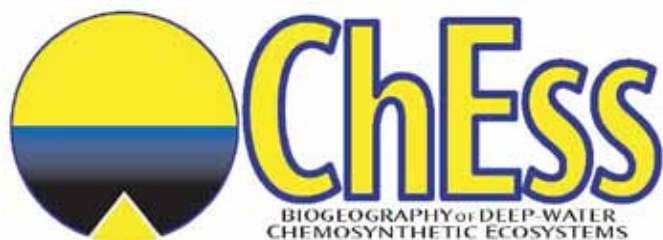
The online version includes links to ChEssBase and the Ocean Biogeographic Information System (OBIS). Please contact Susan Mills (smills@whoi.edu) or Stace Beaulieu (stace@whoi.edu) if you have photos you would like to have included on the website.

This guide is intended to serve as a companion to the Handbook of Deep-Sea Hydrothermal Vent Fauna (Desbruyeres, et al., 2006), which provides photographs and descriptions of the adult forms.

Acknowledgements

We are indebted to the taxonomists who described these species, whose papers appear in the Literature Cited section. In the case of the gastropods, they often included SEM's of the larval shells, which greatly assisted us in assembling this guide. In particular, we would like to thank Anders Warén for assistance with identifications of larval and juvenile gastropods and for advice on mounting specimens for SEM. In addition, we thank Stacy Kim, Pat McMillan, Anne Beaudreau, Andrew Sweetman, and Diane Adams for help in learning how to distinguish larval gastropods.

This work was funded by NSF grants OCE-9619605 to L. Mullineaux, D. Manahan and C. Young, OCE-9712233 to L. Mullineaux, C. Fisher and C. Peterson, OCE-0424593 to L. Mullineaux, A. Thurnherr, J. Ledwell, D. McGillicuddy and W. Lavelle, ATM-0428122 to H. Singh, T. Shank, L. Mullineaux, M. Neubert and others, by a WHOI Deep Ocean Exploration Institute grant to L. Mullineaux and S. Beaulieu and by a grant from the ChEss project of the Census of Marine Life to L. Mullineaux, S. Beaulieu and S. Mills.



For animals living on the seafloor, a planktonic larval stage is a critical phase of the life cycle. Larval dispersal provides ecological and genetic connections among communities in patchy habitats such as hydrothermal vents. Temporal variation in larval supply to benthic communities can lead to fluctuations in the size and genetic composition of adult populations. On long time scales, barriers to dispersal can lead to speciation and are thought to be fundamental factors in generating biogeographic patterns and regional biodiversity. Despite the importance of the larval phase, very little is known about larval dispersal in the deep sea, even at hydrothermal vents where the habitat is patchy and transient, and larval exchange critical to the survival of endemic species.

General difficulties of larval identification for deep-sea studies include the scarcity of larvae in plankton samples, the fact that the adults may be unknown, and the difficulty of matching larval morphotypes to adult forms. However, some hydrothermal vent habitats have well-characterized benthic communities with relatively low species diversity and relatively high biomass and fecundity, resulting in large numbers of larvae in the

plankton compared to typical deep-sea habitats. In addition, a large portion of hydrothermal vent communities can be comprised of gastropods, which can, in many cases, be identified by protoconch morphology. For example, gastropod larvae collected near hydrothermal vents in the eastern Pacific have been identified morphologically under light and electron microscopy (Mullineaux et al., 1996).

Since the discovery of hydrothermal vents thirty years ago, researchers have been collecting larvae in studies to explain the colonization of these oases in the deep (e.g. Lutz et al. 1984, Turner et al. 1985, Kim and Mullineaux 1998). Recent emphasis has been placed on time-series collections of larvae in multi-disciplinary studies of larval dispersal and supply to vent communities, such as the LADDER project at the East Pacific Rise (<http://www.whoi.edu/projects/LADDER/>). The purpose of this photographic identification guide is to serve researchers studying hydrothermal vent larvae in previously collected and future samples. The photographs may also be useful to those studying newly settled colonists.

Collection and preservation of larvae

For this first edition of the identification guide, larvae were collected near hydrothermal vents at the East Pacific Rise (EPR) 9°N site. Specimens were obtained over a 15-yr period, beginning with collection by nets and pumps with small-volume samples from 1991 - 1995 (Kim and Mullineaux, 1998), pumps with large-volume samples from 1998 - 2007 (Mullineaux et al., 2005; Beaulieu et al., 2009), and time-series sediment traps from 2004 - 2007 (Adams, 2007; Adams and Mullineaux, 2008). Net tows, plankton pumps, and sediment traps do not sample larvae in equal proportions – some are better collected by one method or another and a combination of methods is likely to give a more complete description of the larval species composition of a particular site (Beaulieu et al., 2009).

For our recent studies at the EPR, large-volume pumps were used to collect discrete plankton samples over

1-day periods (McLane Large Volume Water Transfer System WTS-LV50; McLane Research Laboratories, Inc., Falmouth, MA, USA). We pumped 30 L min⁻¹ (500 cm³ s⁻¹) over a filter comprised of 63µm Nitex mesh, yielding ~40 m³ pumped per day. For time-series sampling we used a conical, time-series sediment trap with sampling aperture 0.5 m² and 21 cups (McLane PARFLUX Mark 78H-21 Sediment Trap; McLane Research Laboratories, Inc., Falmouth, MA, USA). Prior to deployment, we filled the cups with a solution of 20% dimethylsulfoxide (DMSO) in ultrapure water saturated with NaCl. We chose this preservative to allow for molecular genetic analyses of the collected specimens (e.g. Comtet et al., 2000). The pumps and sediment traps were deployed on autonomous subsurface moorings, with the samples collected between 2 and 175 m above bottom (mab) depending on each mooring configuration. Moorings were positioned within or near (< 2 km off-axis) the axial summit trough.

Methods

Methods

For the large-volume pump samples, after recovery on deck the filter holder was removed into a 20-L bucket with chilled, filtered seawater. All subsequent handling of the sample occurred in a cold room (4° C). Samples were carefully rinsed from the filter using a squirt bottle with chilled, filtered seawater. Many of the collected specimens were alive upon retrieval of the pump. We briefly examined the samples live under a dissecting microscope prior to collecting onto a 63µm sieve, rinsing with fresh water, then preserving in 95% ethanol for examination at our laboratory. For the sediment trap samples, after recovery of the mooring we photographed the cups and stored them at 4° C prior to shipment to our laboratory for examination.

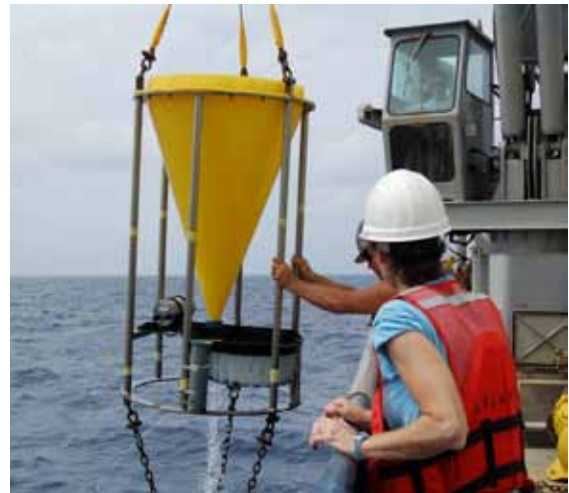
A. McLane Large Volume Water Transfer System WTS-LV50 Plankton Pump.
Photo by Carly Strasser, WHOI.

B. McLane PARFLUX Mark 78H-21 Sediment Trap.
Photo by Skylar Bayer, WHOI.

A.



B.



Sorting and photographing larvae

For sorting at our laboratory within a few months after each cruise, samples were poured over nested 300µm and 63µm sieves, and each fraction was rinsed with fresh water into a petri dish. We sorted larvae under a dissecting microscope at 25X, with identification generally at 50X; some specimens required examination under a compound microscope at 100X. Individual larvae were manipulated with a fine paintbrush or short length (~5 mm) of human hair glued to the end of a wooden stick. Individuals were transferred with a pipette set to ~10µL. For examining under the compound microscope, individuals were transferred to a well slide filled with fresh water. We moved the cover slip gently side-to-side to roll the larva into an appropriate position for measuring and photographing. Larvae sorted from both sediment trap and pump samples were saved in 95% ethanol and stored in Lauren Mul-lineaux's laboratory at Woods Hole Oceanographic Institution. We do not recommend transfer from DMSO solution to ethanol for future studies because it apparently caused tissue degradation for polychaete larvae.

Some gastropod larvae were dried and imaged using scanning electron microscopy (SEM). These specimens were placed on 1.25cm diameter circular cover slips which had been previously coated with a thin layer of white Elmer's glue, which was allowed to dry. The small amount of ethanol clinging to specimens dissolved the glue enough to stick them in place. The cover slip with the specimen was then attached to a SEM stub and sputter-coated for 1 min using Samsputter. These were examined using the JEOL 840 scanning electron microscope at the Marine Biological Laboratory (MBL).

Species identifications were made using a variety of sources. For gastropod protoconchs we relied heavily on the literature, which contains detailed SEM photographs of protoconchs for many species from the EPR 9°N site. For species for which the protoconch is unknown, we occasionally would image the protoconch of an identified juvenile for comparison (e.g., *Gorgolettis spiralis*). For the identification of *Bythograea* sp. zoea, we are indebted to Ana Dittel (University of

Delaware), who examined one of our specimens. Our mussel larvae were all at a stage near to settling and could be directly compared to the shells of settled juveniles. For polychaete larvae, we were forced to use comparisons with newly settled juveniles or similarity to larvae of other, related species; thus, most of these could not be identified to species. Assignment of deep-sea polychaete larvae to species awaits development of molecular genetic probes (e.g., Pradillon et al., 2007).

Most of the photographs in this guide were taken through a Zeiss Axiostar compound microscope under brightfield, usually at 100X and occasionally only at 50X for larger specimens. For most of the photographs we used a Nikon D100 SLR digital camera with resolu-

tion 3008 x 2000 pixels and twelve bit dynamic range. We used an AF Zoom-NIKKOR 28-200mm lens and obtained the best images with F-stop 8, at shutter speed $\sim 1/125$ sec. Some photographs were taken with the same camera and a Zeiss Stemi 2000-C dissecting microscope. A few photographs were taken using a Zeiss Discovery.V12 Axiovision system dissecting microscope and Zeiss Axiocam MRC5 camera with Axiovision software at the MBL. The original images were adjusted using Adobe Photoshop software to enhance details.

For those who would like more information about methods of preserving, handling and storing small gastropods, we highly recommend Geiger et al. (2007).

This guide is intended to serve as a reference for the morphological identification of larvae collected near hydrothermal vents. In this first edition, the species are restricted to those found at EPR 9°N. However, in future editions of this guide, we would like to include hydrothermal vent larvae from other regions, and we encourage contributions to our website. To use this guide to identify larvae, we recommend using both a dissecting and compound microscope, each with a calibrated micrometer in the eyepiece.

Standard Description Format

Top line: Species name (or morphotype), family, and original reference for description of the species.

Photo panels: Light microscopy, followed by SEM for gastropod protoconchs and, often, dark field for polychaete larvae.

Additional references with photographs: listed below the photo panels.

Size: Provided for calibrated dissecting and compound microscopes.

Morphology: Gastropod protoconchs and polychaete larvae are described using standard terminology (see Terminology on next page). If the morphotype is not

identified to species, this section lists references to similar-looking species.

Frequency: For frequency designations, we used larval abundance data at EPR 9°N for on-axis, near-bottom pump samples from 1998-2000 (4 cruises, 4 locations, 12 samples; subset of data in Mullineaux et al., 2005) and 2004 (1 cruise, 1 location, 5 samples; Beaulieu et al., 2009), and one on-axis, near-bottom deployment of a time-series sediment trap from Nov. 2004 - Apr. 2005 (Adams, 2007). Trap frequency data are not available for polychaetes, as they are generally poorly preserved in the DMSO solution used in the traps.

We used four categories to describe the frequency of each species (or morphotype):

Common: Present in majority of samples, at relatively high abundance overall (i.e., >5%)

Frequent: Present in majority of samples, at relatively low abundance overall (i.e., <5%)

Occasional: Present in < 1/2 samples, at variable (usually low) relative abundance per sample

Rare: Present in very few samples, with only a single individual per sample.

“Can be confused with”: This section provides thumbnail photos of similar-looking species (or morphotypes), with comparisons of morphological features.

Using This Guide

Terminology

Gastropod terminology

With a few exceptions, we photographed the protoconchs in the apical view, with the aperture on the bottom right-hand side of the picture, as illustrated in the diagram below. This is the side that remains visible after the larva settles and begins post-larval growth, so the photos can be directly compared to juveniles and adults that have retained their protoconchs. The more proximal (“posterior”) portions are to the left in the diagram, the more distal (“anterior”) to the right. The axis of coiling is the point around which the coil of the shell rotates. Most of these larvae are planispiral, or nearly so, meaning that their coiling is more or less in one plane. This gives them a sort of pseudo-bilateral symmetry and we will sometimes refer loosely to the “base” (at the bottom left-hand side of the diagram) and the “height” of the shell, as well as to the “right” side (facing out of the page in the diagram), the “left” side (facing into the page in the diagram), the “bottom” (the view with the aperture facing out of the page) and the “top” (the view with the aperture facing into the page). Many of these protoconchs have an aperture rim; usually this is visible only with the light microscope.

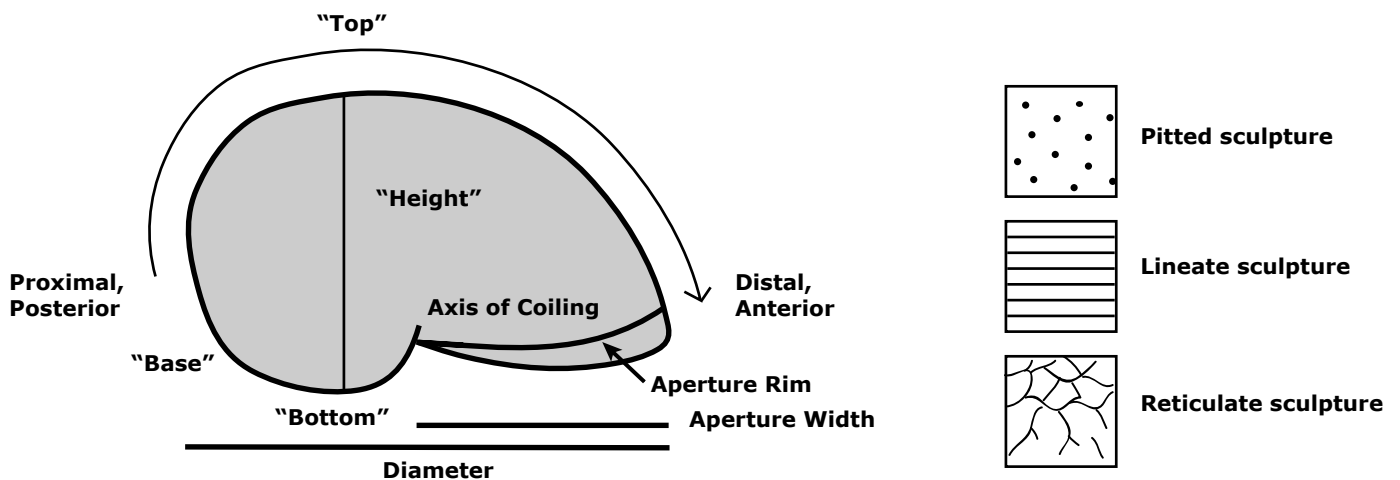
Most of these larvae have some form of sculpture on their shells. In the planispiral species, there are three types, with some degree of overlap:

Pitted sculpture, which is typical of the Family Lepetodrilidae, consists of depressions in the surface of the shell. These may be small or large, shallow or deep and may be widely scattered or so close together that the entire surface of the shell is pitted. Sometimes the pits may follow the curve of the shell, so that the sculpture appears to form lines. Pitted sculpture often appears grainy under the light microscope.

Lineate sculpture, found in the Family Peltospiridae, is a series of regularly-spaced ridges that follow the curvature of the shell. The lines usually start at the axis of coiling, though there are exceptions, and extend most of the way to the aperture. There may be other forms of sculpture present as well, such as tubercles - raised bumps - as found in *Lirapex granularis*.

Reticulate sculpture is formed by raised ridges, but instead of following the curvature of the shell, they spread out to form a mesh. This network may be very regular and interconnected or consist of relatively few irregularly forking lines. Sometimes the mesh covers the entire shell; more commonly it is limited to the more proximal portions of the shell. This kind of sculpture is found in the Neomphalidae.

Terminology for planispiral forms, with protoconch I. Apical view.

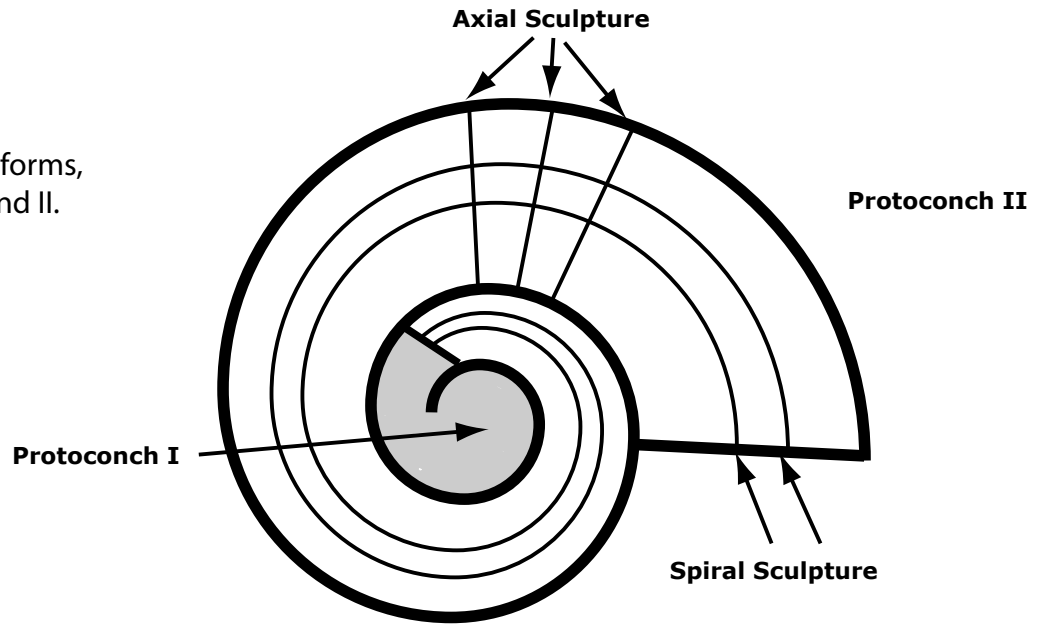


Terminology

For coiled forms we use slightly different terminology. These shells generally show two different growth stages, often with different types of sculpture. The earliest shell, protoconch I (PI), usually is formed while the larva is non-feeding, the second, protoconch II (PII) is formed after the larva begins feeding in the plankton. All of these shells are right-handed, meaning that when the shell is oriented with the apex at the top and the ap-

erture opening facing out of the page, the aperture will be to the right. Our photographs usually show both the apical view, to illustrate PI, and the aperture view, which shows the larva as it is usually found in samples. In these species, we refer to sculpture that follows the curvature of the shell as spiral and sculpture that radiates out from the axis of coiling as axial.

Terminology for coiled forms, with both protoconchs I and II. Apical view.

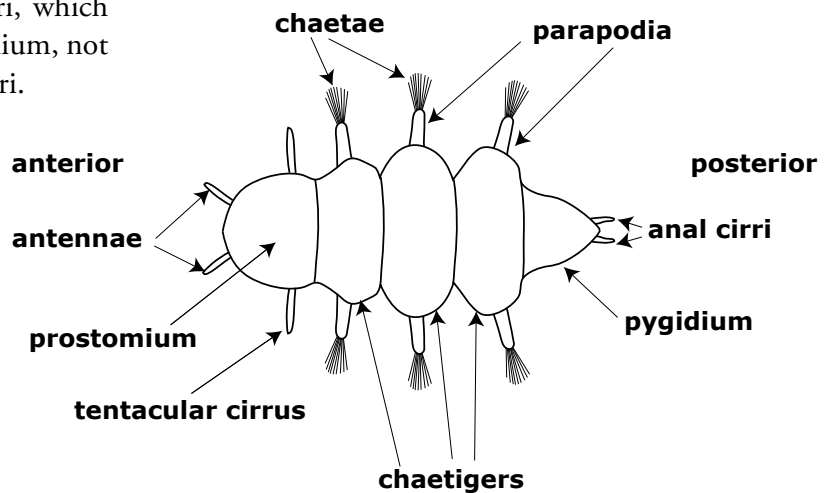


Polychaete Terminology

We are not qualified to give a detailed description of larval polychaete terminology, but for those unfamiliar with the group we have included definitions for a few of the standard terms. The first segment of a polychaete (the “head”) is called the prostomium; the final segment (“tail”) is the pygidium. The head may include appendages such as antennae (shown here) and palps and also one or more pairs of tentacular cirri, which are often on the second segment (the peristomium, not shown here). The pygidium may have anal cirri.

The main body segments often have fleshy, paired “feet” (parapodia) protruding to the sides, which have bunches of bristles (chaetae) at the tips. A body segment with chaetae is referred to as a chaetiger. Chaetigers may have cirri or branchiae (gills) as well (not shown in this diagram).

Terminology for polychaete larvae and juveniles. Dorsal view.



Can be confused with:

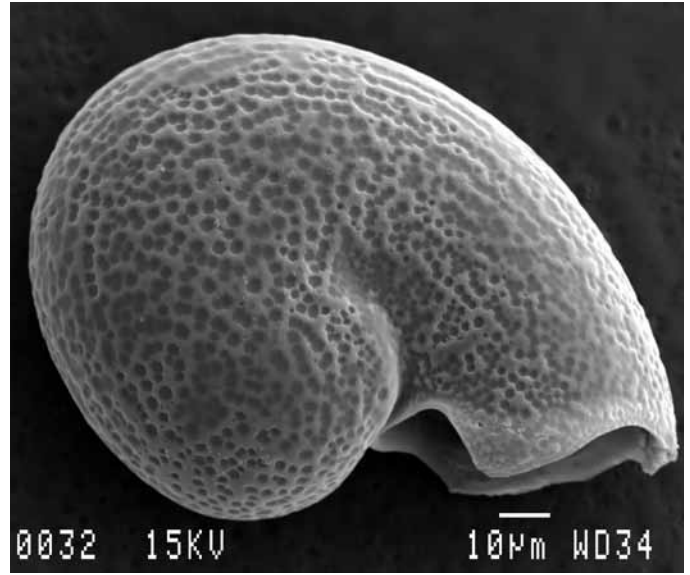
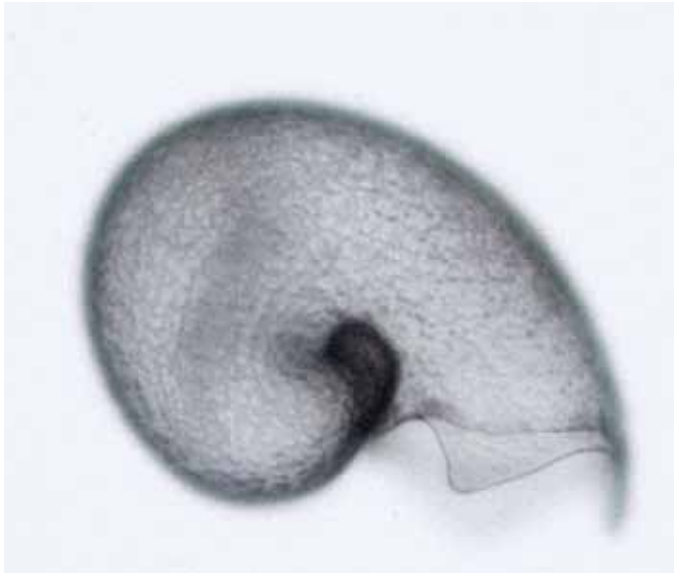


Gorgoleptis emarginatus strongly resembles *G. spiralis* in everything but size; *G. spiralis* is about 30µm smaller.



Gorgoleptis sp. 3. This presumed *Gorgoleptis* species is also about 30-35µm larger than *G. spiralis*. The point at the outer edge of the aperture is more pronounced in this group, it lacks the side points and is much less common.

Gorgoleptis spiralis McLean, 1988. Family Lepetodrilidae.



Size: 140-150µm

Morphology:

Gorgoleptis spiralis is one of three presumed *Gorgoleptis* morphs we find in plankton samples at EPR 9°N. It has coarse pitted sculpture in rows that follow the curve of the shell. The most distinctive feature of these protoconchs is the scalloped edges of the aperture, with sharp points at the anterior edge and on either side. There is a narrow aperture rim, tapering toward the posterior edge. The protoconch matches that of *Gorgoleptis spiralis* in size and sculpture, but the scallops are not preserved in post-larval specimens, making the identification somewhat tentative.

Frequency:

Pump EPR 1999-2000: Frequent

Pump EPR 2004: Frequent

Trap EPR 2004-2005: Frequent



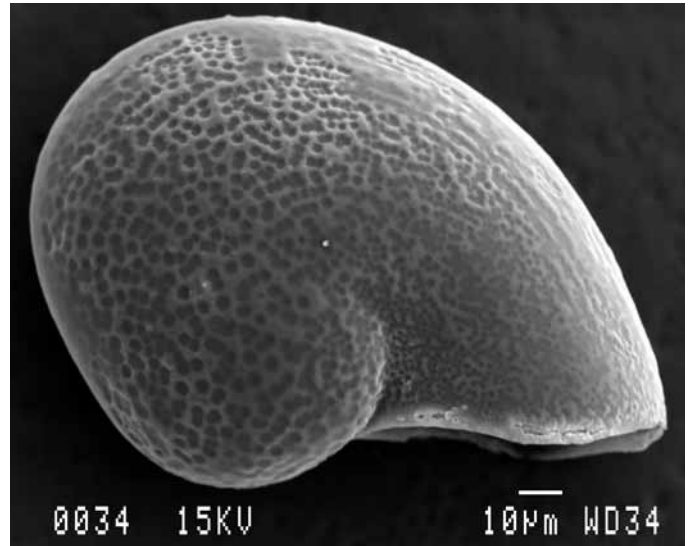
Clypeosectus delectus is about 25µm larger than *G. spiralis*. The sculpture is also very similar, but the aperture is nearly straight, rather than scalloped.



Pointy apex is about 10µm larger than *G. spiralis*. The sculpture is also very similar, but the aperture is nearly straight, rather than scalloped.

“Pointy apex” (unknown slit limpet in Mullineaux et al., 2005).

Family ?Lepetodrilidae.



Size: 155-160µm

Morphology:

These are small protoconchs with dense, shallow pitted sculpture over the entire shell, forming lines on the outer distal face. The shell itself is rather angular in overall appearance, with portions of the outline appearing almost flat. The aperture is slightly sinuous, with a narrow rim visible under the light microscope. The protoconch resembles *Sutilizona theca*, a slit limpet described from EPR 13°N in McLean (1989; SEM Fig. 4F).

Frequency:

Pump EPR 1999-2000: Frequent

Pump EPR 2004: Frequent

Trap EPR 2004-2005: Frequent

Can be confused with:



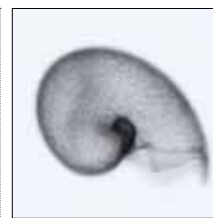
Clysossectus delectus is very similar in size and appearance to pointy apex. It is possible that both protoconchs represent different forms of the same species (or possibly

two species in the same genus), but because of consistent differences in their morphology, we have kept them separate for the present. Pointy apex can be distinguished by the more angular shape of this species, by its slightly smaller size (160µm vs. 175µm for *Clysossectus*) and by its narrower aperture rim.



Lepetodrilus spp. have finer pitted sculpture that doesn't usually show lineation. The base of the shell lines up with the aperture in these protoconchs,

whereas in pointy apex it protrudes below. Pointy apex is about 15-20µm smaller.



Gorgoleptis spp., especially *G. spiralis*, pictured at left. All *Gorgoleptis* species have a sharp point at the outer edge of the aperture, and two have points at the sides as

well. *Gorgoleptis spiralis* is slightly smaller than pointy apex; the other two *Gorgoleptis* species are about 20µm larger.

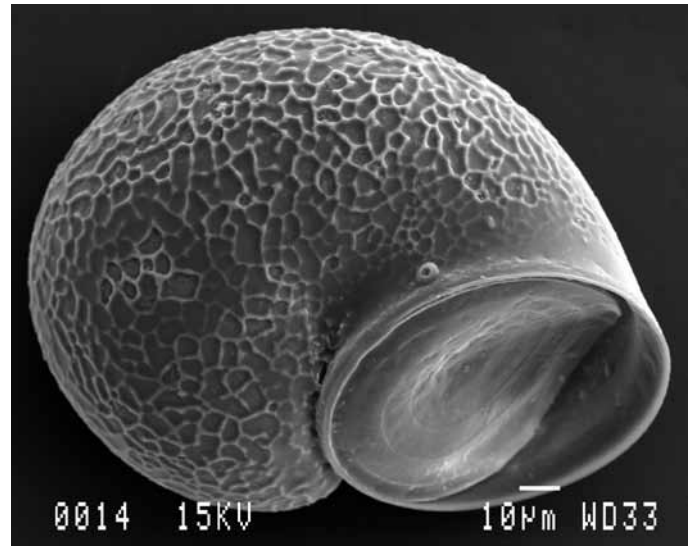
Unknown benthic sp. A Family ?Neomphalidae.



Size: 160-170 μ m

Morphology:

This is a small distinctive protoconch. Nearly all the vent protoconchs are planispiral, with a very slight right-hand twist. This one, however, has a distinct left-hand twist, so that if you try to set it on its left side in our standard orientation for photographing the protoconchs, it will roll to show the aperture, as in the SEM above. It has overall regular reticulate sculpture and may be a neomphalid.



Frequency:

Pump EPR 1999-2000: Common

Pump EPR 2004: Common

Trap EPR 2004-2005: Common

Can be confused with:

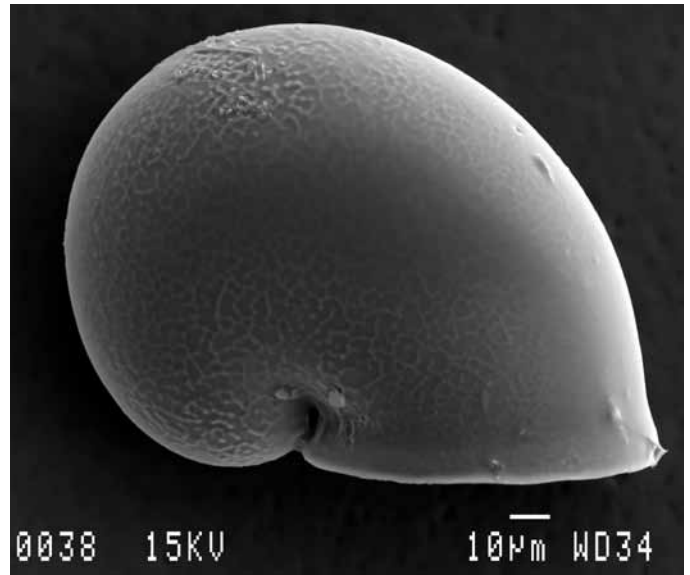
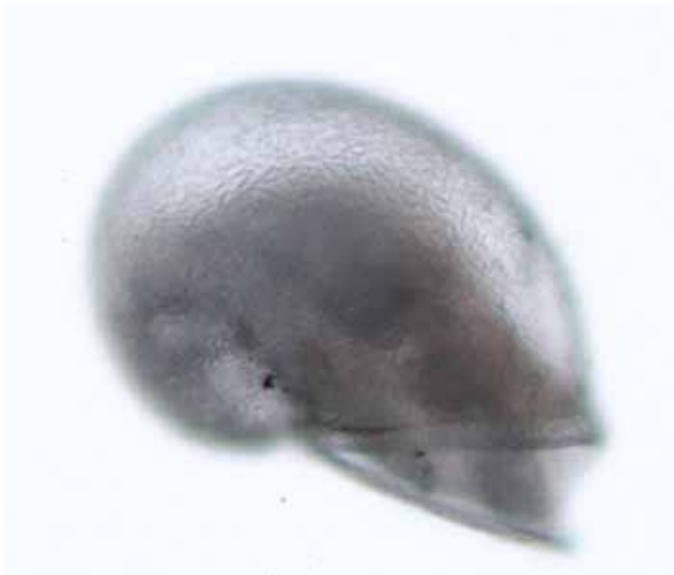


Unknown 5 looks very much like Unknown A, though it is about 10 μ m larger. It has a distinct flare to the aperture rim, which is wider than that of Unknown A. The easiest way to distinguish them quickly is to roll them; Unknown A will generally roll to expose the aperture, while Unknown 5 is stable on its side, as shown at left.



Lepetodrilus spp. is about 10 μ m larger than Unknown A. *Lepetodrilus* spp. has pitted sculpture rather than reticulate and is also stable on its side.

Unknown neomphalid 5 Family ?Neomphalidae.



Size: 170-180µm

Morphology:

This is a small bulbous protoconch with overall fine reticulate sculpture. It has a straight aperture with a narrow rim which flares out all around. Seen from the side, the aperture and the lowest part of the base line up. From this angle the aperture measures about 2/3 of the total diameter of the shell. It resembles some of the *Lacunoides* protoconchs in the literature (especially *L. vitreus* from Juan de Fuca; Warén and Bouchet, 2001, p.167, Figure 29e), but neither of the described species has been reported from EPR 9°N, to our knowledge. Because of the reticulate sculpture, we suspect that it is a neomphalid.

See also Fig. 4A in Mullineaux et al. (1996)

Frequency:

Pump EPR 1999-2000: Occasional

Pump EPR 2004: Common

Trap EPR 2004-2005: Common

Can be confused with:



Lepetodrilus spp. is the most likely to be confused with Unknown 5. They are of similar size, and in both the apertures are straight and line up with the base of the shell. In

Unknown 5, however, the aperture, when seen from the side, appears to take up about 2/3 of the shell diameter, whereas in *Lepetodrilus* it is about half. Unknown 5's aperture rim is narrower and it flares out to the sides and at the outer edge. *Lepetodrilus* has pitted sculpture rather than reticulate, but this is not usually obvious under the light microscope.



Unknown benthic sp. A is about 10µm smaller than Unknown 5, but is similar in appearance and also has reticulate sculpture. It has a slight left-hand twist, which tends to make it roll to

expose the aperture. Unknown 5, however, is stable resting on its side.



Clypeosectus delectus is similar in size to Unknown 5, but the aperture does not form a straight line with the base, and it has coarse pitted sculpture, rather than reticulate.

Can be confused with:



Unknown 5. *Lepetodrilus* spp. has a more streamlined appearance, with the aperture length about half the diameter of the protoconch. Unknown 5 is more rounded and

the aperture is closer to $\frac{2}{3}$ the protoconch diameter. The aperture rim is narrower in Unknown 5, and it flares out at the anterior edge and at the sides. Unknown 5 has reticulate rather than pitted sculpture, but this may not be apparent under the light microscope.



Gorgoleptis emarginatus is approximately the same size as *Lepetodrilus* spp. Its sculpture is much coarser, and it has points at the outer edge and both sides of the aperture, giving it

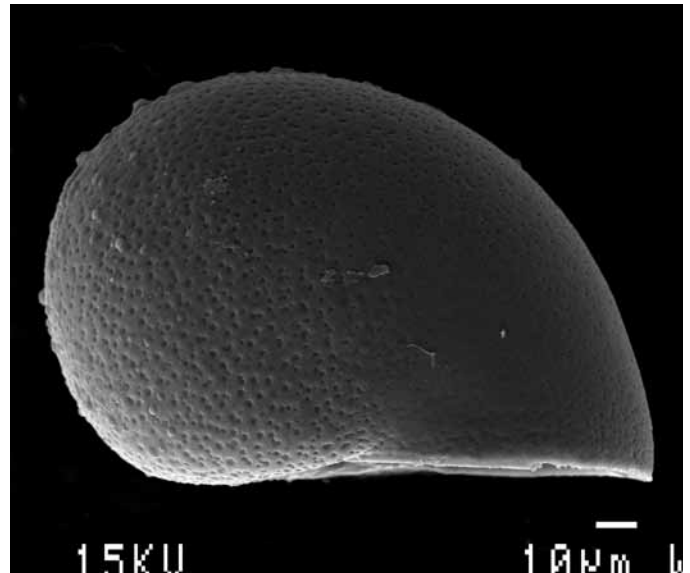
a scalloped appearance. The aperture does not line up with the base as it does in *Lepetodrilus*.



Gorgoleptis sp. 3 is also approximately the same size as *Lepetodrilus* spp. Its sculpture is much coarser, it has a point at the outer edge of the aperture. The aperture does not line up with

the base as it does in *Lepetodrilus*.

Lepetodrilus spp. Family Lepetodrilidae.



Size: 170-180μm

Morphology:

These are small protoconchs with fine pitted sculpture. In some individuals the pits appear to form lines, but this is not usually evident under the light microscope. The line of the aperture continues straight to the posterior edge of the shell in the apical view. There is a distinct medium-width aperture rim visible under the compound microscope. Five species of *Lepetodrilus* - *L. cristatus*, *L. elevatus*, *L. ovalis*, *L. pustulosus* (all described in McLean, 1988) and *L. tevnianus* McLean 1993, are present at EPR 9°N. All of these species have protoconchs that are similar in size and shape. Under the light microscope some individuals are nearly transparent (as shown above), while others are more opaque; it is possible that this is a taxonomically useful trait, but the species cannot be distinguished morphologically at this time.

See also Fig. 1 in Mullineaux et al. (1996)

Frequency:

Pump EPR 1999-2000: Common

Pump EPR 2004: Common

Trap 2004-2005: Common



Unknown benthic sp. A is about 10μm smaller than *Lepetodrilus* spp. and has reticulate rather than pitted sculpture. It tends to roll to expose the aperture when moved with a probe,

while *Lepetodrilus* is stable in the apical view.



Clypeosectus delectus has coarser sculpture than does *Lepetodrilus* spp., and its aperture does not line up with the base.



Lepetodrilus-like. There is a group of slightly larger protoconchs (~190-195μm) that closely resembles *Lepetodrilus* spp. We have termed them *Lepetodrilus*-like. They

have coarser pitted sculpture than *Lepetodrilus* spp., and the aperture is slightly curved, sometimes appearing to come to a blunt point in the front. They appear to lack an aperture rim.

Can be confused with:



Gorgoleptis emarginatus is approximately the same size as *Clypeosectus* and has similar sculpture. The chief distinction between the two genera is that *Gorgoleptis*

emarginatus has a sharp point at the anterior edge and sides of the aperture, giving it a scalloped appearance. If these points have been broken off, the curved remnants of the aperture rim can give a clue to their presence.



Gorgoleptis sp. 3 is approximately the same size as *Clypeosectus* and has similar sculpture. *Gorgoleptis* sp. 3 has a sharp point at the anterior edge of the aperture and apparently

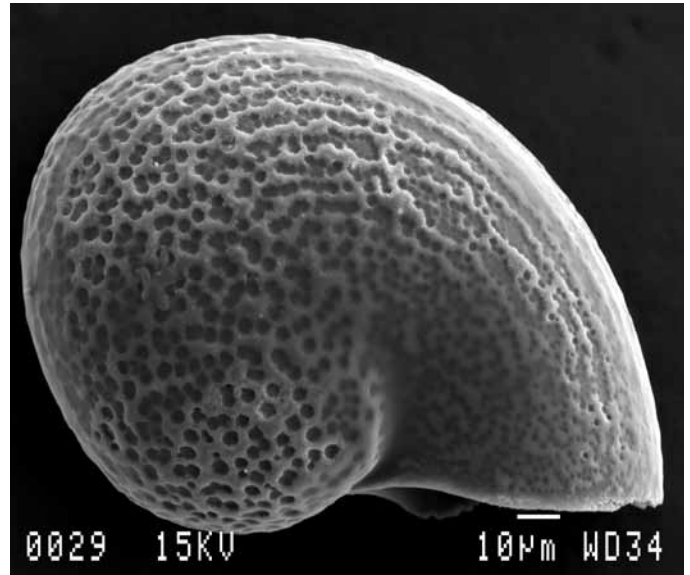
lacks an aperture rim.



Lepetodrilus-like. These are about 15-20µm larger than *Clypeosectus delectus*. Their sculpture is somewhat finer and does not show any lineation. Unlike *Clypeosectus*, their

apertures more or less line up with their bases, though the apertures themselves may be slightly curved. They appear to lack an aperture rim.

Clypeosectus delectus McLean, 1989. Family Lepetodrilidae.



Size: 170-180µm

See also Fig. 2 in Mullineaux et al. (1996), Fig. 10 in Turner et al. (1985), and p. 86 in Desbruyères et al. (2006; right photo shows the larva, left shows a juvenile with the protoconch visible)

Morphology:

Small protoconchs with coarse pitted sculpture in closely spaced rows, giving the effect of lineate sculpture. The aperture is slightly wavy, with a distinct medium-width rim visible under the compound microscope.

Frequency:

Pump EPR 1999-2000: Occasional
 Pump EPR 2004: Frequent
 Trap EPR 2004-2005: Occasional



Pointy apex is very similar to *Clypeosectus delectus*. It is possible that both protoconchs represent different forms of the same species (or possibly two species in the same



Lepetodrilus spp. is approximately the same size as *C. delectus*. The distinguishing features are that in *C. delectus* the line of the aperture does not line up with the posterior



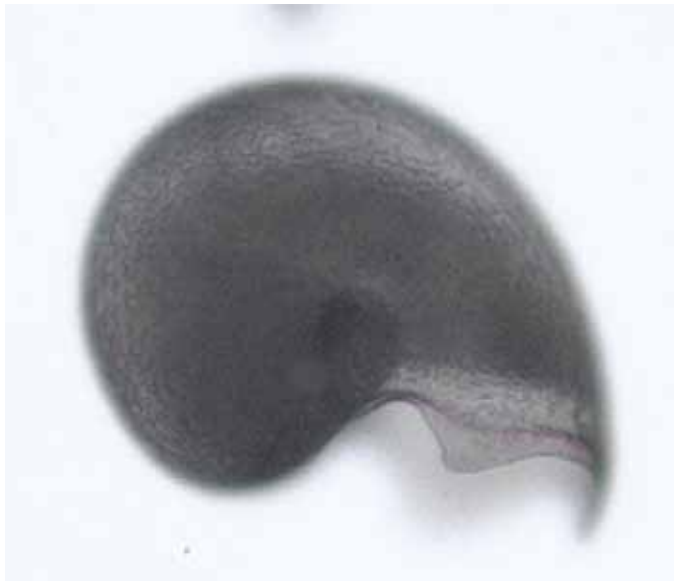
Unknown 5 is about the same size as *C. delectus*, but as for *Lepetodrilus*, the aperture and the base form a nearly straight line. The narrow aperture rim flares out

genus), but because of consistent differences in their morphology, we have kept them separate for the present. The chief differences between the two groups are that the sculpture of *C. delectus* is coarser, the shape of the shell is more rounded and the aperture rim is wider. The protoconch of *C. delectus* is also slightly larger (175µm vs. 160µm) than pointy apex.

portion of the shell, whereas in *Lepetodrilus* it forms a nearly straight line. The sculpture in *Lepetodrilus* is much finer and more widely spaced and usually doesn't show any obvious lineation under the dissecting microscope.

to the sides and at the outer edge. This species has reticulate, rather than pitted, sculpture.

Gorgolectis emarginatus McLean, 1988. Family Lepetodrilidae.



Size: 175-180µm

Morphology:

Gorgolectis emarginatus is one of three presumed *Gorgolectis* morphs we find in plankton samples at EPR 9°N. It has coarse pitted sculpture in rows that follow the curve of the shell. The most distinctive feature of these protoconchs is the scalloped edges of the aperture, with sharp points at the anterior edge and on either side. There is a narrow aperture rim, tapering toward the posterior edge. The protoconch matches that of *Gorgolectis emarginatus* in size and sculpture, but the scallops are not preserved in post-larval specimens, making the identification somewhat tentative.

See also Fig. 2 in Mullineaux et al. (1996)

Frequency:

Pump EPR 1999-2000: Occasional

Pump EPR 2004: Frequent

Trap EPR 2004-2005: Frequent

Can be confused with:



Gorgolectis spiralis is the most similar protoconch to *G. emarginatus*. In general appearance and sculpture the two are nearly identical, but *G. spiralis* is about 30µm

smaller.



Gorgolectis sp. 3 is approximately the same size as *G. emarginatus*, with similar sculpture. It has a more pronounced point at the outer edge of the aperture and lacks the

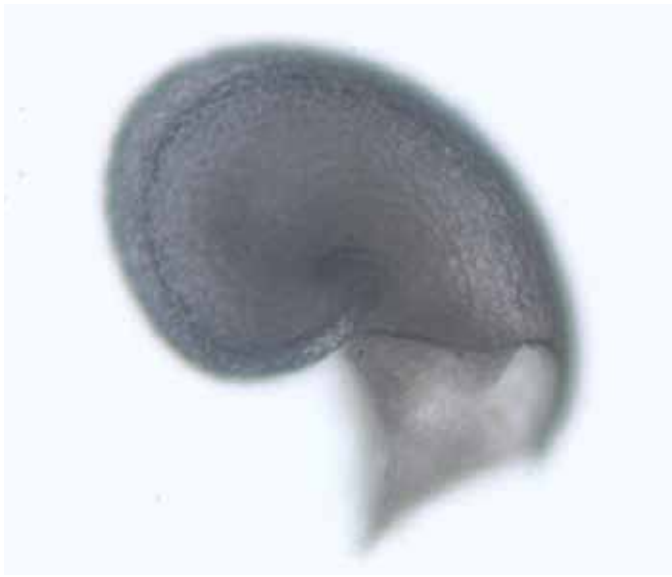
side points. It is also much less common.



Clypeosectus delectus is similar in size and sculpture to the *Gorgolectis* species. The main difference is in the shape of the aperture: all the *Gorgolectis* species have at least one

sharp point, whereas in *Clypeosectus* it is nearly straight.

Gorgolectis sp. 3 Family Lepetodrilidae.



Size: 180-185µm

Morphology:

This protoconch closely resembles the two *Gorgolectis* protoconchs in sculpture and is roughly the same size as *Gorgolectis emarginatus*. It differs from the others in having only a single sharp point at the anterior edge of the aperture, and the sides are sinuous rather than being scalloped. If it has an aperture rim, it is very narrow.

A third species of *Gorgolectis*, *Gorgolectis patulus* McLean, 1988, was described from the Galápagos Rift. Its protoconch is unknown, but it could be a possible candidate for this morph. The species has not been reported from EPR 9°N.

Frequency:

Pump EPR 1999-2000: Rare

Pump EPR 2004: Rare (1 individual collected off-axis)

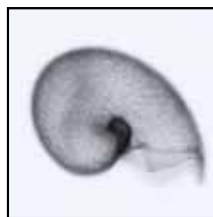
Trap EPR 2004-2005: Not collected

Can be confused with:



Gorgolectis emarginatus is nearly the same size as *Gorgolectis* sp. 3, being about 5µm smaller. It has points on the sides of the aperture, whereas *Gorgolectis* sp. 3's aperture is only slightly

wavy. *Gorgolectis emarginatus* is much more common.



Gorgolectis spiralis is about 35µm smaller than *Gorgolectis* sp. 3 and has side points on the aperture.



Clypeosectus delectus is similar in size and sculpture to the *Gorgolectis* species. The main difference is in the shape of the aperture: *Gorgolectis* sp. 3 has a sharp point at the outer

edge, whereas in *Clypeosectus* it is nearly straight.

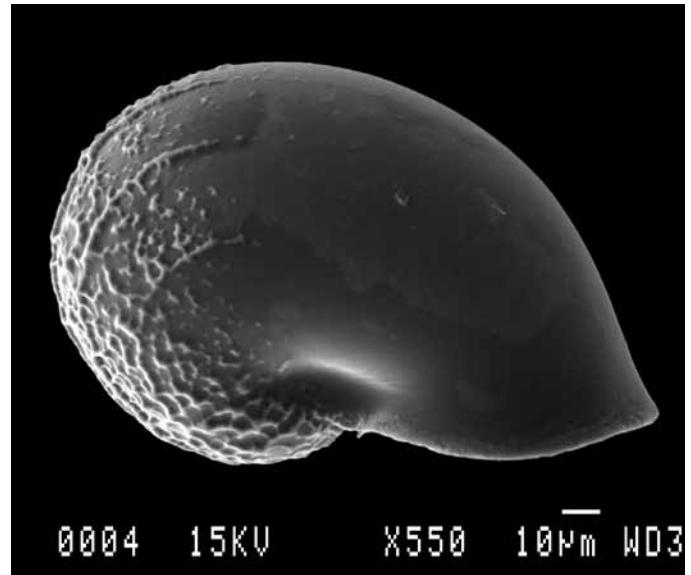
Unknown 7. Family Unknown.



Size: 180-190 μ m

Morphology:

This is a small protoconch with sculpture consisting of a coarse raised network of reticulate sculpture overlain by five widely spaced lines. These lines are difficult to see with the light microscope, but show up clearly in the SEM. The anterior portion of the shell is smooth. The aperture is slightly sinuous and flared at the anterior edge and it has a medium-width rim, tapering toward the posterior.



Frequency:

Pump EPR 1999-2000: Occasional

Pump EPR 2004: Occasional

Trap EPR 2004-2005: Not collected

Can be confused with:



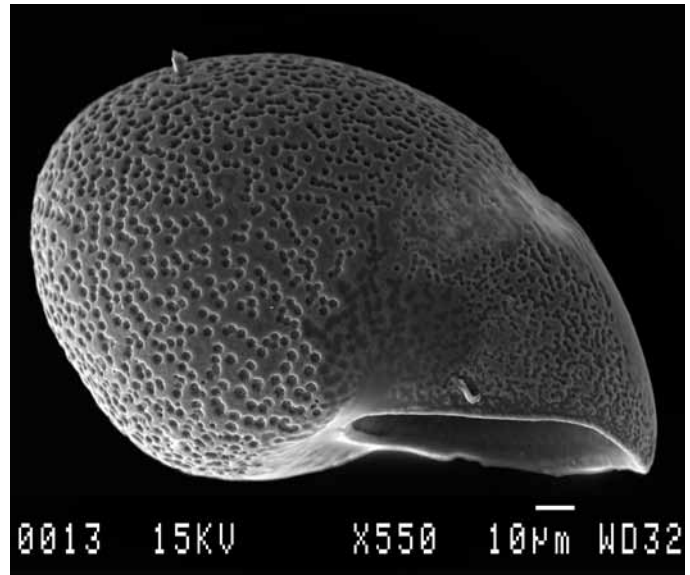
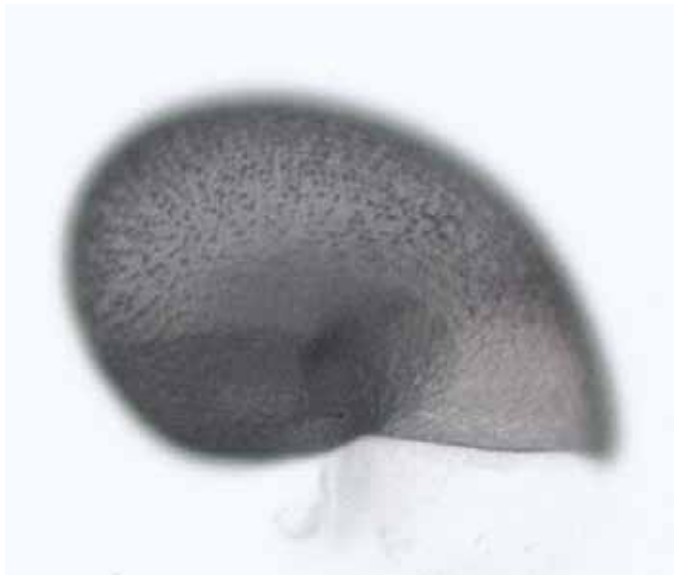
Unknown 7 is most likely to be confused with Unknown 9, which has a similar type of sculpture. Unknown 9 is slightly larger and some of its lineate sculpture extends all the way to the aperture, whereas all five lines in Unknown 7 stop well short of the aperture. Unknown 9 is also shorter in height for its diameter than Unknown 7. The approximate

height:diameter figures are 110:190 μ m for Unknown 9 and 125:180 μ m for Unknown 7.



Unknown 7's sculpture and size are similar to that of Unknown 8. Unknown 8 has more closely spaced lines, and it is also greater in height for its diameter than Unknown 7. The approximate height:diameter figures are 135:190 μ m for Unknown 8 and 125:180 μ m for Unknown 7.

Lepetodrilus-like protoconchs Family ?Lepetodrilidae.



Size: 185-200µm

Morphology:

Lepetodrilus-like protoconchs are quite similar in general appearance to *Lepetodrilus* spp. They are slightly larger and have coarser pitted sculpture. The aperture is slightly curved and comes to a blunt point at the outer edge. There appears to be no aperture rim.

Frequency:

Pump EPR 1999-2000: Occasional
 Pump EPR 2004: Occasional
 Trap EPR 2004-2005: Occasional

Can be confused with:



These protoconchs are most likely to be confused with *Lepetodrilus* spp. *Lepetodrilus* spp. are slightly smaller (170-180µm) and have a straight aperture, which

forms a line with the base of the shell. They also have an aperture rim, which this group lacks.



Gorgolettis emarginatus (upper) and *Gorgolettis* sp. 3 (lower). Both species are slightly smaller (175-185µm) and have pitted sculpture, as does this species. The most obvious difference is that both *Gorgolettis* have sharp points at the outer edge of the aperture (and *G. emarginatus* has scallops on the sides as well),

whereas *Lepetodrilus*-like protoconchs have only a blunt point on the distal edge.



Clypeosectus delectus is smaller (170-180µm) and has an aperture rim. In *Clypeosectus* and *Gorgolettis*, the pitted sculpture often appears to form lines, which has not been seen in the

Lepetodrilus-like protoconchs.

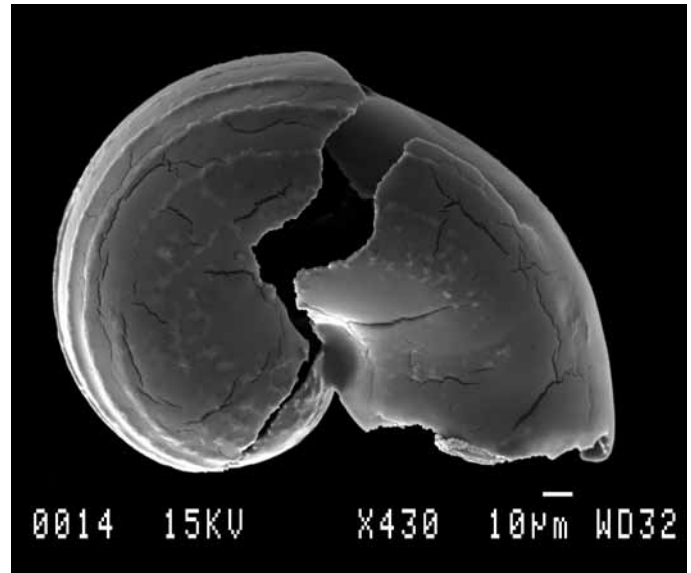
Unknown 8. Family Unknown.



Size: 190-200 μ m

Morphology:

This is a rather fragile protoconch, generally found with at least the aperture damaged. It is very rounded in appearance, with regularly spaced lines extending about 3/4 of the way to the aperture. There is some hint of sparse reticulate sculpture on the sides and base. The aperture is probably sinuous, and we have seen no evidence of a rim. This protoconch resembles several in the family Skeneidae; for example, see Warén and Bouchet (1993; Fig. 23, A & C) for images of the protoconchs of *Xyloskenea costulifera* Marshall, 1988, from deep-sea wood falls and *Ventsia tricarinata* Warén and Bouchet, 1993, from the Lau Basin.



Frequency:

Pump EPR 1999-2000: Rare

Pump EPR 2004: Rare

Trap EPR 2004-2005: Not collected

Can be confused with:



Unknown 8's sculpture and size are similar to that of Unknown 7. Unknown 7 has only five lines that are more widely spaced than those on Unknown 8. It is also shorter in height for its diameter than Unknown 8. The approximate height:diameter figures are 135:190 μ m for Unknown 8 and 125:180 μ m for Unknown 7.

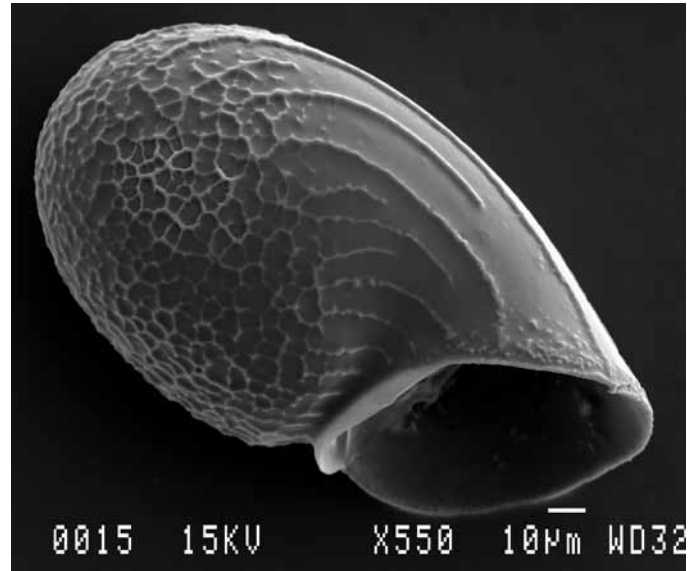
Unknown 9. Family Unknown.



Size: 190-210 μ m

Morphology:

This protoconch has a short stretch of lineate sculpture at the axis of curvature which then spreads out into an area of interconnected reticulate sculpture that covers the proximal 1/3 of the shell. From this point a few lines extend toward the aperture, most stopping well short of it, but a few reaching all the way. The aperture is roughly circular and is only about 1/3 of the diameter of the shell. There appears to be a narrow aperture rim, surrounded by a wider region of stippling, possibly a continuation of the reticulate sculpture.



Frequency:

Pump EPR 1999-2000: Not collected on axis

Pump EPR 2004: Rare

Trap EPR 2004-2005: Not collected

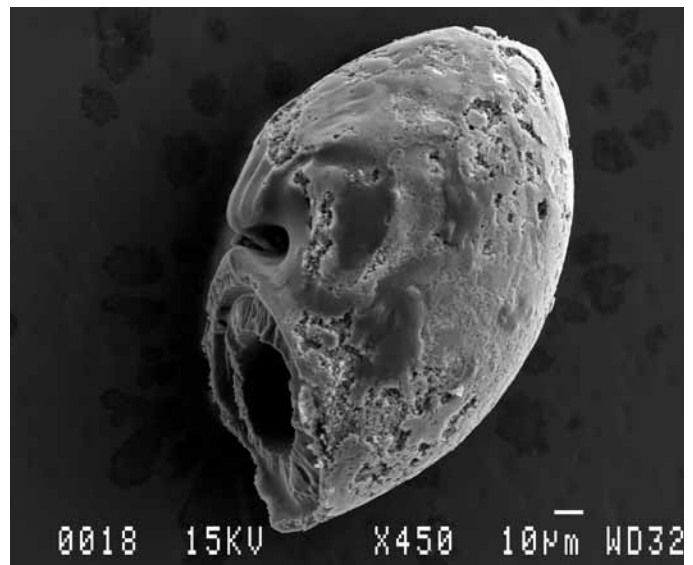
Can be confused with:



Unknown 9 is most likely to be confused with Unknown 7, which has a similar type of sculpture. Unknown 9 is slightly larger and some of its lineate sculpture extends all the way to the aperture, whereas all five lines in Unknown 7 stop well short of the aperture. Unknown 7 is greater in height for its diameter than Unknown 9. The approximate height:diameter figures are

110:190 μ m for Unknown 9 and 125:180 μ m for Unknown 7.

Echinopelta fistulosa McLean, 1989. Family Peltospiridae.



Size: 210-220µm

Morphology:

This group is quite angular in appearance and has the lines beginning on a raised platform at the base of the shell. In this form the lines become indistinct for most of the shell. The aperture is slightly flared and has a narrow rim. We believe this morphotype corresponds to *Echinopelta fistulosa*, which has the same raised platform on the base (see SEM photo at right of a protoconch broken off a juvenile *E. fistulosa*).

Frequency:

Pump EPR 1999-2000: Frequent (but combined with unknown peltospirid 240µm)

Pump EPR 2004: Frequent

Trap EPR 2004-2005: Occasional

Can be confused with:



Lirapex granularis is approximately 10µm larger and lacks the raised platform at the base. It also has tubercles at the posterior end in addition to the lineate

sculpture.



Peltospira sp. is slightly larger and less angular in appearance than *Echinopelta*. It also does not have the raised platform at the base.



Unknown peltospirid 240µm is similar in outline but is approximately 30µm larger in diameter and does not have the raised platform at the base.

Can be confused with:



Lirapex granularis is approximately the same size as *Peltoospira*, but is greater in height for its diameter. It also has tubercles at the posterior end in addition to the lineate

sculpture.



Echinopelta fistulosa is slightly smaller and more angular in appearance than *Peltoospira*. It also has a raised platform at the base where the lines begin.



Unknown peltospirid 240µm is greater in height for its diameter, which is approximately 20µm larger than that of *Peltoospira*.

Peltospira spp. Family Peltospiridae.



Size: 210-220 μ m

Morphology:

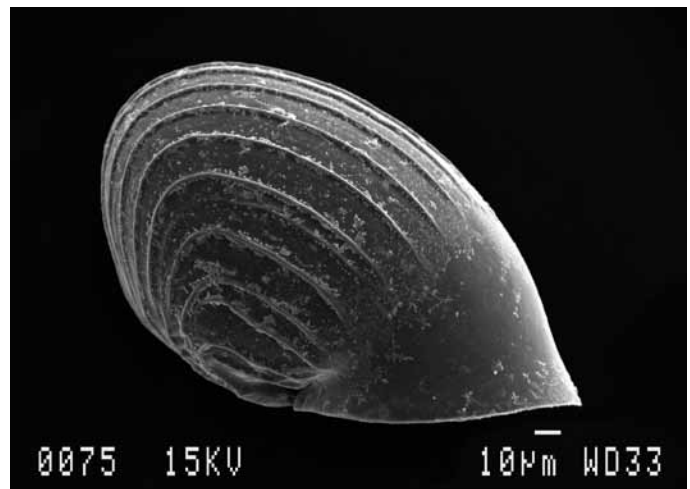
This protoconch has approximately 16-18 lines, beginning in a V at the axis of coiling and following the curvature of the shell, stopping abruptly at the same point about 2/3 of the way to the aperture. The aperture is perfectly circular when viewed from the bottom and is surrounded by a narrow rim which flares out to the sides when viewed from the top. It looks more streamlined than most peltospirids, since it is shorter for its diameter and the base is more smoothly rounded. It matches the SEM of *Peltospira operculata* in Mullineaux et al. (1996) in size and general appearance, but is also very similar to the *Nodopelta subnoda* protoconch SEM in Desbruyères et al. (2006; p. 117). Molecular work is ongoing and may help to resolve the issue. In the meantime, we have attributed this protoconch to *Peltospira*, as it is the most common genus at EPR 9°N. There are at least two species of *Peltospira* present at EPR 9°N: *Peltospira delicata* McLean, 1989, and *Peltospira operculata* McLean, 1989. A third species, *Peltospira lamellifera* Warén & Bouchet, 1989, has been described from 13°N and may also be at 9°N.

Frequency:

Pump EPR 1999-2000: Occasional

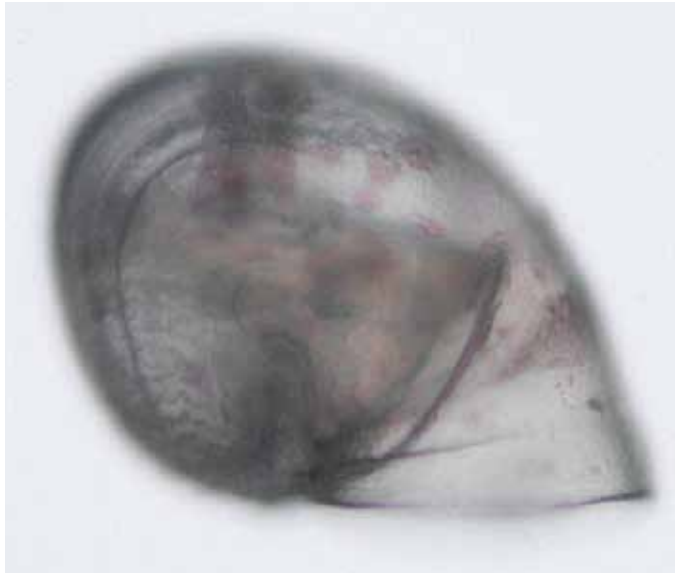
Pump EPR 2004: Occasional

Trap EPR 2004-2005: Not collected



See also Fig. 3 in Mullineaux et al. (1996)

Lirapex granularis Warén & Bouchet, 1989. Family Peltospiridae.



Size: 215-220µm

Morphology:

Lirapex has an unusual type of sculpture consisting of the lineate sculpture typical of peltospirids with numerous tubercles between them, especially near the axis of coiling. Both fade out about halfway to the aperture. When viewed from the bottom under the light microscope, a thick bar running across the shell is visible just posterior to the aperture. The aperture is nearly straight, with a wide rim tapering toward the posterior. The shell is transparent and glassy-looking.

Frequency:

The species was described from EPR 21°N and has been reported from 9°N, though adults are rarely collected there.

Pump EPR 1999-2000: Occasional

Pump EPR 2004: Occasional

Trap EPR 2004-2005: Occasional



See also Fig. 3 in Mullineaux et al. (1996) and p. 115 in Desbruyères et al. (2006)

Can be confused with:



Peltospira spp. is similar in size to *Lirapex*. However, *Peltospira* is more streamlined in appearance and doesn't have tubercles or the bar posterior to the aperture.



Echinopelta fistulosa is similar in size to *Lirapex*; however, it is about 10µm smaller, more angular in appearance, has a raised platform at the base and no tubercles.



Unknown peltospirid 240µm closely resembles *Lirapex* in general morphology, but does not have tubercles and is slightly larger.

Can be confused with:



Peltospira spp. is about 20µm smaller than Unknown peltospirid 240µm and is more streamlined in general appearance, being less in height for its diameter.



Echinopelta fistulosa is about 30µm smaller and is more angular in appearance. It also has a raised platform at the base where the lines begin.

Unknown peltospirid 240 μ m Family ?Peltospiridae.



Size: 230-240 μ m

Morphology:

This is another possibly heterogeneous group of protoconchs. They are slightly larger than the “*Peltospira*” group and are taller for their diameter, although not as angular as *Echinopelta fistulosa*. The sculpture begins at the axis of curvature and continues about 2/3 of the way to the aperture, which is slightly flared. From below it closely resembles *Peltospira* sp., though it is slightly wider for its diameter. The aperture rim is similar in width to *Lirapex granularis*, wider than in the other peltospirid forms. It may be that the ratio of the diameter to the height will be useful in distinguishing the forms.

Frequency:

Pump EPR 1999-2000: Frequent (but combined with 210 μ m size class)

Pump EPR 2004: Frequent

Trap EPR 2004-2005: Occasional

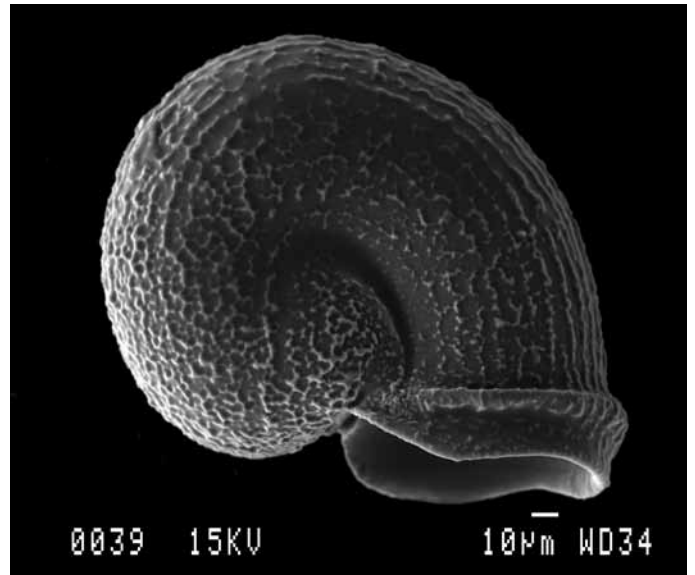


Unknown neomphalid W is quite similar in general appearance and size. The easiest way to distinguish the two is to look at the sculpture - Unknown neomphalid W has reticulate sculpture instead of lineate.



Lirapex granularis is about 20 μ m smaller than Unknown peltospirid 240 μ m and has tubercles at the base as well as lineate sculpture.

Unknown neomphalid B Family ?Neomphalidae.



Size: 230-240µm

Morphology:

These protoconchs are moderately large and very distinctive. They have reticulate sculpture over the entire shell, more or less disorganized at the base, but becoming regularly spaced lines toward the aperture. The aperture is slightly sinuous and has a distinct ridge above it. We have not been able to match them with a known vent species, but have tentatively assigned them to Neomphalidae because of their reticulate sculpture and similarity to other neomphalids.

Frequency:

Pump EPR 1999-2000: Rare
 Pump EPR 2004: Not collected
 Trap EPR 2004-2005: Occasional

Can be confused with:



This group is most likely to be confused with one of the *Melanodrymia* species which they superficially resemble in morphology and size. *Melanodrymia aurantiaca* has finer

reticulate sculpture with no lineation and a more gradual bump above the aperture, rather than a raised ridge.



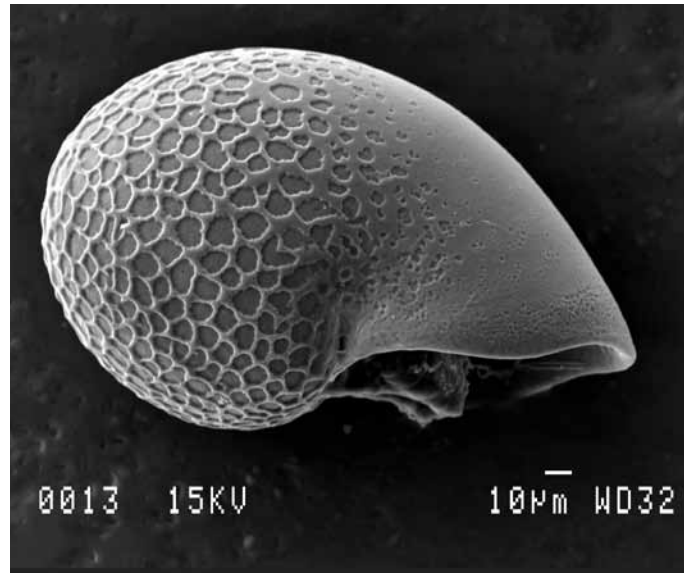
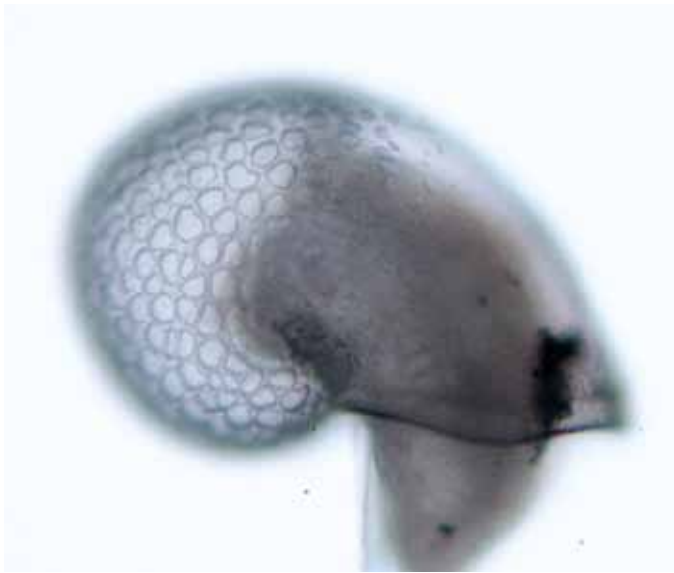
Melanodrymia galeronae also has finer and more irregular reticulate sculpture and no lineation. It lacks either a ridge or a bump above the aperture, which is more sinuous than that

of Unknown neomphalid B.



Unknown neomphalid 290µm is about 50µm larger and lacks the ridge above the aperture. Its sculpture is similar near the base, but does not form regular lines distally.

Cyathermia naticoides Warén & Bouchet, 1989. Family Neomphalidae.



Size: 230-240µm

Morphology:

Cyathermia naticoides has a moderately large protoconch. The posterior is covered by coarse reticulate sculpture which gives the appearance of bubbles under the light microscope. The anterior portion is smooth. The aperture is slightly sinuous and there is a medium-width rim.

Frequency:

Pump EPR 1999-2000: Common

Pump EPR 2004: Common

Trap EPR 2004-2005: Common

Can be confused with:



The protoconchs can be easily confused with those of *Neomphalus fretterae*, although the adults look quite different. The chief differences between the two are that *Neomphalus* has finer reticulate sculpture and the outer edge flares out at the aperture. The aperture rim is wider in *Neomphalus* than in *Cyathermia*, tapering toward the posterior edge.

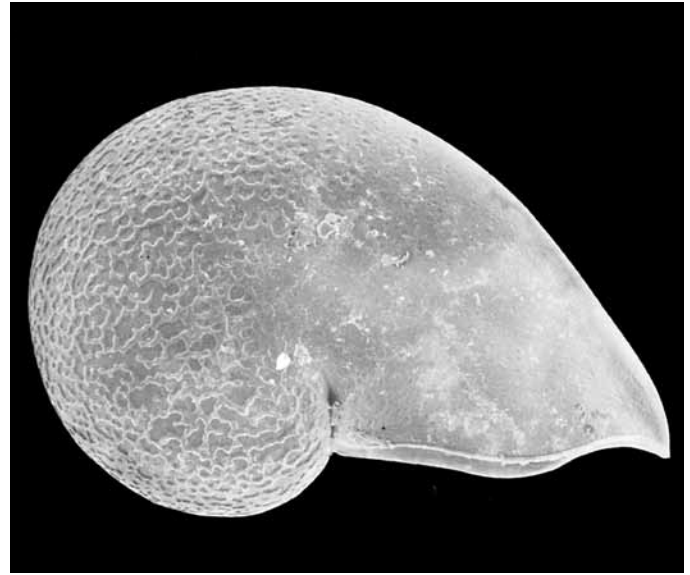
Neomphalus fretterae McLean, 1981. Family Neomphalidae.



Size: 240-250µm

Morphology:

Neomphalus fretterae has a moderately large protoconch with reticulate sculpture over the proximal half of the shell. The distal half is smooth, with the outer edge flaring out above the aperture. The aperture is sinuous and there is a wide rim, tapering toward the inner edge, which is visible under the light microscope.



The SEM above is Fig. 2D in Mullineaux et al. (1996), with kind permission of Springer Science and Business Media.

Frequency:

Pump EPR 1999-2000: Frequent
 Pump EPR 2004: Frequent
 Trap EPR 2004-2005: Frequent

Can be confused with:



The species that *Neomphalus fretterae* is most likely to be confused with is *Cyathermia naticoides*, as both are the same size and very similar in appearance. The main differences are that *Neomphalus fretterae* has finer reticulate sculpture, a flare at the outer edge of the aperture and the aperture rim is about twice as wide.

Can be confused with:



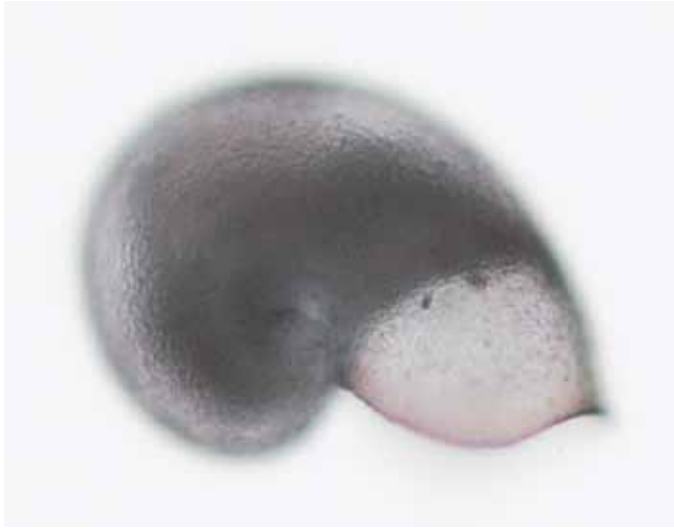
Unknown neomphalid sp. B. This protoconch is very similar in size and general appearance. However, it has a thin ridge that parallels the aperture, forming a distinct rim. The aperture is straighter in this species and the sculpture is stronger and more regular, forming distinct rows at the anterior end of the shell.



Bathymargarites symplector. This protoconch is similar in general appearance, but is much larger (~350µm) and lacks the overall reticulate sculpture.

Melanodrymia ?galeronae Warén & Bouchet, 2001.

Family Neomphalidae.



Size: 240-250µm

Morphology:

This is a moderately large protoconch with overall fine reticulate sculpture. The anterior edge flares at the aperture, which is strongly sinuous.

Frequency:

Pump EPR 1999-2000: Rare

Pump EPR 2004: Not collected

Trap EPR 2004-2005: Rare



Melanodrymia ?galeronae is most likely to be confused with its congener, *Melanodrymia aurantiaca*. The protoconchs are very similar in size and general appearance. However, the sculpture is finer on *M. ?galeronae*, the aperture is less strongly sinuous and it lacks the distinct bump above the aperture.



Unknown neomphalid 290µm. This protoconch is very similar in general appearance and sculpture and may well be an undescribed *Melanodrymia* species. It is, however, larger (290µ against 250µm) and the aperture is more deeply sinuous, as well as flaring out more at the outer edge.

Neolepetopsis spp. Four species (McLean, 1990). Family Neolepetopsidae.



Size: 240-260µm

Morphology:

This protoconch is moderately large and has fine pitted sculpture over the entire surface, giving it a grainy appearance under the light microscope. It is flattened, so it will generally be found lying with the aperture down, and there are deep indentations at the sides of the aperture. From above, the outline of the shell is oval (photo above, left), but when viewed from the side the back of the shell comes to a blunt point, as if it had been compressed from the sides. The morphology and size match *N. densata*, the only species for which the protoconch is known and it is the most likely candidate based on adult habitat (it is found at 13°N and the other species are from 21°N or Gorda Ridge), but we cannot eliminate the other possibilities.



See also SEM in Warén & Bouchet, 2001, p. 144 (Fig.15a-c).

Frequency:

Pump EPR 1999-2000: Not collected
 Pump EPR 2004: Not collected
 Trap EPR 2004-2005: Rare

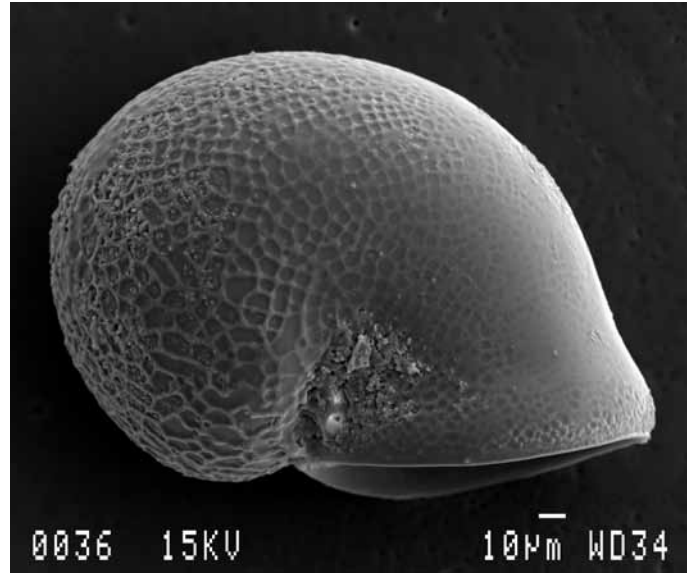
Can be confused with:



The only other protoconch this is likely to be confused with is *Eulepetopsis vitrea*, in the same family. Their sizes and general appearance are similar and they both have the deep indentations at the sides of the aperture. However, viewed from above, the base of *Neolepetopsis* is oval, while that of *Eulepetopsis* is indented where the

aperture meets the base. In the apical view, the posterior portion of *Eulepetopsis* is smoothly rounded, but *Neolepetopsis* comes to a point, as mentioned above.

Pachydermia laevis Warén & Bouchet, 1989. Family Neomphalidae.



Size: 245-250µm

Morphology:

Pachydermia laevis has a moderately large protoconch with regular overall interconnected reticulate sculpture, strongly marked in the proximal region and becoming finer and less distinct toward the aperture. The aperture is slightly curved with a thickened broad rim that tapers slightly toward the inner edge.

Frequency:

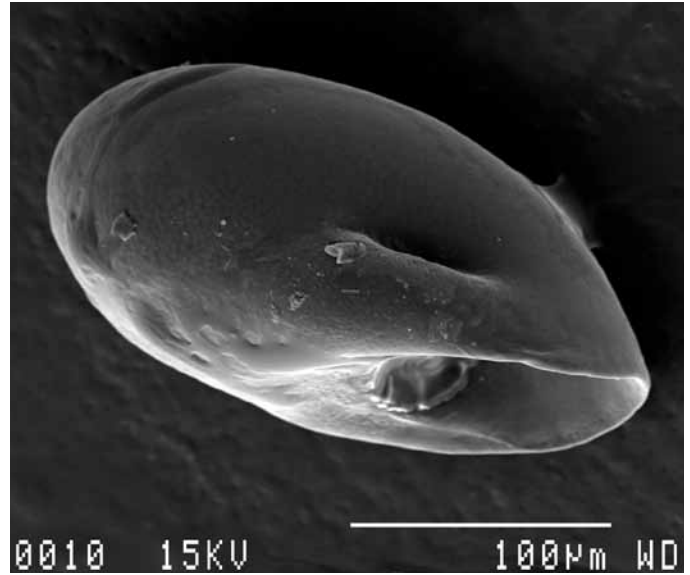
Pump EPR 1999-2000: Frequent
 Pump EPR 2004: Frequent
 Trap EPR 2004-2005: Occasional

Can be confused with:



Pachydermia laevis is most likely to be confused with Unknown neomphalid W, as they are approximately the same size and both have reticulate sculpture. However, Unknown neomphalid W lacks the thickened aperture rim and its sculpture is coarser and less regular and is limited to the proximal half of the shell.

Eulepetopsis vitrea McLean, 1990. Family Neolepetopsidae.



Size: 245-250µm

Morphology:

This is a moderately large protoconch, with shallow, coarse pitted sculpture over the entire shell, giving it a grainy appearance under the light microscope. The shell is dorsoventrally flattened, so it is usually found either with the aperture facing down or lying at an angle with the aperture visible. The posterior portion of the aperture flares out from the body, forming a deep indentation on both sides. The posterior of the shell is smoothly rounded.

Frequency:

Pump EPR 1999-2000: Frequent
 Pump EPR 2004: Frequent
 Trap EPR 2004-2005: Occasional

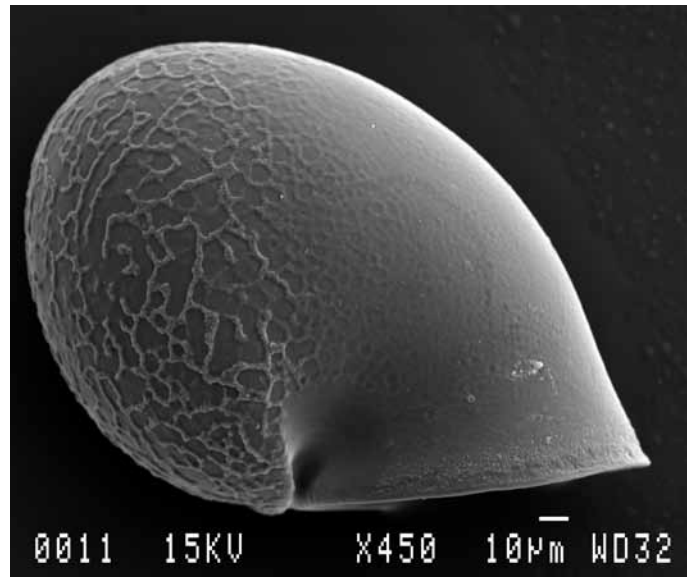
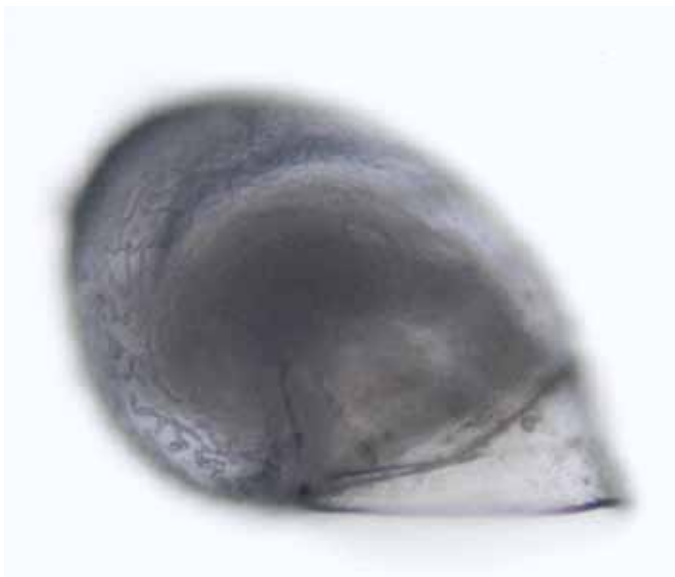
Can be confused with:



The only protoconch that is likely to be confused with *Eulepetopsis vitrea* in our samples is another genus in the same family, *Neolepetopsis* sp. Both protoconchs are about the same size and similar in appearance. However, the posterior edge of *Neolepetopsis* is slightly flattened laterally, giving it a more pointed look. This is best seen when viewed from the side. Viewed from above, the *Neolepetopsis* protoconch is oval, whereas that of *Eulepetopsis* is indented behind the aperture.



Unknown neomphalid W Family Neomphalidae.



Size: 250-260µm

Morphology:

This is a moderately large protoconch with coarse reticulate sculpture over the proximal half of the shell. Under the dissecting microscope the sculpture sometimes appears lineate and the general outline of the shell is typical of peltospirids, but the reticulate sculpture is easily visible under the compound microscope. The aperture is straight and there is a wide rim, tapering toward the posterior edge of the aperture, visible under the light microscope. Warén & Bouchet, 1989, described a species with a very similar protoconch as *Depressigyra planispira* (later amended to *Planorbidella planispira*), but since later specimens of this species appear to have a different protoconch (A. Warén, pers. comm.), we have kept our original designation.

Frequency:

Pump EPR 1999-2000: Frequent
 Pump EPR 2004: Frequent
 Trap EPR 2004-2005: Occasional

Can be confused with:



Pachydermia laevis. Unknown neomphalid W lacks the thickened aperture rim and its sculpture is coarser, less regular and limited to the proximal portion of the shell.



Unknown peltospirid 240µm is similar in size and shape, but has lineate sculpture, instead of reticulate. This may not be obvious viewed from the side, but when viewed from the top, the edges of the lines can be seen if lineate sculpture is present.

Can be confused with:



Melanodrymia aurantiaca is most likely to be confused with its congener, *Melanodrymia ?galeronae*. The protoconchs are very similar in size and general appearance. However, the sculpture is finer on *M. ?galeronae*, the aperture is less deeply sinuous and it lacks the distinct bump above the aperture, instead having a gentle curve which ends in a flare at the aperture.



Bathymargarites symplector. This protoconch is similar in general appearance, but is much larger (~350µm) and lacks the overall reticulate sculpture.

Melanodrymia aurantiaca Hickman, 1984. Family Neomphalidae.



Size: 250-260µm

Morphology:

Melanodrymia aurantiaca has a moderately large protoconch entirely covered with irregular reticulate sculpture, giving it a grainy appearance when viewed under a light microscope. The aperture is deeply sinuous and there is a broad ridge or bump at the anterior edge of the shell above the aperture.

Frequency:

Pump EPR 1999-2000: Frequent
 Pump EPR 2004: Frequent
 Trap EPR 2004-2005: Occasional



Unknown neomphalid sp. B. This protoconch is very similar in size and general appearance. However, instead of having a thick bump at the anterior edge, it has a narrow ridge that parallels the aperture, forming a distinct rim. The aperture is much straighter in this species and the sculpture is stronger and more regular, forming distinct rows at the anterior end of the

shell.



Unknown neomphalid 290µm. This protoconch is very similar in general appearance and sculpture and may well be an undescribed *Melanodrymia* species. It is, however, larger (290µm against 260µm) and the aperture is more deeply sinuous, as well as flaring out at the outer edge.

Can be confused with:

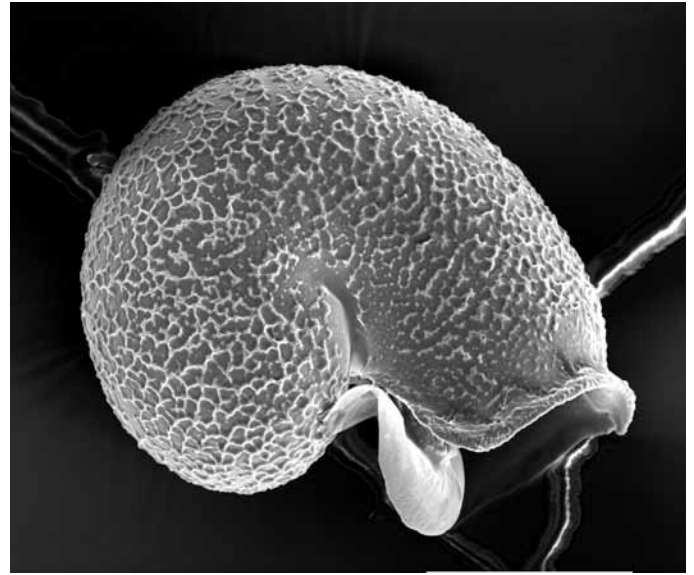
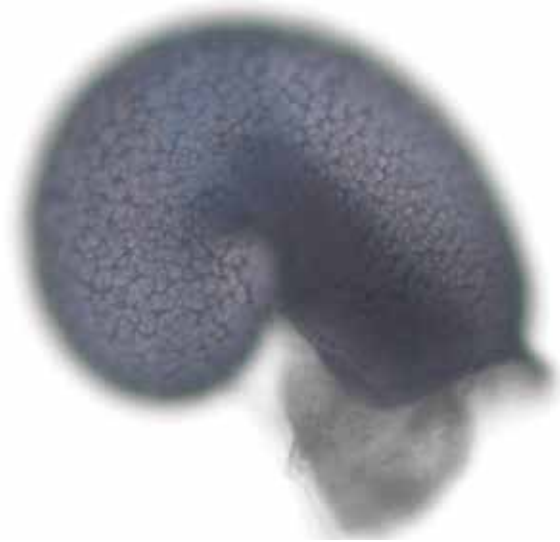


Melanodrymia aurantiaca is about 30µm smaller, with finer sculpture. Its aperture is more smoothly curved.



Melanodrymia ?galeronae is about 40µm smaller, also with finer sculpture and a more smoothly curved aperture.

Unknown ?neomphalid 290 μ m Family ?Neomphalidae.



Size: 280-290 μ m

Morphology:

This is a large protoconch with reticulate sculpture over the entire shell. The outer edge of the aperture flares out and the sides are deeply sinuous, coming to blunt points. The outline of the shell is smoothly rounded and there is no apparent aperture rim. It resembles *Melanodrymia* spp. in general appearance and sculpture and may well be an undescribed species in that genus.

Frequency:

Pump EPR 1999-2000: Not collected

Pump EPR 2004: Rare

Trap EPR 2004-2005: Rare

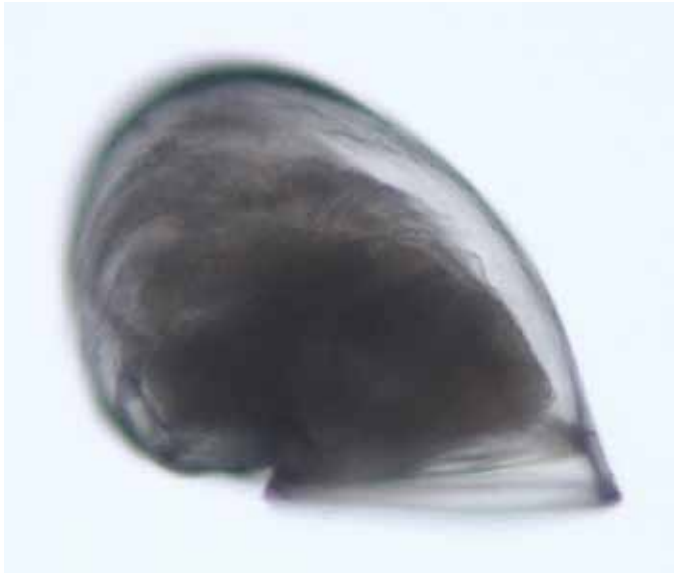


Unknown neomphalid B is about 50 μ m smaller. Its sculpture forms regular lines distally and it has a distinct ridge parallelling the aperture.



Bathymargarites symplector is 30-50 μ m larger. Its shell is nearly smooth, with only a few faint axial striations on distal half of shell.

Rhynchopelta concentrica McLean, 1989. Family Peltospiridae.



Size: 280-290µm

Morphology:

This is one of the few easily identified peltospirids. It is a large protoconch with strong lineation extending about 2/3 of the way to the aperture. Like most peltospirids, the aperture is straight viewed from the side and flares out to the sides when viewed from from the top. There is also an abrupt ridge on either side of the base near the axis of coiling. The shell is transparent and robust; they are seldom found damaged.

Frequency:

Pump EPR 1999-2000: Frequent

Pump EPR 2004: Frequent

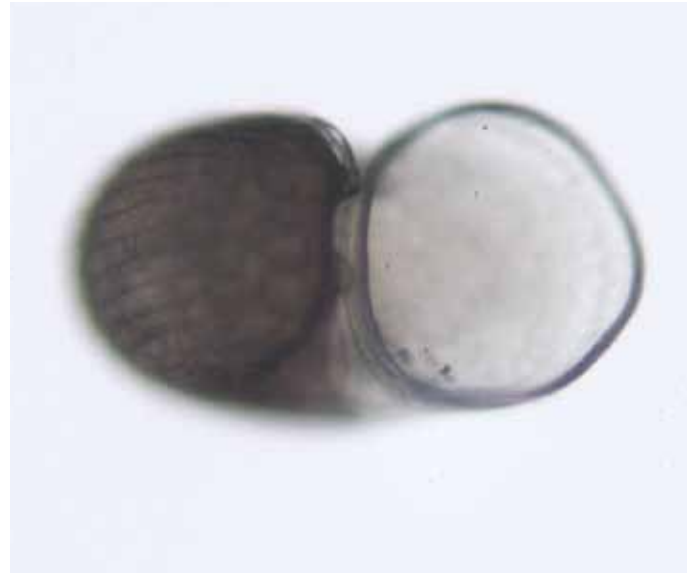
Trap EPR 2004-2005: Frequent

Can be confused with:



Rhynchopelta is unlikely to be confused with any other protoconch. The only other peltospirid protoconch close to it in size, *Ctenopelta porifera* (pictured at left), is quite different morphologically.

Ctenopelta porifera Warén & Bouchet, 1993. Family Peltospiridae.



Size: 290-310µm

Morphology:

This is the largest peltospirid protoconch we have found at EPR. Lineate sculpture, narrowly spaced, covers the posterior half of the protoconch. The anterior portion is smooth. The aperture is deeply sinuous and not circular when viewed from beneath, unlike all other peltospirids we have found.

Frequency:

Pump EPR 1999-2000: Not collected

Pump EPR 2004: Rare

Trap EPR 2004-2005: Rare

Can be confused with:



Because of its size and distinctive sculpture and morphology, this species is unlikely to be confused with any other protoconch. *Rhynchopelta concentrica* (pictured at left) is nearly as large, but is quite different in appearance.

Bathymargarites symplector Warén & Bouchet, 1989.

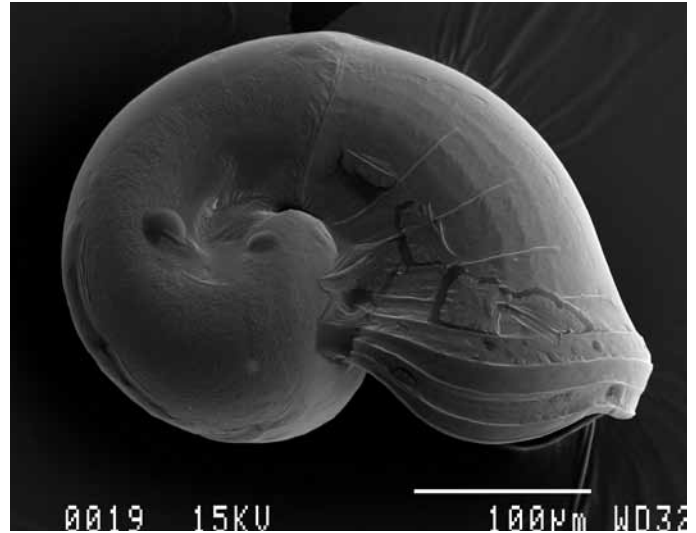
Family Trochidae.



Size: 320-350µm

Morphology:

The shell consists of two parts, a proximal smooth portion approximately 200µm in diameter and a distal portion with axial striations. The aperture is curved, flares out at the anterior edge and is asymmetrical, extending farther out on the apical side than on the basal side.



See also Warén & Bouchet, 1989, Figure 10, for SEM photos of larval and juvenile shells.

Frequency:

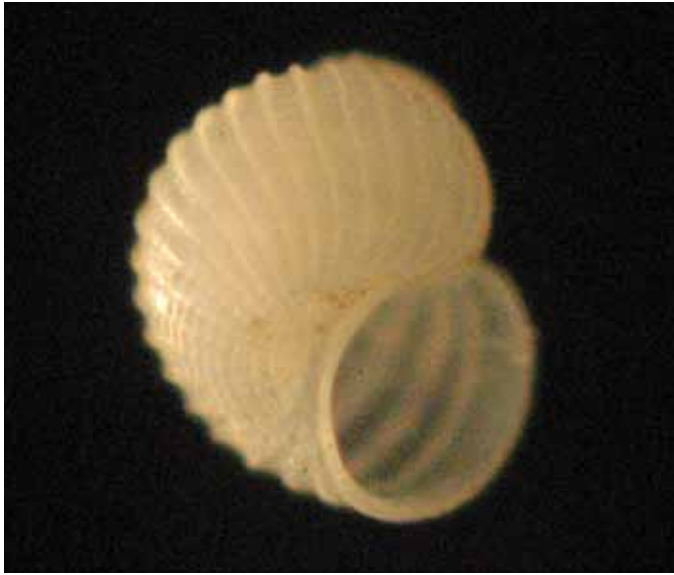
Pump EPR 1999-2000: Rare

Pump EPR 2004: Rare

Trap EPR 2004-2005: Frequent

Can be confused with:

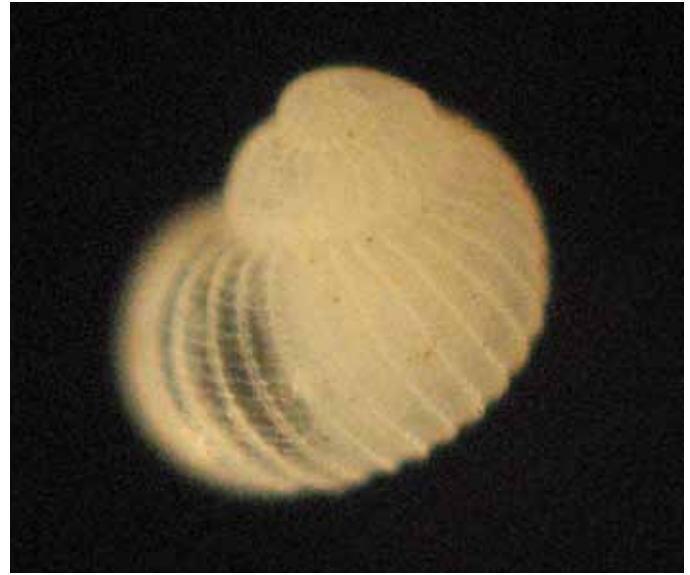
Bathymargarites' larval shell is unique among the species at 9°N and is therefore not likely to be confused with any other species. It has a superficial similarity to *Melanodrymia aurantiaca*, shown at left, but the latter is much smaller (~260µm) and has reticulate sculpture over the entire shell.

Laeviphitus sp. Family Elachisinidae.

Size: 360-400µm

Morphology:

Laeviphitus has a large coiled protoconch. It is presumably planktotrophic, with an unornamented protoconch I and protoconch II with fine spiral ridges and strong axial ribs to form a distinctive crosshatched pattern. The species is unknown, as no adults in this genus have been collected on the EPR, though members of the genus have been collected at vent and seep sites elsewhere.



See also Mullineaux et al. (1996), Figure 5e&f, for SEM photos

Frequency:

Pump EPR 1999-2000: Frequent

Pump EPR 2004: Common

Trap EPR 2004-2005: Common

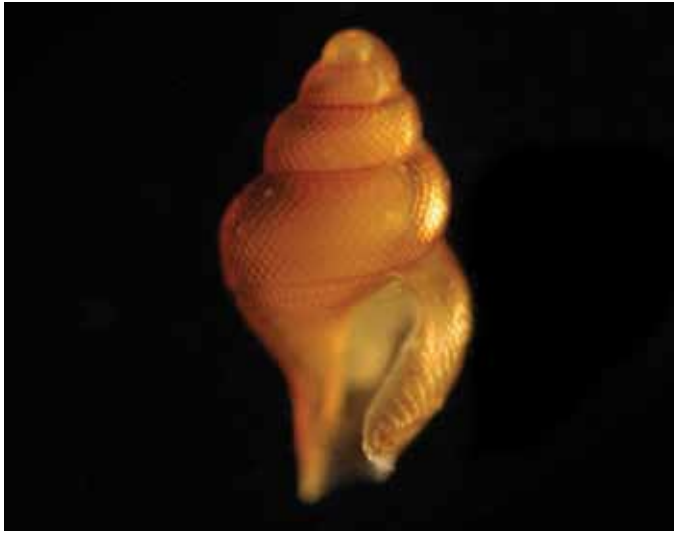
Can be confused with:



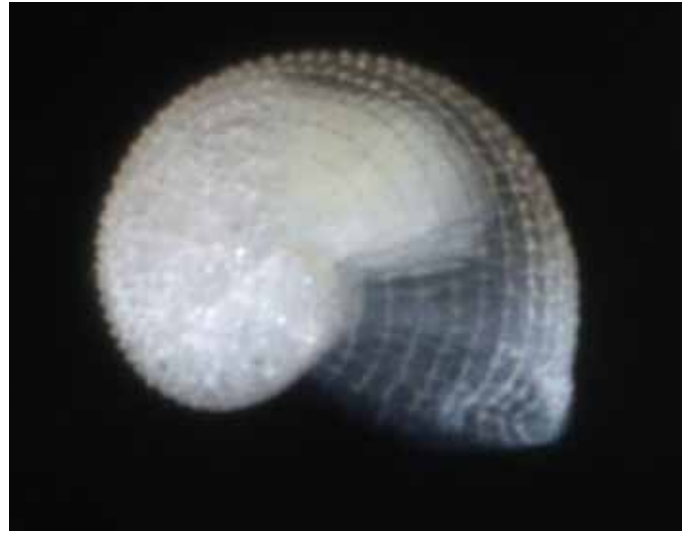
There are few coiled larvae in the plankton at 9°N and it is unlikely that this species would be confused with any other. *Phymorhynchus* protoconchs are also large and coiled, but have a taller spire and an ornamented protoconch I. The patterning on protoconch II in *Phymorhynchus* is diamond-shaped.

Phymorhynchus sp.

(presumably *Phymorhynchus major* Warén & Bouchet, 2001). Family Conidae.



Size: >1mm (late-stage, left photo),
240µm (PI only, right photo)



See Gustafson and Lutz (1994) for SEM of larva collected from an egg capsule at the Galápagos Rift and Lutz et al. (1986), Fig 1C,D for SEM's of larval shell on juvenile

Morphology:

This is a large coiled larva with planktotrophic development. The sculpture of PI appears to consist of parallel spiral lines under the light microscope, although there are short axial bars on each line visible at high magnification (above, right). PII has regularly spaced diagonal axial ribs that cross to form a diamond-shaped pattern. Most late stage individuals appear golden brown, as shown above left.

Frequency:

Pump EPR 1999-2000: Not collected on axis
Pump EPR 2004: Not collected
Trap EPR 2004-2005: Not collected

Can be confused with:

smaller (400µm).

The larva of *Phymorhynchus major* is unlikely to be confused with any other species, as there are so few coiled larvae at 9°N and its sculpture is so distinctive. *Laeviphitus* also shows cross-hatched sculpture on PII, but in that case the lines form rectangles rather than diamonds and the spire is much flatter. It is also generally white and much

Bathymodiolus thermophilus Kenk & Wilson, 1985.

Family Mytilidae.



Size: 400-450µm

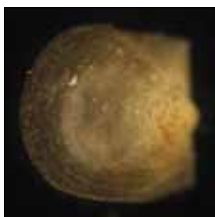
Morphology:

Bathymodiolus thermophilus have planktotrophic larvae. We find them in our plankton samples when they are close to settling. It is possible that we do not collect them as trochophores or D-stage larvae because they may be too small to be caught on our 63µm sieves. Near to settlement they are brownish in color.

Frequency:

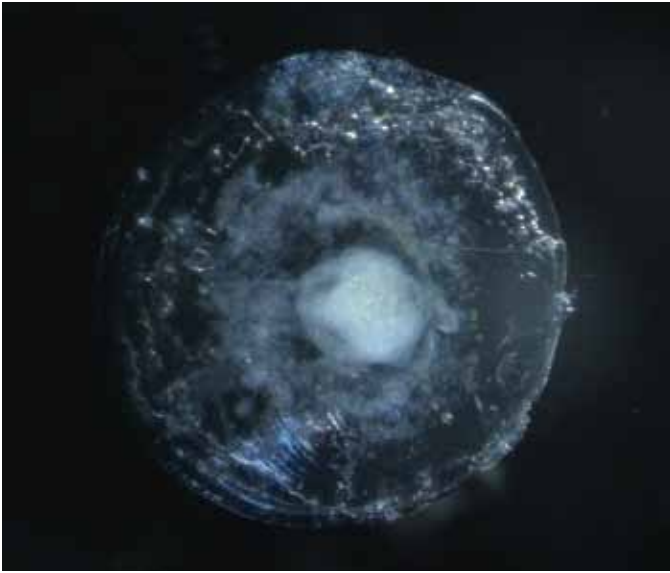
Pump EPR 1999-2000: Occasional
 Pump EPR 2004: Rare
 Trap EPR 2004-2005: Not collected

Can be confused with:



Bathymodiolus thermophilus is similar in color to juvenile *Bathypecten*, but is much smaller (< 450 µm vs. >1mm) and not scallop-shaped.

Bathypecten vulcani Schein-Fatton, 1985. Family Pectinidae.



Size: 840 μ m (larva, above left), >1mm (juvenile)

Morphology:

Shell thin, fragile, transparent to translucent. Most of the individuals we collect are larger than 2mm and possess the typical scallop morphology of the specimen on the right. These would presumably be swimming juveniles rather than larvae. The smaller specimen (above, left) is the only larva we've collected to date. Desbruyères et al. (2006) describe the species as having non-planktotrophic larval development.

Frequency:

Pump EPR 1999-2000: Not collected

Pump EPR 2004: Not collected

Trap EPR 2004-2005: Not collected

Can be confused with:



Bathymodiolus thermophilus is similar in color to juvenile *Bathypecten*, but is much smaller (< 450 μ m vs >1mm) and not scallop-shaped.

Amphisamytha galapagensis Zottoli, 1983. Family Ampharetidae.



Size: 280-500 μ m

Morphology:

Smallest individuals (3-4 chaetigers) have neither appendages nor distinctive morphology, as shown above left. At around 400 μ m and 5-6 chaetigers they develop a pair of smooth gills behind the prostomium (shown above in right photo); the adults will ultimately have four pairs, but the remaining three pairs appear much later in development. Since the smallest larvae are so featureless, it is possible that there may be more than one species represented.

Frequency:

Pump EPR 1999-2000: Not distinguished from other polychaete larvae

Pump EPR 2004: Not collected

Can be confused with:

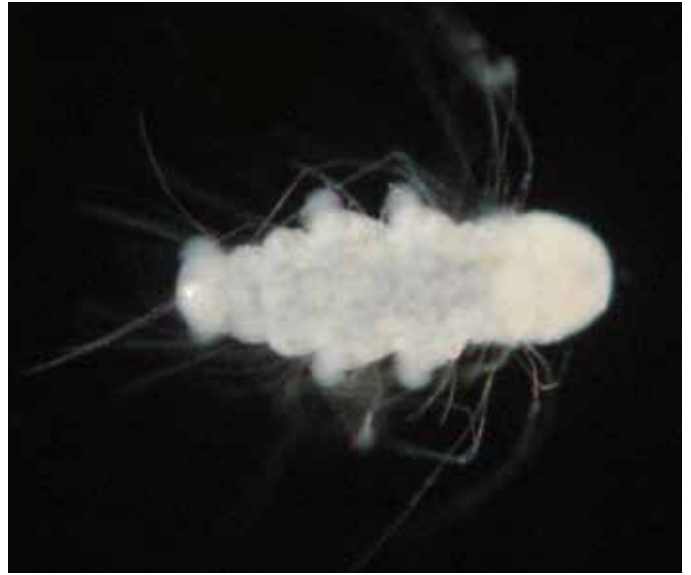


The smallest *Amphisamytha* larvae fall in the size range of the nectochaetes. Nectochaete larvae have a ciliary band circling the body near the anterior end (at right in photo) and are generally thinner for their length than *Amphisamytha*.



Ophryotrocha larvae are similar in size and general outline to *Amphisamytha*, but have a prominent jaw apparatus visible through the body wall. Their parapodia are also more prominent than those of *Amphisamytha*.

Archinome rosacea Blake, 1985. Family Archinomidae.



Size: 310-490µm

Morphology:

These larvae are very distinctive and unlikely to be confused with anything else. They are thick-bodied, tapering slightly toward the ends. Their chaetae are long, delicate and flexible and they often become tangled with debris or other animals in the sample. There are usually three pigmented areas visible on the head, as shown above at left.

Frequency:

Pump EPR 1999-2000: Occasional

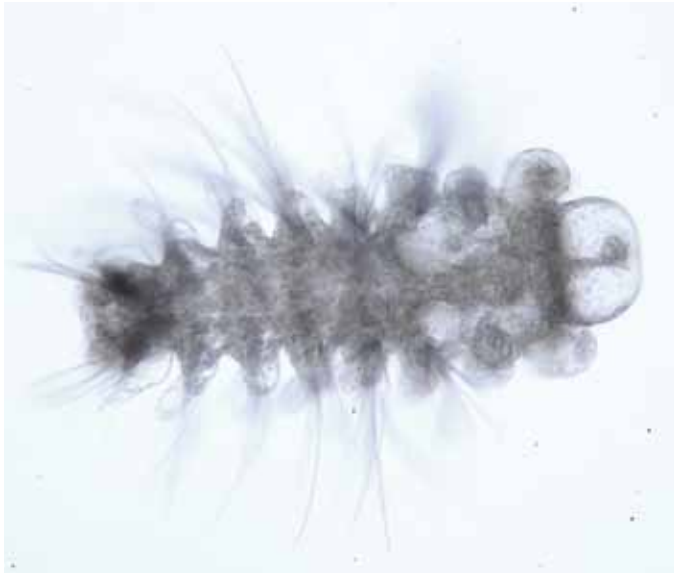
Pump EPR 2004: Frequent

Can be confused with:



Unknown polychaete B is similar in size and general outline; however, it lacks the long delicate chaetae of *Archinome*. In larger specimens a distinct jaw apparatus is visible through the body wall.

“Chaetosphaerids” Unknown families.



Size: Regular type: 280-400 μ m,
Spiny type: 200-320 μ m

Morphology:

We have been referring to these larvae as “chaetosphaerids” because many of them bear a superficial resemblance to some spionid larvae. However, we do not believe that they are necessarily spionids, nor that they are a homogeneous group. These larvae are common enough that it seems likely that they are vent species. Nonetheless, we have not been able to match them up with any known species, as they do not resemble the young juveniles of any polychaete we have seen. Attempts to resolve the identification using molecular methods are ongoing.

Frequency:

Pump EPR 1999-2000: Occasional
Pump EPR 2004: Common

Glycera sp. Family Glyceridae.

Size: ~600-700µm, depending
on number of chaetigers

Morphology:

These larvae have long parapodia, usually angled toward the posterior of the body. The head is blunt and conical, with a dark pigmented collar around it, and there are four small antennae which form a cross at the tip of the prostomium, though these are not always visible. Small jaws can usually be seen through the body wall. We have found glycerid polychaetes (*Glycera* sp.) on settlement blocks around the periphery of the 9°N vents. These larvae may be that species or possibly another non-vent species.

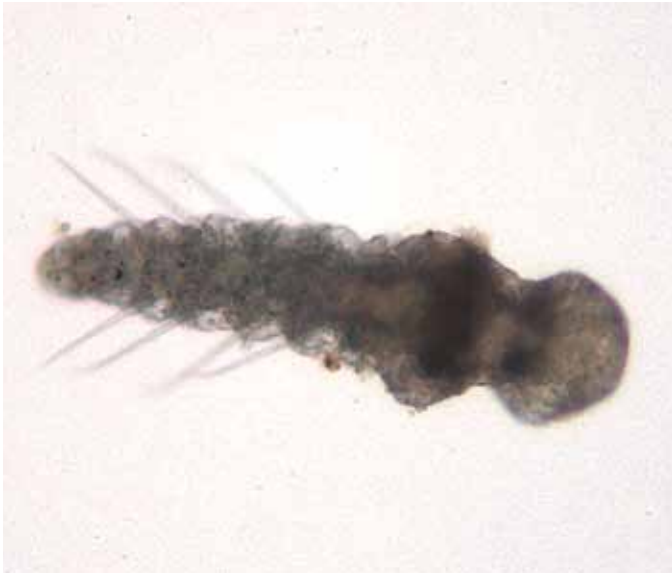
Frequency:

Pump EPR 1999-2000: Not collected on axis
Pump EPR 2004: Frequent

Can be confused with:

Glycera sp. is most likely to be confused with *Ophryotrocha* sp., since both species have visible jaws. However, the shape of the jaws is quite different and we generally find *Ophryotrocha* as 2-3 chaetiger larvae (~ 280 - 350µm), while *Glycera* is usually much larger (~7-9 chaetigers, ~ 600 - 700µm)

Nectochaetes Unknown families.



Size: 170-380µm

Morphology:

Nectochaetes of several varieties are often present in our plankton samples. They have a blunt, bulbous prostomium with a ciliary collar surrounding the body. They are relatively thin for their length and their chaetae, usually at least as long as the body is wide, are angled toward the posterior. Preliminary molecular analyses indicate that more than one family is represented in this group.

Frequency:

Pump EPR 1999-2000: Occasional
Pump EPR 2004: Common

Can be confused with:



The smallest *Amphisamytha* larvae fall in the size range of the nectochaetes and have a similar number of chaetigers. Nectochaete larvae have a ciliary band behind the head and are generally thinner for their length than *Amphisamytha*.

Nereis sp., possibly *Nereis sandersi* Blake 1985. Family Nereididae.



Size: ~300-450µm, depending on number of chaetigers

Morphology:

Nereidid larvae are usually found at the 3-4 chaetiger stage in our samples. They have visible antennae and tentacular cirri projecting from the sides of the head, as well as a pair of anal cirri. The parapodia are well-developed and there are usually dark or reddish spots visible at the bases of two adjacent pairs, as shown above. This is presumably *Nereis sandersi* Blake, the only nereidid at 9°N.

Frequency:

Pump EPR 1999-2000: Occasional
Pump EPR 2004: Frequent

Can be confused with:



These larvae are most likely to be confused with *Ophryotrocha* sp., which is superficially similar, but lacks the tentacular cirri and the dark spots on the parapodia. *Nereis* has larger parapodia with longer chaetae, but lacks the obvious jaw apparatus that *Ophryotrocha* has.

Can be confused with:



This group is most likely to be confused with *Nereis* sp. It can be quickly distinguished by its easily visible jaws and by the fact that *Nereis* larvae have four dark or reddish dots at the base of two adjacent pairs of parapodia. *Nereis* also has obvious antennae and tentacular cirri projecting from the sides of the head and is generally somewhat larger (300-450µm;

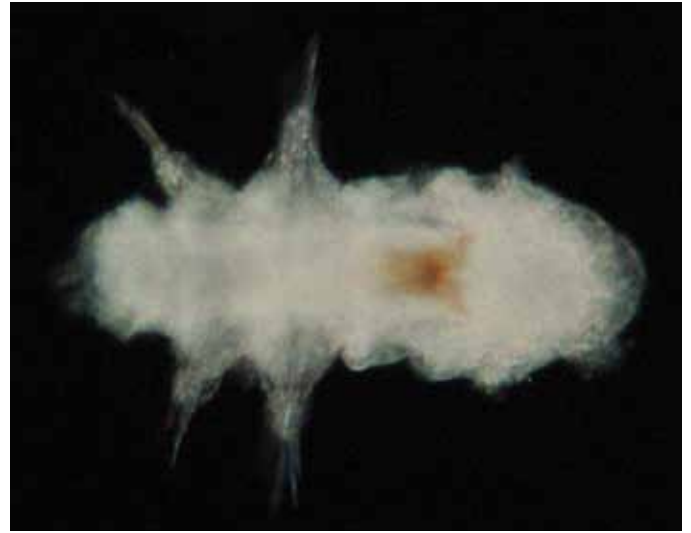
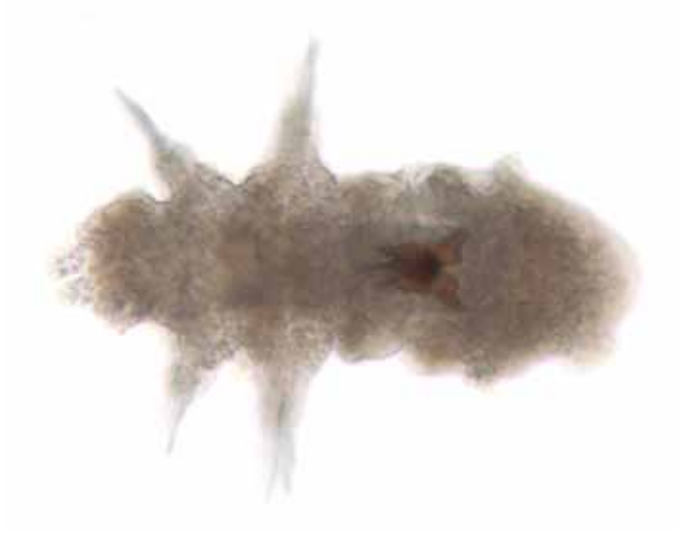
individual at left is 400µm).



It is possible that *Ophryotrocha* might be mistaken for a small *Glycera* sp., as both species have visible jaws. However, the shape of the jaws is quite different and *Glycera* has four antennae in the form of a cross at the tip of its prostomium. We generally find *Glycera* sp. when it is much larger - - 600 - 700µm - and with more chaetigers.

Ophryotrocha sp., possibly *Ophryotrocha akessoni* Blake, 1985.

Family Dorvilleidae.



Size: 280 μ m at 2 chaetigers

Morphology:

We have attributed these larvae to *Ophryotrocha*, based on their general appearance, especially the jaw apparatus, which can be seen clearly through the body wall. They have prominent parapodia that stick out to the sides and two anal cirri are usually visible at the posterior end. The adults possess two antennae toward the front of the prostomium and two lateral palps anterior to the jaws; these are sometimes visible in the larvae, but often are indistinct.

Frequency:

Pump EPR 1999-2000: Not distinguished from other polychaete larvae
Pump EPR 2004: Common



Amphisamytha larvae are approximately the same size as *Ophryotrocha*, but lack jaws and obvious parapodia.



Unknown polychaete A is similar in general outline to *Ophryotrocha*, but is smaller (this individual is 200 μ m), yellower in color and lacks the jaw apparatus. In this group, the chaetae are angled toward the posterior rather than sticking out to the sides.

Polynoids Family Polynoidae.



Size: 190 μ m (left) to >1mm

Morphology:

There are many species of polynoids at the 9°N vents and we have not attempted to assign any of the forms we find in the plankton samples to species. Most of the morphotypes we collect are actually juveniles; it is not uncommon for polynoids to metamorphose in the plankton and live there for extended periods before settlement (Young et al., 2001, p.211). They are characterized by having long parapodia and chaetae and large blunt heads with various appendages. They may retain their scales, but these are easily lost.

Frequency:

Pump EPR 1999-2000: Occasional
Pump EPR 2004: Frequent

Unknown polychaete A, Unknown Family.



Size: ~200µm

Morphology:

Small nectochaete larva, generally found at the two-chaetiger stage. Chaetae about as long as the body is wide, angled toward the posterior end. No prostomial appendages or jaws. This group has been present in sampling prior to the 2005-2006 eruptions at 9°N, EPR, but was not distinguished from other unknown polychaetes. It may be a smaller version of a member of our nectochaete group, but because of consistent differences in morphology and color, we have listed it separately.

Frequency:

Pump EPR 1999-2000: Not distinguished from other polychaete larvae
 Pump EPR 2004: Not distinguished from other polychaete larvae

Can be confused with:



Ophryotrocha sp. is similar in general outline, but is larger (this two-chaetiger specimen is 280µm). In *Ophryotrocha* the parapodia stick straight out to the sides rather than being angled back to the posterior and it also has a jaw apparatus visible through the body wall.

Unknown polychaete A tends to be yellow or tan in color when preserved in ethanol rather than gray to white like *Ophryotrocha*.

Unknown polychaete B, Unknown Family.



Size: 535 μ m (left), 340 μ m (right)

Morphology:

Oval-shaped larva, quite wide for its length. No chaetae visible, but four evenly spaced ciliary bands encircle the body and there appear to be patches of cilia on the anterior and posterior ends. In larger individuals, jaws can be seen through the body wall, as in the specimen on the left. This form was not collected prior to the 2005-2006 eruptions at 9°N, EPR and we do not know if it belongs to the vent fauna.

Frequency:

Pump EPR 1999-2000: Not collected

Pump EPR 2004: Not collected

Can be confused with:



Archinome rosacea is similar in size and general outline; however, it has long, delicate chaetae, whereas Unknown polychaete B has only cilia. *Archinome* has dark pigmentation on its prostomium, but does not have a jaw apparatus.

Barnacle cyprids, Order Cirripedia.



Size: various from ~600 μ m to >1mm

Morphology:

We have found a variety of cyprids in our plankton samples, most (and perhaps all) non-vent. The only vent species at 9°N is *Neolepas zevinae* Newman, 1979; nothing is known about its larval life, but a few newly settled cyprids, approximately 800 μ m in length, were recovered on our settlement blocks (Mullineaux et al., 2003) which presumably belong to this species. Two of these are pictured above (right photo).

Frequency:

Pump EPR 1999-2000: Rare
Pump EPR 2004: Occasional
Trap EPR 2004-2005: Occasional

Bythograea microps de Saint Laurent, 1984.

Infraorder Brachyura, Family Bythograeidae.



Size: megalopa ~3mm

Morphology:

This is a small megalopa with long eyestalks. It has been attributed to *B. microps* by de Saint Laurent (1988), who originally described the species and recent molecular work has confirmed the identification (L. Hurtado, personal communication).

Frequency:

Pump EPR 1999-2000: Not collected

Pump EPR 2004: Not collected

Trap EPR 2004-2005: Occasional

Can be confused with:

We have only collected two types of megalopae at this site, this one and a much larger one which has been attributed to *Bythograea thermydron* (on the left). The size difference should be sufficient to distinguish the two species.

Bythograea thermydron Williams, 1980.

Infraorder Brachyura, Family Bythograeidae.



Size: megalopa ~8mm, zoea ~1.5mm (right)

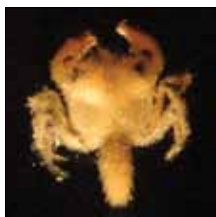
Morphology:

Typical brachyuran megalopa, reddish in life, but generally tan to whitish in preservative. The zoea is similar to those collected from *B. thermydron* females (A. Dittel, personal communication) and we believe it also belongs to this species.

Frequency:

Pump EPR 1999-2000: Rare
 Pump EPR 2004: Rare
 Trap EPR 2004-2005: Occasional

Can be confused with:



We have only collected two types of megalopae at this site, this one and a much smaller one which has been attributed to *Bythograea microps*. The size difference should be sufficient to distinguish the two species

FORAMINIFERA

?*Tretomphalus* sp. Class Foraminifera.



Size: ~250-300µm in diameter

Morphology:

Roughly spherical foraminiferan with coarse perforations on the ventral surface (above right). The dorsal surface is composed of a brownish spiral of increasing sized flat chambers; the whole specimen appears to be a benthic foraminiferan with an inflated chamber (similar to those in planktonic species) on the ventral side. Our specimens have been examined by an expert (S. Richardson) and appear similar to the dispersal form of the genus *Tretomphalus*, a shallow-water benthic group. Most, though not all, are empty shells.

Frequency:

Pump EPR 1999-2000: Occasional
 Pump EPR 2004: Not collected
 Trap EPR 2004-2005: Not collected

Can be confused with:



At first glance *Tretomphalus* might be mistaken for a chamber of a planktonic foraminiferan, such as is shown at left, but these do not have the flat-chambered spiral shown above left.

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Taxonomic Index

Bivalvia

- Bathymodiolus thermophilus* 71
- Bathypecten vulcani* 73

Crustacea

- Barnacle cyprids 95
- Bythograea microps* 97
- Bythograea thermydron* 99

Foraminifera

- ?*Tretomphalus* sp. 101

Gastropoda

- Bathymargarites symplector* 65
- Clypeosectus delectus* 19
- Ctenopelta porifera* 63
- Cyathermia naticoides* 43
- Echinopelta fistulosa* 33
- Eulepetopsis vitrea* 53
- Gorgoleptis emarginatus* 21
- Gorgoleptis* sp. 3 23
- Gorgoleptis spiralis* 9
- Laeviphitus* sp. 67
- Lepetodrilus*-like protoconchs 27
- Lepetodrilus* spp. 17
- Lirapex granularis* 37
- Melanodrymia aurantiaca* 57
- Melanodrymia ?galeronae* 47
- Neolepetopsis* spp. 49
- Neomphalus fretterae* 45

- Pachydermia laevis* 51
- Peltoospira* spp. 35
- Phymorhynchus* sp. 69
- Pointy apex 11
- Rhynchopelta concentrica* 61
- Unknown 7 25
- Unknown 8 29
- Unknown 9 31
- Unknown benthic sp. A 13
- Unknown neomphalid 5 15
- Unknown ?neomphalid 290µm 59
- Unknown neomphalid B 41
- Unknown neomphalid W 55
- Unknown peltospirid 240µm 39

Polychaeta

- Amphisamytha galapagensis* 75
- Archinome rosacea* 77
- Chaetosphaerids 79
- Glycera* sp. 81
- Nectochaetes 83
- Nereis* sp. 85
- Ophryotrocha* sp. 87
- Polynoids 89
- Unknown polychaete A 91
- Unknown polychaete B 93

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16. Abstract (Limit: 200 words) The purpose of this guide is to assist researchers in the identification of larvae of benthic invertebrates at hydrothermal vents. Our work is based on plankton sampling at the East Pacific Rise (EPR) 9-10°N vent field from 1991–present. We have included frequency data from large-volume plankton pump samples taken between 1999 and 2004 and time-series sediment trap samples from 2004-2005. The guide includes an "Introduction and Methods" section that details larval collection techniques, a "Terminology" section for gastropod and polychaete larvae, and "Literature Cited" for descriptions of species. Gastropod larvae are sorted by size and other larvae are sorted alphabetically within their taxonomic class. Each species information page also includes images of species that are similar in appearance. While our sampling was limited to EPR 9-10°N, the guide is useful to researchers working in other areas, since some species range from 21°N to the southern EPR, and some have congeners in other chemosynthetic environments, e.g., <i>Lepetodrilus</i> (Juan de Fuca Ridge, Mid-Atlantic Ridge, wood falls), and <i>Bathymodiolus</i> (Mid-Atlantic Ridge, seeps). We would like to expand the guide by including additional species from other areas and welcome contributions from other researchers. This guide is also available online at http://www.who.edu/vent-larval-id .			
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