



# In situ growth of the vestimentiferan *Ridgeia piscesae* living in highly diffuse flow environments in the main Endeavour Segment of the Juan de Fuca Ridge

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## Introduction

At many hydrothermal vents and hydrocarbon seep locations vestimentiferans are an ecosystem structuring organism. The vestimentiferan *Ridgeia piscesae* Jones, 1985 is one of the most abundant macrofauna present at the vent sites of the Juan de Fuca Ridge, and due to its endosymbiotic relationship with chemoautotrophic bacteria can be characterized as a primary producer. The tube-worms' tubes provide surface for colonization and the tube-worm aggregations provide refuge for other vent-endemic micro and macro fauna. The different *R. piscesae* morphotypes found on the Juan de Fuca Ridge were originally thought to represent up to five different species but further investigations using allozymes and morphological reassessments demonstrate that they all are one species (Southward et al., 1995). Preliminary observations suggest that the different morphotypes are a reflection of the different temperature and sulphide regimes that this species inhabits.

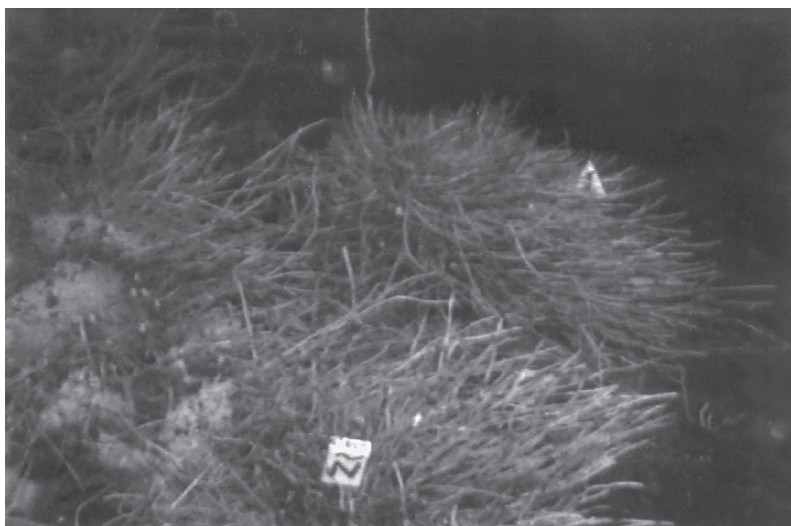
The wide tolerance of habitat conditions seems to be the exception, rather than the rule, among vestimentiferan species. For example, in sharp contrast to *R. piscesae*, the East Pacific Rise vestimentiferan *Riftia pachyptila* Jones, 1981 is only found in areas of relatively strong and continuous diffuse hydrothermal flow, and high sulphide availability (Fisher et al., 1988). *R. pachyptila* not only requires a high level of diffuse flow for survival but it also demonstrates very fast growth. This species has been observed to increase its tube length by more than 1 metre over a 2 year period and has been referred to as the fastest growing invertebrate in the planet (Lutz et al., 1994). However, it should be noted that tube growth in this species is not equivalent to tissue growth, since *R. pachyptila* does not inhabit the entire length of its tube. At the other end of the environmental and growth spectrum, vestimentiferans

from the Gulf of Mexico hydrocarbon seeps grow very slowly (< 1 cm/year) (Fisher et al., 1997). A primary objective of our ongoing studies on the main Endeavour Segment of the Juan de Fuca Ridge is to measure the in situ growth rates of the different *R. piscesae* morphotypes living in a variety of different diffuse flow habitats. Here we report some preliminary results of a growth study on the long-skinny morphotype.

## Materials and methods

The long-skinny morphotype can be found within active areas of the vent field where dilute vent fluid emanates from fractures in the basaltic substrate. These are usually locations of above-ambient temperatures with occasional visible shimmering water. This morphotype is found in habitats where very high temperatures, black smokers and sulphide deposits are not evident. The tube-worm aggregations can be found extensively covering wide areas and/or in dense bush-like aggregations (Fig. 1). Here the average tube-worm tube is conical in shape and about a metre long. The tube-worms inhabit the entire length of their tubes. Four separate tube-worm aggregations located at two different sites in the Main Endeavour segment (S&M and Easter Island), were used in this study.

In order to measure tube growth, we used several different methods including direct measurements, time-lapse still photography and videoscopic analysis. All these methods were used on tube-worms previously marked with an in situ tube staining device. The staining device uses a permanent dye to stain the outside on the anterior end of the vestimentiferans tubes. After a year, these previously stained individuals are either collected and/or carefully video surveyed. New anterior tube growth is denoted by white tube increments anterior to the stained tube location (Fig. 2).



**Figure 1.** Aggregation of the *Ridgeia piscesae* tube-worm in the Easter Island study site. These are the clump “3” (triangle marker) and clump “2” (square marker ‘N’) in the text. The individual tube-worms in this clumps are representatives of the long-skinny morphotype.



**Figure 2.** New *Ridgeia piscesae* growth within clump “2”. Previously stained blue tube is readily visible and the new tube material is denoted by white increments.

Two methods were used to characterize the tube-worm's immediate habitat. In situ temperature and sulphide levels were quantified with a chemical analyser (SUAVE) during the 1995 research cruise. In order to monitor the exposure of stained *R. piscesae* to vent fluids between cruises, the temperature was measured at 4 or 8 separate points within each tube-worm clump using recording thermistor arrays (Fig. 3). Equal numbers of thermistors were placed at the base of the clumps and at the tube-worm's plume level. These arrays were deployed at three study locations for a one year deployment between the 1996 and 1997 field seasons.

## Results and Discussion

### *Habitat description*

In some stained clumps we were not able to detect temperature anomalies at plume level using the ROV temperature probe during a dive. However, a three-day thermistor deployment in one of these clumps measured occasional temperature excursions of up to 0.5°C above ambient. Higher temperatures and sulphide concentrations were generally found at the base of the tube-worm clumps. However, the data also show extreme microhabitat



**Figure 3.** Thermistor array deployed at marker “Ñ” (clump ‘2’). Two thermistors are buried at the base of the clump and the two top thermistors are located at plume level.

variability at plume level in temporal and spatial scales. In each study clump, 4 or 8 thermistors were deployed. Each thermistor produced over 18,500 data points. A full analysis of this temperature data is beyond the scope of this abstract. However, some generalizations are appropriate. Clump ‘1’ had the lowest overall recorded temperature at base and plume level. The highest temperature recorded at the base of this clump was 17°C while the mean temperatures at the plume and base levels were 2°C and 4.5°C respectively (ambient temperature is 1.9°C). Clump ‘2’ experienced an overall higher temperature regime. Mean temperature recorded at plume level was 2.6°C and at base level was 6°C. The maximum temperature recorded at the base of this clump was 35°C. This was the maximum temperature recorded at any of our deployment locations; however, the highest overall temperatures were recorded in clump ‘3’. Here, the mean plume and base level temperatures were 2.3°C and 9°C respectively. The maximum base temperature recorded here was 24.5°C. It should be noticed that the mean plume level temperature recorded at clump ‘2’ is higher than the mean plume level temperature at clump ‘3’. Clump ‘2’ was a very diffuse and open tube-worm aggregation while clump ‘3’ was a very densely packed aggregation. The clump ‘2’ morphology would easily allow a more unrestricted flow of diluted vent fluid among the bush, but clump ‘3’ would have more likely channeled the diffuse flow towards the outside of the clump and away from the plumes of many tube-worms in that aggregation. Although the highest temperature recorded was at the base of clump ‘2’, consistently higher temperatures were recorded from the two thermistors placed near the base of clump ‘3’. Temperature data for clump ‘4’ is not available.

All of the stained tube-worms recovered were alive at the time of collection. However, many of these individuals had not grown since the original time of staining. At clump ‘1’, the clump with the overall lowest temperatures, none of the stained tube-worms had grown during the one year period (96-97). At clump ‘3’, 22 of the 42 recovered tube-worms had not grown over a two year period (95-97), while, all of the 27 stained tube-worms in the nearby clump ‘2’ had. Individual growth between tube-worms in the same clump is also variable (Table 1). Tube-worms in clump ‘2’ grew between 0.3-21 cm over the two year study period, while tube-worms in clump ‘3’ grew between 0-4 cm during the

**Table 1.** In situ yearly tube growth of stained *Ridgeia piscesae*. The time period between tube staining and collection is approximately one year for markers Ñ, IA, R, L and two years for markers \* IA and \* Ñ. The numbers in parenthesis are the numbers of the bush as they are referred to in the text. For comparison, the known growth rates for the Gulf of Mexico (GOM) cold-seep and the East Pacific Rise (EPR) vestimentiferans are also shown. Ri = *Ridgeia piscesae*, La = *Lamellibrachia* sp., Rp = *Riftia pachyptila*, n = number of individuals measured.

Location	Marker	Species	n	Average Tube Growth (cm)	Median Tube Growth (cm)
<b>JdeFR</b>	*Ñ(2)	Ri	27	6.1	5.1
	*IA (3)	Ri	42	0.7	0
	Ñ (2)	Ri	22	2.3	1.7
	IA (3)	Ri	25	0.25	0
	R (1)	Ri	8	0	0
	L (4)	Ri	10	2.7	2.6
<b>GOM</b>		La	37	0.8	
<b>EPR</b>		Rp		>50	

same time. This variation in growth between individuals in the same clump can be seen in Fig. 2. The growth of *R. piscesae* is therefore variable both between adjacent clumps and between individuals located in the same clump.

The time-lapse photographs documented four stained individuals over a one year period. The data show that anterior tube growth occurs as episodic "growth spurts" which can last as long as 18 days. These growth periods are followed by 'resting periods' which can be as short as 18 days. Each new anterior segment is laid down as a white, semi-translucent, cylinder-shape increment. At the end of the growth period, a flare is added to the anterior-most end of the new increment and the entire new section appears to be reinforced over a longer time period.

*Ridgeia piscesae* can survive, and grow, in a very low diffuse venting environment. This is very different from its EPR cousins such as *Riftia pachyptila* which are only found living in areas with much more robust diffuse flow. *R. piscesae* can take advantage of even slightly higher sulphide levels with substantially faster growth. The range of growth rates measured on this growth form, and the rates reported by other for this species (Tunnicliffe, 1990), suggest that *Ridgeia*'s growth rates may span the entire range between the fast growing EPR species and the slow

growing cold seep vestimentiferans. This ability to survive and thrive under a wide range of environmental conditions allows this one single species of tube-worm to exploit many of the different habitats available at the North East Pacific vents.

## References

- Fisher C.R., Childress J.J., Arp A.J., Brooks J.M., Distel D., Favuzzi J.A., Macko S.A., Newton A., Powell M.A., Somero G.N. & Soto T. 1988. Physiology, morphology and biochemical composition of *Riftia pachyptila* at Rose Garden in 1985. *Deep-Sea Research*, **35**: 1745-1758.
- Fisher C.R., Urcuyo I.A., Simpkins M.A. & Nix E. 1997. Life in the slow lane: growth and longevity of cold-seep vestimentiferans. *Marine Ecology*, **18**: 83-94.
- Lutz R.A., Shank T.M., Fornari D.J., Haymon R.M., Lilley M.D., Von Damm K.L. & Desbruyères D. 1994. Rapid growth at deep-sea vents. *Nature*, **371**: 663-664.
- Southward E.C., Tunnicliffe V. & Black M. 1995. Revision of the species of *Ridgeia* from northeast Pacific hydrothermal vents, with a redescription of *Ridgeia piscesae* Jones (Pogonophora: Obturata = Vestimentifera). *Canadian Journal of Zoology*, **73**: 282-295.
- Tunnicliffe V. M. 1990. Effects of sampling on hydrothermal vent deposits and animals. *Journal of Geophysical Research*, **95**: 12961-12966.