

# Vent Fauna in the Mariana Trough

# 25

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## Abstract

The Mariana Trough is a back-arc basin in the Northwestern Pacific. To date, active hydrothermal vent fields associated with the back-arc spreading center have been reported from the central to the southernmost region of the basin. In spite of a large variation of water depth, no clear segregation of vent faunas has been recognized among vent fields in the Mariana Trough and a large snail *Alviniconcha hessleri* dominates chemosynthesis-based communities in most fields. Although the Mariana Trough approaches the Mariana Arc at both northern and southern ends, the fauna at back-arc vents within the trough appears to differ from arc vents. In addition, a distinct chemosynthesis-based community was recently discovered in a methane seep site on the landward slope of the Mariana Trench. On the other hand, some hydrothermal vent fields in the Okinawa Trough backarc basin and the Izu-Ogasawara Arc share some faunal groups with the Mariana Trough. The Mariana Trough is a very interesting area from the zoogeographical point of view.

## Keywords

*Alviniconcha hessleri* • Chemosynthetic-based communities • Hydrothermal vent • Mariana Arc • Mariana Trough

## 25.1 Introduction

The Mariana Trough is a back-arc basin in the Northwestern Pacific (Fig. 25.1). The present hydrothermal activity in the Mariana Trough is estimated to have started about 7 million years ago (Ma) (Stern et al. 2003) and some dating studies reported records of mineralization in this region since 12,000 years ago (Stüben et al. 1994; Takamasa et al. 2013; Ishibashi et al. Chap. 23).

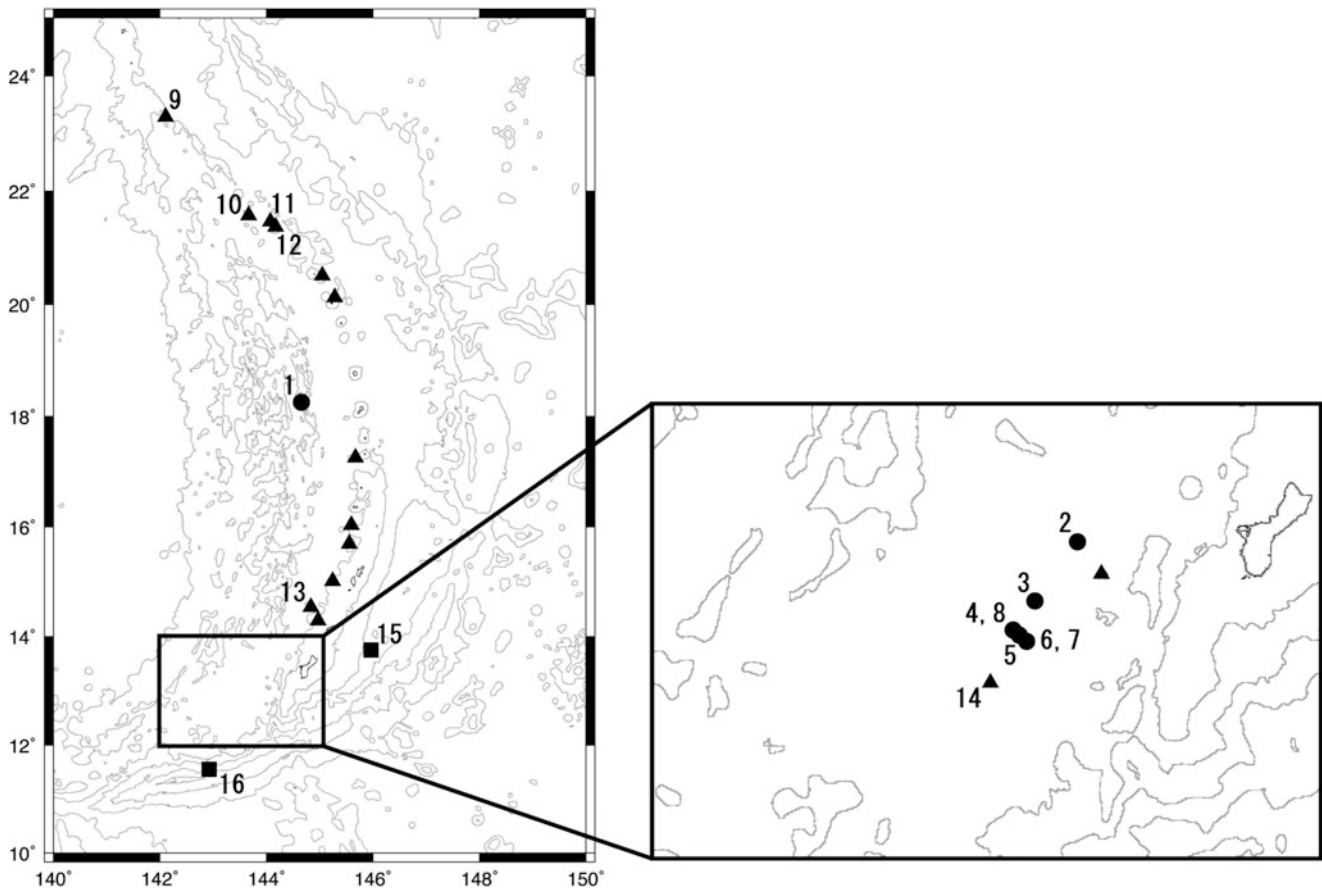
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The first hydrothermal vent field discovered in the Mariana Trough was the Alice Springs, in the Central Mariana Trough (18° 13' N, 144° 43' E: 3,600 m depth) in 1987 (Craig et al. 1987). Although an unnamed vent field was discovered 20 km south of the Alice Springs (18° 03' N, 144° 45' E: 3,660 m depth), biological research have not yet conducted there (Hessler and Lonsdale 1991). Next vent field was discovered at the Forecast Vent site (13° 24' N, 143° 55' E: 1,470 m depth) in 1992 (Johnson et al. 1993). This site has been classified as an arc-related vent (e.g. Embley et al. 2007), however a recent study proposed that volcanic style in the region around the Forecast seamount reflects strong extension in the back-arc basin (Stern et al. 2013). Although the geologic setting of the Forecast site would be considered as in transition, vent fauna of this field is more similar to other vent fields in the Mariana Trough than arc vents as mentioned below, and we treat it as a vent field in the Mariana Trough in this paper.

In the southernmost region of the Mariana Trough, various hydrothermal vent fields have been discovered



**Fig. 25.1** A map of hydrothermal vent fields in the Mariana Trough (closed circles) and the Mariana Arc (Closed triangles), and a methane seep sites in the Mariana Trench (closed squares). Bathymetrical contour intervals are 2,000 m. 1, Alice Springs and an unnamed vent field; 2, Forecast Vent site; 3, 13°N Ridge site; 4, Snail site; 5, Archaean site;

6, Pika site; 7, Urashima site; 8, Yamanaka site; 9, Nikko Seamount; 10, Dai-ni (second) Kasuga Seamount; 11, NW Eifuku Seamount; 12, Daikoku Seamount; 13, NW Rota-1 Seamount; 14, TOTO Caldera; 15, South Chamorro Seamount; 16, Shinkai Seep Field

(Yoshikawa et al. 2012). First in this region, a low-temperature vent site (the 13°N Ridge site) was discovered at 13°06'N on the Backarc Spreading Center (13°06'N, 143°41'E, 2,945 m depth) in 1999 (Mitsuzawa et al. 2000; Masuda et al. 2001b). Thereafter, an active vent field was discovered at the Snail site (=Fryer site; 12°57'N, 143°37'E, 2,850 m depth), which is also situated on the back-arc spreading center, in 2003 (Wheat et al. 2003). The Yamanaka site (=Y site; 12°57'N, 143°37'E, 2,826 m depth), which is about 1.1 km SW of the Snail site, was also discovered on the spreading center in 2003 (Kakegawa et al. 2008). The Pika site (12°55'N, 143°39'E, 2,770 m depth) and the Archaean site (12°56'N, 143°38'E, 2,990 m depth) were discovered on off-axis seamounts in 2003 (Urabe et al. 2004; Ishibashi et al. 2004). The newest hydrothermal vent field was discovered at the Urashima site (12°55'N, 143°39'E, 2,922 m depth), which is situated about 0.5 km north of the Pika site, in 2010 (Nakamura et al. 2012). The Snail, Archaean, Pika, and Urashima sites are distributed almost on a straight line from ridge axis to the

off-ridge, which suggests that the locality of hydrothermal activity is controlled by tectonic fractures.

## 25.2 Vent Fauna of the Mariana Trough

### 25.2.1 Research History

Hessler and Lonsdale (1991) report 30 species from the chemosynthetic communities at the Alice Springs site (Table 25.1). They pointed out faunal affinity at the genus level between vent fields of the Mariana Trough and the central ridges in the Eastern Pacific Ocean, although they stated that eight genera were known only from the western Pacific vents. After 6 years, Fujikura et al. (1997) and Hasegawa et al. (1997) summarized vent faunas at the Alice Springs and Forecast sites based on specimens collected using the submersible *SHINKAI 2000* in 1996 (Table 25.1). In spite of a large difference in water depth

**Table 25.1** List of animals collected in hydrothermal vent fields in the Mariana Trough

Phylum	Class	Family	Species	Sites <sup>a</sup>	Description	Remarks
Porifera	Demospongiae	Cladorhizidae	<i>Abyssocladia</i> sp.	4		
Cnidaria	Actinulida	Actinostolidae	<i>Marianactis bythios</i>	1, 2	Fautin and Hessler (1989)	
			Small sea anemone	1		Hessler and Lonsdale (1991), photograph only
			White sea anemone	7		Video and photograph only
			Actinostolid-like anemone	4		Video and photograph only
			Anemone	3, 5		Video and photograph only
Platyhelminthes	Polycladida		unidentifid species	2		Fujikura et al. (1997)
Annelida	Polychaeta	Alvinellidae	<i>Paralvinella hessleri</i>	1	Desbruyères and Laubier (1989)	
		Polynoidae	<i>Branchinotogluma burkensis</i>	1, 2	Pettibone (1989)	
		Polynoidae	<i>Branchinotogluma marianus</i>	1, 2		Described as <i>Opisthotrochopodus marianus</i>
		Lepidonotopodinae	<i>Lepidonotopodium minutum</i>	1		
		Lepidonotopodinae	<i>Levensteiniella raisae</i>	1		
		Hesionidae	<i>Hesiocaeca hessleri</i>	1	Blake (1991)	<i>Hesiocaeca</i> sp. in Hessler and Lonsdale (1991)
		Maldanidae	<i>Nicomache</i> sp.	1		<i>Nicomache arwidssoni</i> in Hessler and Lonsdale (1991); <i>Nicomache</i> cf. <i>ohtai</i> in Desbruyères et al. (2006)
		Ampharitidae	<i>Amphisamytha galapagensis</i>	1	Zottoli (1983)	
			unidentified species	1, 2		Fujikura et al. (1997)
		Mollusca	Aplacophora	Simrothiellidae	undescribed species	1
	Bivalvia	Mytilidae	<i>Bathymodiolus</i> sp.	1, 2		It forms a monophyletic group with <i>B. septemdiarium</i> , <i>B. brevior</i> , and <i>B. marisindicus</i> (Fujita et al. 2009).
			undescribed species ( <i>Malletia</i> sp.?)	2		Fujikura et al. (1997)
			Gastropoda	Provannidae	<i>Alviniconcha hessleri</i>	1, 2, 3, 4, 5
		Provannidae	<i>Provanna nassariaeformis</i>	1	Okutani (1990)	
		Provannidae	<i>Desbruyeresia marianaensis</i>	1, 2		Described as <i>Provanna marianaensis</i>
		Provannidae	<i>Desbruyeresia</i> cf. <i>mariaensis</i>	4, 5, 6		
		Provannidae	<i>Desbruyeresia</i> cf. <i>spinosa</i>	2		Hasegawa et al. (1997)
		Neomphalidae	<i>Symmetromphalus regularis</i>	1, 2	McLean (1990)	
		Lepetodrilidae	<i>Lepetodrilus</i> aff. <i>schrolli</i>	1, 2		<i>L. elevatus</i> in Hessler and Lonsdale (1991); Johnson et al., (2008)
		Lepetodrilidae	<i>Lepetodrilus</i> sp.	4		
	Phenacolepadidae	<i>Shinkailepas</i> spp.	1, 2, 3, 4, 5, 6		<i>Shinkailepas</i> cf. <i>kaikatensis</i> in Hessler and Lonsdale (1991) and Fujikura et al. (1997)	
	Acmaeidae	Undescribed species	1		Hessler and Lonsdale (1991)	

(continued)

**Table 25.1** (continued)

Phylum	Class	Family	Species	Sites <sup>a</sup>	Description	Remarks
		Turridae	<i>Phymorhynchus</i> cf. <i>starmeri</i>	1, 2, 5		Fujikura et al. (1997), probably Buccinidae indet. in Hessler and Lansdale (1991)
		Turridae	<i>Phymorhynchus</i> sp.	3, 5		
		Clypeosectidae	<i>Pseudorimula marianae</i>	1, 2	McLean (1990)	
		Skeneidae	<i>Ventsia</i> cf. <i>tricarinata</i>	1, 2		Fujikura et al. (1997)
		Peltospiridae	<i>Pachydermia</i> cf. <i>sculpta</i>	2		
		Peltospiridae	<i>Lirapex</i> sp.	5		
		Scissurellidae	<i>Anatoma</i> sp.	4		
		Acmaeidae	<i>Bathyacmaea</i> sp.	4		
			Protobranchia sp.	6		
			Unidentified gastropod	4, 5, 6		
Arthropoda	Pycnogonida	Ammotheidae	<i>Sericosura cochleifovea</i>	1	Child (1989)	
	Copepoda	Dirivultidae	<i>Stygiopontius pectinatus</i>	1	Humes (1987)	
		Dirivultidae	<i>Stygiopontius stabilitus</i>	1	Humes (1990)	
		Dirivultidae	<i>Chasmatopontius thescalus</i>	1		
	Amphipoda		Amphipoda gen. et sp.	2		Fujikura et al. (1997)
	Cirripedia	Neoverrucidae	<i>Neoverruca brachylepadoformis</i>	1, 2, 3, 4, 5	Newman and Hessler (1989)	
			Scalpellomorpha gen. et sp.	1		Hessler and Lonsdale (1991), photograph only
	Decapoda	Galatheidae	<i>Munidopsis marianica</i>	1, 2	Williams and Baba (1989)	
		Galatheidae	<i>Munidopsis</i> sp.	3, 5, 6		
		Bythogreidae	<i>Austinograea williamsi</i>	1, 2, 3, 4, 5, 6	Hessler and Martin (1989)	
		Alvinocarididae	<i>Chorocaris vandoverae</i>	1, 2, 3, 4, 5, 6	Martin and Hessler (1990)	
		Alvinocarididae	<i>Chorocaris</i> sp.	3, 5, 6		

<sup>a</sup>1, Alice Springs site; 2, Forecast site; 3, Snail site; 4, Archaean site; 5, Pika site; 6, Urashima site; 7, Yamanaka site

between two sites (3,600 vs. 1,470 m), they reported that the faunas are quite similar to each other (Fujikura et al. 1997).

During 2000s, vent fields in the southernmost region of the Mariana Trough were surveyed in the second stage of the Archaean project (2003–2004) and the NOAA VENTS program. As few macrobiologists joined these projects, little information on their vent faunas was available. Wheat et al. (2003) reported they sampled a provannid snail *Alviniconcha hessleri* and crabs from the Snail site. An abundant anemone colony was observed in the southern part of the Yamanaka site (Kakegawa et al. 2008).

As an activity of the TAIGA Project, we collected biological specimens at four vent sites in the southernmost region of the Mariana Trough, namely, the Snail, Archaean,

Pika, and Urashima sites, during the cruise YK10-11 of the R/V *YOKOSUKA* and the submersible *SHINKAI 6500* of Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Results obtained from the sampling are also shown in Chap. 26.

At the Snail site, the largest animal community was observed around the chimney with fringe structure. The center of the community was dominated by *A. hessleri* assemblage and accompanied with *Shinkailepas* limpets, *Austinograea* crabs, and *Chorocaris* shrimps. Further apart from the chimney, only a few shrimp and crab were observed. The outermost part of the vent field was occupied by the turrid snail *Phymorhynchus* sp., two kinds of sea anemones, and opheidiiformes. At the Archaean site, only

small and scattered animal communities were observed. On the steep terrain of the mound, galatheid crabs, brisingids, actinostolid-like anemones, and Abyssocladia sponges were observed. Around active chimneys, *Shinkailepas* limpets were abundant and attached to the vertical surface. *Alviniconcha hessleri* inhabits the narrow place covered with white bacterial mat. We observed a wide size range of galatheids and small bythograeids, actinostolid-like anemones in diffuse flow, and shrimp and crabs were abundant in the shimmering flow of the vent itself. Two large bivalves were found in a crevice at the base of the chimney but could not be collected. *Chorocaris* shrimps and *Austinograea* crabs were also common. On the steep slope of the Pika mound, a few white bythograeid crabs are distributed and many empty shells of *Alviniconcha* seemed to have fallen from above. With approaching to the summit, *Phymorhynchus* snails, galatheid and bythograeid crabs, and *Desbruyeresia* gastropods appeared although the fauna was very sparse there. We noticed a small population of *A. hessleri* on the side of a chimney. Shrimps were swimming around them. There were also scattered limpets. At the Urashima site, vent fauna was not so abundant, although shrimps, galatheid crabs, anemones and a few small gastropods were distributed in a place with strong diffuse flow. In total 19 species were observed and collected in these four hydrothermal vent sites. Although the most flourishing fauna was observed at the Snail site on-axis, the number of species was highest at off-axis Pika and Archaean sites. During this cruise, the sampling of larvae of vent animals was carried out around vent fields using plankton pump systems for the first time in the southernmost region of the Mariana Trough and 13 and 15 morphotypes of polychaete and gastropod larvae were sampled, respectively (Beaulieu et al. 2011; Sasaki et al. unpublished data).

We also revisited the Yamanaka site where abundant white sea anemones were observed on pillow lavas. This site was thought to have passed its peak of hydrothermal activity (Yoshikawa et al. 2012).

Unfortunately, no detailed faunal information is available for the 13°N Ridge site with the exception of observation of animals around hydrothermal vents by the Deep Tow Camera system and the ROV *KAIKO* (Mitsuzawa et al. 2000; Masuda et al. 2001b).

### 25.2.2 Mollusca

The most dominant species of the communities in hydrothermal vent fields in the Mariana Trough is a large provannid gastropod *Alviniconcha hessleri* (Okutani and Ohta 1988). To date, this species is known only from the Mariana Trough, and *Alviniconcha* gastropods inhabiting the Manus, North Fiji, and Lau Basins, and the Indian Ocean

are thought to be other undescribed species (Kojima et al. 2001; Suzuki et al. 2006). Although no genetic differentiations between the Alice Springs and the Forecast Vent site were detected for this species (Kojima et al. 2001), our more detailed analysis showed a slight difference between populations of the Central and Southern Mariana Trough (Hidaka et al. Chap. 26). By using the DNA barcoding, two larvae of this species were identified in the specimens collected by plankton pump systems mentioned above (Sasaki et al. unpublished data). Based on shell morphology, they are judged to be planktotrophic as Warèn and Bouchet (1993) concluded based on young adult specimens of an undescribed *Alviniconcha* species from the Lau Basin. Sulfur-oxidizing endosymbiotic bacteria were discovered in specialized gill cells (bacteriocytes) of *A. hessleri* (Stein et al. 1988; Endow and Ohta 1989). They belong to the gammaproteobacteria, although some undescribed *Alviniconcha* species endosymbiose with epsilonproteobacteria (Suzuki et al. 2005, 2006). Wittenberg and Stein (1995) reported that the gill of *A. hessleri* contains hemoglobin at a comparable concentration to endosymbiont-retaining solemyid, lucinid, and vesicomid clams. Sulfur stable isotope ratios of *A. hessleri* showed sulfide in hydrothermal fluid is the major source of assimilated sulfur, which is supplied by endosymbiotic bacteria (Maki and Mizota 1997).

Two small provannid gastropod species were described by Okutani (1990). They are classified into the genus *Provanna* as *P. nassariaeformis* and *P. marianensis*, and the latter was transferred to the genus *Desbruyesia* in Warèn and Bouchet (1993).

Vrijenhoek et al. (1997) showed that a limpet of the genus *Lepetodrilus* from the Mariana Trough, which had been thought to be conspecific to that in the Eastern Pacific, is genetically distinct from East Pacific species. Johnson et al. (2008) analyzed phylogenetic relationships among *Lepetodrilus* limpets and showed those of the Mariana Trough form a species complex with *L. schrolli* from the Manus Basin and unidentified individuals from the North Fiji and Lau Basins. Limpets of the genus *Shinkailepas* also dominate vent fields in the Mariana Trough as well as the Izu-Ogasawara Arc. Although *Shinkailepas* limpets of the Mariana Trough resemble to *S. kaikatensis* of which the type locality is the Kaikata Seamount in the Izu-Ogasawara Arc and were referred as *Shinkailepas* cf. *kaikatensis* in Hessler and Lonsdale (1991) and Fujikura et al. (1997), DNA barcoding and detailed morphological examination clearly showed those of the Mariana Trough are not *S. kaikatensis* which was described based on specimens from the Izu-Ogasawara Arc (Kano et al., unpublished data).

Genetic analysis with mitochondrial DNA also showed little genetic deviation among morphologically-distinct

species, namely, *Bathymodiolus septemdiemum* from the Izu-Ogasawara Arc, *Bathymodiolus* sp. from the Mariana Trough, *B. brevior* from the North Fiji and Lau Basins, and *B. marisindicus* from the Indian Ocean (Fujita et al. 2009). If they are a single species with extremely high ability of larval dispersion, the situation is very similar to that of a vestimentiferan *Paraescarpia echinospica*, which are distributed from the Nankai Trough in the northwestern Pacific to the Java Trench in the Indian Ocean but not in the Mariana Trough (Kojima et al. 2002).

### 25.2.3 Arthropoda

A bythograeid crab, *Austinograea williamsi*, which was described by Hessler and Martin (1989) is also a representative vent-endemic species in the Mariana Trough. Its heterochely, relative growth and gonad morphology were reported in Tsuchida and Fujikura (2000).

To date, all alvinocarid shrimps collected in the Mariana Trough have been classified into the genus *Chorocaris*. Besides a dominant alvinocarid shrimp *Chorocaris vandoverae*, we collected some specimens of an undescribed *Chorocaris* shrimp at the Snail, Pika, and Urashima sites. Based on sulfur stable isotope ratio analysis, Maki and Mizota (1997) reported that *C. vandoverae* is supplied sulfur from hydrogen sulfide in hydrothermal fluid.

A hydrothermal vent-endemic barnacle *Neoverruca brachylepadoformis* is closely related to an undescribed species inhabiting the Okinawa Trough, Izu-Ogasawara Arc, and the Mariana Arc. Their ancestors were estimated to have migrated from the Mariana Trough to the Izu-Ogasawara Arc and the Mariana Arc via the Okinawa Trough based on the molecular phylogenetic and phylogeographic analyses (Watanabe and Kojima 2009; Watanabe et al. 2005).

### 25.2.4 Annelida

*Paralvinella hessleri* is one of the dominant annelid species. This species is also thought to inhabit the Okinawa Trough and the Izu-Ogasawara Arc. A molecular phylogenetic analysis using the mitochondrial COI gene showed that populations of the Okinawa Trough and the Izu-Ogasawara Arc are almost deviated from each other (Pradillon et al., unpublished data). As no molecular data is available for the Mariana Trough population and we cannot deny the possibility that *Paralvinella* annelids of the Okinawa Trough and the Izu-Ogasawara Arc are another cryptic species of *P. hessleri*.

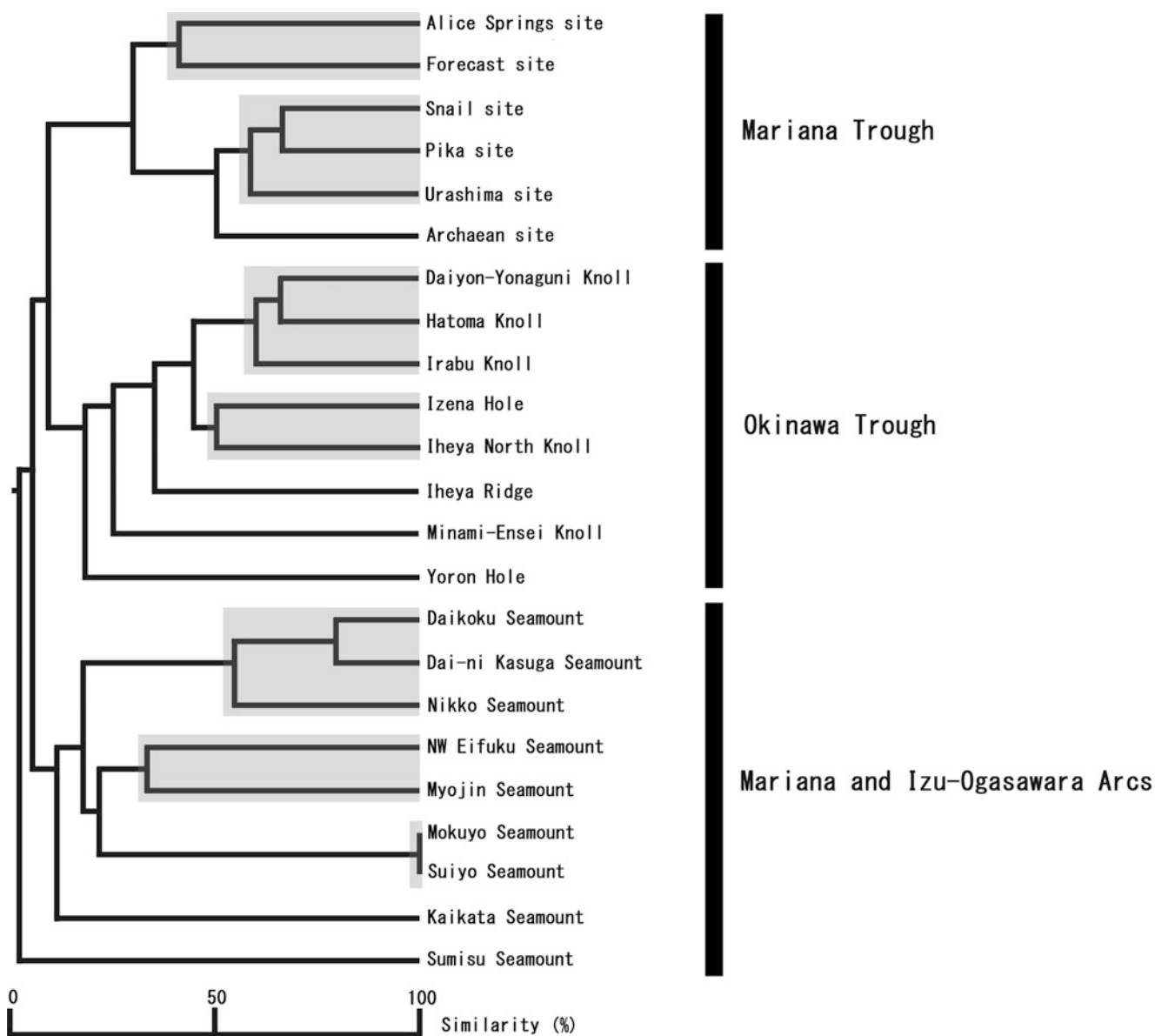
## 25.3 Vent/Seep Faunas of Neighboring Sea Areas

### 25.3.1 Mariana Arc, Izu-Ogasawara Arc, and Okinawa Trough

The Mariana Trough approaches to the Mariana Arc at both northern and southern ends (Fig. 25.1). Along the Mariana Arc, hydrothermal activities were discovered on 13 submarine volcanoes at the depths from 50 to 3,000 m, and chemosynthetic-based communities was reported from the Nikko, Daini (second) Kasuga, NW Eifuku, Daifuku, and NW Rota-1 Seamounts and TOTO Caldera (Fujikura et al. 1998; Masuda et al. 2001a; Embley et al. 2007). At the northern end, the Mariana Arc connects with the Izu-Ogasawara Arc. Although the Mariana Trough also adjoins the Mariana Arc at the northern end, the recent hydrothermalism has not yet been discovered in the northern region of the Mariana Trough. Indeed, the vent fauna of the Mariana Trough is rather similar to that of the Okinawa Trough (Fig. 25.2). As planktonic materials can be transported by the North Equatorial Current and the Kuroshio Current from the Mariana Trough to the Okinawa Trough, historical larval migration might have occurred along this route (Watanabe et al. 2005).

An *Alviniconcha* snail, which is a representative vent-endemic taxon of the Mariana Trough, has not been reported north of the Mariana Trough with the exception of a single specimen collected from the Suiyo Seamount, the Izu-Ogasawara Arc. It phylogenetically differs from *A. hessleri* and all other *Alviniconcha* lineages (Fujiwara et al. 2013) and is suspected to have immigrated to this vent field accidentally. Habitat(s) of this undescribed species may be situated in other vent fields in the Izu-Ogasawara and/or Mariana Arcs. Although small gastropods of the genera *Provanna*, *Desbruyeresia*, *Lepetodrilus* and *Shinkailepas* inhabit vent fields in both the Mariana Trough and neighboring sea areas, the existence of endemic species to the Mariana Trough was shown for each genus. Vesicomylid clams were collected in the TOTO Caldera and identified as *Calyptogena nautilei* (Kojima et al., unpublished data).

*Alvinocaris* shrimps have not yet been reported from the Mariana Trough while an undescribed species of this genus was discovered in two vent fields of the Mariana Arc, namely, NW Rota (Limén et al. 2006) and NW Eifuku, which will be described as a new species (Tsuchida, personal communication). Four *Alvinocaris* shrimps, namely, *A. longirostris*, *A. dissimilis*, *A. brevitelsonis*, and an undescribed species inhabit the Okinawa Trough (Komai and Segonzac 2005; Fujikura et al. 2012; Yahagi et al., unpublished data). This undescribed species was also



**Fig. 25.2** A cladogram of hydrothermal vent faunas in the Mariana Trough, Mariana Arc, Izu-Ogasawara Arc, and Okinawa Trough, generated by the group average method using the Jaccard similarity coefficient based on genera. Data of Table 25.1 were used for the Mariana Trough, data of the Mariana Arc, Izu-Ogasawara Arc, and

Okinawa Trough were updated from those in Watanabe et al. (2010), and only data of identified genera were used. Among faunas in gray areas, no significant difference ( $p > 0.05$ ) was detected by the SIMPROF (similarity profile) test with 1,000 permutations

collected from the Suiyo Seamount in the Izu-Ogasawara Arc (Yahagi et al., unpublished data). *Austinograea williamsi* is an endemic species to the Mariana Trough and differs from bythograeid crabs from the Izu-Ogasawara and Mariana Arcs at the genus level. *Munidopsis marianica* is also endemic to the Mariana Trough while some congeneric species inhabit vent fields in the Mariana Arc, Izu-Ogasawara Arc, and/or Okinawa Trough. For *Neoverruca* barnacles, significant genetic differences were shown among specimens from the Mariana Trough, the Okinawa Trough, and the Izu-Ogasawara Arc (Watanabe 2004). Individuals

of the Izu-Ogasawara Arc were further shown to form a monophyletic group with those from the Mariana Arc (Watanabe et al., unpublished data).

Vestimentiferan tube worms, which form one of representative groups of hydrothermal vent fields in the Okinawa Trough and the Manus Basin, has not yet been reported from the Mariana Trough. They are also rare in the Mariana Arc where two species are found; *Lamellibrachia satsuma* from the Nikko and Daikoku Seamounts (Black et al. 1997; Kojima et al. 2012) and *L. juni* from the TOTO Caldera (Kojima et al. 2006). The former is known from the seep

area around the Japanese Islands at shallower depths than 330 m. The absence of this species in the Mariana Trough might be attributable to the absence of such a shallow vent site. The latter is also known from the DESMOS site in the Manus Basin and the Brothers Caldera in the Kermadec Arc (Kojima et al. 2006). All of three habits of this species are characterized by extreme acidic hydrothermal fluids (around pH 2). If this species has been specialized to such a harsh environment, it may explain its absence in the Mariana Trough.

While symphurine tonguefish are distributed in the Mariana Arc, the Izu-Ogasawara Arc, and the Okinawa Trough, they have not been reported from the Mariana Trough. Tunnicliffe et al. (2010) reported that a symphurine tonguefish *Symphurus thermophilus* inhabiting vent fields at the Daikoku, Nikko, and Daini (second) Kasuga Seamounts is genetically distinct from those of the Kermadec arc in spite of no morphological difference between them and suggested the possibility that the latter is a cryptic species. The type locality of *S. thermophilus* is the Kaikata Seamount of the Izu-Ogasawara Arc (Munroe and Hashimoto 2008) and individuals in the Mariana Arc might be classified into another cryptic species. Unfortunately, no molecular information is available for symphurines of the Izu-Ogasawara Arc and the Okinawa Trough.

### 25.3.2 Mariana Forearc and Mariana Trench

Many serpentinite mud volcanoes are known in the Mariana forearc between the Mariana volcanic island arc and the Mariana Trench. In 1997, a methane seep area with a highly alkaline fluid was discovered on one of those mud volcanoes, the South Chamorro Seamount (Fryer and Mottl 1997). *Bathymodiolus* mussels inhabiting this field were shown to be genetically distinct from those of the Mariana Trough (Fujita et al. 2009). Vesicomid clams collected in this area were identified as *Calyptogena nautilei* (Kojima et al., unpublished data). Although Fryer and Mottl (1997) also reported “tube worms” from this site, their detailed information is not available.

A distinct chemosynthesis-based community was recently discovered in a methane seep area (Shinkai Seep Field) on the landward slope of the Mariana Trench (Ohara et al. 2012). From there, a new species of vesicomid clams *Calyptogena mariana* was described (Okutani et al. 2013). This species was classified into the subgenus *Abyssogena* and shown to be more related to species of the abyssal depths such as *C. kaikoi* from seep areas in the Nankai Trough off the Japanese mainland than inhabitants of the Mariana Arc. To date, no species of the Mariana Trough have been reported from methane seep areas around Japan.

### 25.3.3 Backarc Basins in the South Pacific

Hydrothermal vent fields in backarc basins in the South Pacific, namely, the Manus Basin, the North Fiji Basin, and the Lau Basin, share *Alviniconcha* snails as a dominant species with the Mariana Trough. Those of the South Pacific were estimated to have speciated into two different undescribed species. *Ifremeria nautilei* is also a large snail with endosymbiotic chemoautotrophic bacteria. Although this species forms a monophyletic group with *Alviniconcha* snails, it is not distributed in the Mariana Trough. Chemosynthesis-based communities of the Mariana Basin lack vestimentiferan annelids and *Calyptogena* clams, while the former is distributed in the Manus Basin and the Lau Basin (Desbruyères et al. 2006) and the latter is distributed at a single site (the DESMOS caldera) in the Manus Basin (Hashimoto et al. 1999). Bythograeid crabs of the genus *Austinograea* are known from the Mariana Trough (*A. williamsi*), the South Pacific (*A. alayseae*), and the Indian Ocean (*A. rodriguezensis*).

## 25.4 Conclusion

Diversity of hydrothermal environments and vent faunas in the western Pacific is probably due to their various backgrounds and two-dimensional distribution, which results in complicated connectivity between vent sites, in addition to proximity of vent areas with different geological settings as well as cold seep areas. In contrast, hydrothermal vent fields in the eastern Pacific, Atlantic and Indian Oceans are distributed along the mid-oceanic ridges and essentially aligned. Thus, the western Pacific is expected to offer interesting subjects for researches of dispersal, genetic deviation, and speciation processes of animals endemic to chemosynthesis-based communities. Comparative studies between the western Pacific and other sea areas are important for understanding evolution and ecology of vent fauna.

The Mariana Trough is situated in the central position in hydrothermal areas in the northwestern Pacific, surrounded by the Okinawa Trough, the Izu-Ogasawara Arc, the Mariana Arc, and the Manus Basin. Chemosynthesis-based communities in the Mariana Trough are characterized by the absence of vestimentiferans and *Calyptogena* clams, which are dominant in both vent and seep sites around the Ryukyus and Japan Islands, the dominance of *Alviniconcha* snails and *Austinograea* crabs, which is shared with the South Pacific and the Indian Ocean. Phylogeographic analyses showed *Neoverruca* barnacles have historically migrated from the Mariana Trough to the Izu-Ogasawara Arc and the Mariana Arc via the Okinawa Trough (Watanabe and Kojima 2009; Watanabe et al. 2005). They were further estimated to have deviated from a common ancestor species which inhabited



the Manus Basin (Watanabe 2004), which suggest the primary historical migration in the western Pacific occurred in the northward direction. Similar suggestions have been noted for *Alviniconcha* snails (Kojima et al. 1999) and *Alaysia*-like vestimentiferans (Kojima et al. 2003).

A very interesting issue is a biogeographic break of the vent fauna between the Mariana Trough and the Izu-Ogasawara and Mariana Arcs. It may be attributable to directions of surface currents, namely, the North Equatorial Current and the Kuroshio Current, and/or the absence of active vent sites in the northernmost region of the Mariana Trough where the trough is adjacent to the arcs. In the southernmost region, extreme acidic hydrothermal fluids of the TOTO Caldera might prevent the vent fauna of the Mariana Trough from colonizing to the arc area.

The Mariana Trough is a key place connecting various vent and seep sites in the western Pacific. Exhaustive survey in this area with joint research using phylogeographic and larval ecological methodologies will provide fruitful results for understanding organization mechanisms of vent communities.

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