

Observations on the fauna from submarine and associated anchialine caves in Christmas Island, Indian Ocean Territory, Australia

Tan Heok Hui¹*, Tohru Naruse², Yoshihisa Fujita³ & Tan Siong Kiat¹

Abstract. We report on opportunistic sampling and/or observations of the fauna of five submarine and six associated anchialine caves in Christmas Island conducted over a total of five weeks from 2010 to 2012. The surveys were conducted mainly via hand picking, overturning of coral rubble, baited fish traps (using baitfish and fish food pellets) and with the use of clove oil. A total of 54 species of cnidarian, gastropod, crustacean, echinoderm, enteropneusta and teleost fish were observed or obtained, with some uncommon species; and interesting taxa including *Neoliomera cerasinus*, *Palinurellus wieneckii*, *Enoplometopus voightmanni*, *Carupa ohashii*, *Carupa tenuipes*, *Pagurixus nomurai*, and cave Paguridae species.

Key words. Christmas Island, submarine cave, anchialine cave, SCUBA, biodiversity

INTRODUCTION

The reports and surveys on cave exploration and fauna have thus far been mainly limited to terrestrial subterranean anchialine systems in Christmas Island (see Humphreys & Eberhard, 2001; Meek, 2001). There have been much fewer reports on the submarine cave systems, and are typically limited to treatments of selected marine and anchialine faunal groups (e.g., gastropods by Laseron (1956), Kano & Kase (2000, 2008), Takano & Kano (2014); ostracods by Namiotko et al. (2004), Humphreys & Danielopol (2006), Humphreys et al. (2009); crustaceans by Ng (2002), Ng & Takeda (2003), Bruce & Davie (2006), Davie & Ng (2012)). Grimes (2001) provides an excellent overview on the karstic features and geological history of Christmas Island.

The accessible and diveable caves in the waters around Christmas Island are within 10 to 20 m depth mainly along the northwestern coast (Grimes, 2001). Some of these submarine caves are rather extensive, with air-filled caverns and can involve walking over some distances to where anchialine cave conditions exist. One of the most extensive explorable marine cave systems in Christmas Island is the Lost Lake Cave (Grimes, 2001). Apparently no SCUBA gear is needed, and snorkeling gear is sufficient to traverse over

shallow seawater-filled sections, walking for over 3–4 km and access to water-filled sections (anchialine). We could not access the Lost Lake Cave during our brief surveys as it is highly tide- and wave condition-dependent.

Over the short surveys conducted in January–February 2010, March 2011 and February 2012 periods, a total of five marine and six associated anchialine caves were accessed, totaling 47 dives (19 in 2010, 19 in 2011 and 9 in 2012) (see Tan et al. (2014a) for more details on the dive locations). Most of these accessible caves were located along the northwestern coast. A brief description of the caves surveyed is listed in Table 1 and some more background information can be found in Grimes (2001), Humphreys & Eberhard (2001) and Tierney & Tierney (2009). Some abiotic parameters of selected associated anchialine caves are listed in Table 2. For a comparison of abiotic parameters of Runaway Cave and Hole 19 Cave (listed as 19th Hole), please refer to Namiotko et al. (2004: 50, table 1).

A discussion with the dive operator revealed that there are more caves on other parts of the island but was accessible only during calm weather. Some of these caves are deeper, at around 40 m depth or more. They will need to be sampled at a future date.

MATERIAL AND METHODS

The following sampling methods employed for the survey work, which were conducted using SCUBA gear were hand picking and containment of specimens within plastic containers or mesh bags, overturning of coral rubble and picking of specimens under the rubble, baited traps using baitfish (*Cololabis saira* (Brevoort)) for cave dives and using fish food pellets for land accessed anchialine caves (these traps were usually left for a day before re-collection), and with the use of clove oil in ethanol emulsion to anaesthetise

¹Lee Kong Chian Natural History Museum, Faculty of Science, National University of Singapore, Singapore 117600; Email: nhmthh@nus.edu.sg (*corresponding author THH)

²Tropical Biosphere Research Center, Iriomote Station, University of the Ryukyus, 870 Uehara, Taketomi, Okinawa 907-1541, Japan

³University Education Center, University of the Ryukyus, 1 Senbaru, Nishihara, Okinawa 903-0213, Japan (&) Marine Learning Center, 2-95-101 Miyagi, Chatan, Okinawa 904-0113, Japan

Table 1. Description of submarine and associated anchialine caves in Christmas Island (*denotes submarine caves along the northwest coast).

| Name of submarine cave | GPS coordinates | Brief description |
|--|-----------------------------|---|
| Coconut Point | 10°24.741'S 105°41.868'E | This is a submarine cave system, with a narrow mouth ca. 3 m across, affected by strong surge during tidal change. Cave mouth ca. 15 m depth. |
| Daniel Roux Cave*, Smith Point | 10°26.315'S 105°39.699'E | This cave system is accessible by land, with both an upper and lower opening, with a colony of Christmas Island Swiftlets in the upper cave. The submarine cave system is accessible by an upper mouth (ca. 1.5 m across, ca. 2–3 m depth) and a lower mouth (ca. 2 m across, ca. 7 m depth). This is a narrow system, affected by strong surge during tidal change. Submarine cave merges into the anchialine system, with obvious thermocline and chemocline. |
| Thunderdome Cave* | 10°27.956'S 105°36.465'E | This is a submarine cave system, with a wide mouth (ca. 10–15 m across, ca. 17 m depth). There is a shallow extension to the right, the left passage (ca. 20–30 m) leads to an extensive system, which opens up to an airpocket with anchialine body, with obvious thermocline and chemocline. |
| Thundercliff Cave* | 10°27.964'S 105°36.404'E | This is a submarine cave system, with a wide mouth (ca. 10–15 m across, ca. 8 m depth) with two branches. The right branch ends abruptly in a cavern, the left branch extends ca. 30 m into an extensive airspace. The submerged area occupies just one side of the cave floor. Proceed on land for about 100 m and a second anchialine body is present with water temperature from the surface to a depth of about 1 m being much colder than below this. A further extension can be accessed down to about a depth of 10 m by SCUBA, but it continues further inland. No openings or light sources were observed. The second anchialine body has been named “Hama’s Sushi Bar” for Hama (dive operator of Christmas Island Wet ‘N’ Dry Adventures) and after the presence of many hippolytid shrimps. |
| West White Cave*, West White Beach (Fig. 1) | 10°27.733'S 105°35.054'E | This is a submarine cave system, with a wide mouth (ca. 15–20 m wide), narrowing to 5 m and following a fairly extensive system into an anchialine system, with obvious thermocline and chemocline. This system can be affected by strong unidirectional surge during tidal change. Cave mouth ca. 12 m depth. |
| Name of associated anchialine cave | GPS coordinates | Brief description |
| Grotto, Waterfall Road | 10°25.386'S 105°42.127'E | This is a partially collapsed marine coastal cave, penetrated by sea currents (strong water currents during tidal change) and accessible by land along Waterfall Bay Road near the Golf Course. |
| Whip Cave, near golf course | 10°25.377'S 105°42.081'E | This is a cave system with lower chamber with anchialine water affected by tidal change. Accessed via a narrow cave mouth. |
| Runaway Cave, near golf course | 10°25.386'S 105°42.063'E | This is a cave system with lower chamber with anchialine water affected by tidal change. The cave entrance to the water source is narrow and down a distance. |
| Hole 19 Cave, golf course | 10°25.492'S 105°42.074'E | This is a non-descript cave mouth, very shallow opening, requiring crawling down a slope, but opens up to a larger anchialine chamber, with tidal influence. |
| Freshwater Cave, near Blowholes | 10°30.796'S 105°37.448'E | This cave access is large but steep and leads to several anchialine chambers with deep water. |
| Daniel Roux Cave*, Smith Point | 10°26.328'S 105°39.792'E | Anchialine water is available in the lower chamber, down a steep drop with a series of rock-mounted steel ladder. The anchialine water is tidal influenced and can be dived to reach the sea. |

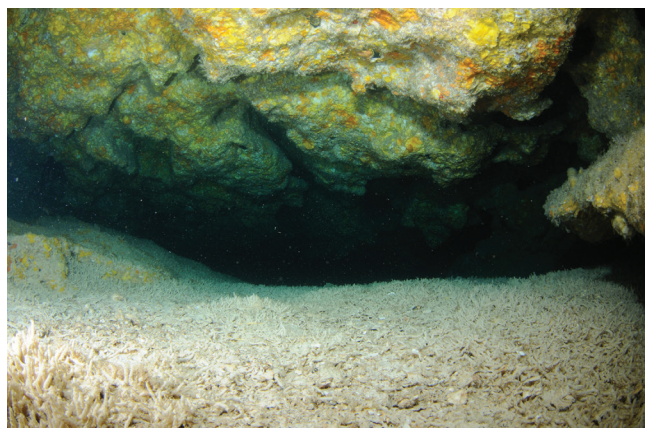


Fig. 1. West White Cave, view of cave interior at ca. 10 m depth, showing mats of tubes probably made by serpulid worms (THH 2010).



Fig. 2. Close up of the tiny *Edwardsiella* species, photographed in-situ in West White Cave (THH 2011).

small specimens in crevices or difficult to access nooks and crannies in marine caves. Specimens obtained were placed in ice slurry and freshly dead colouration documented using digital photography. Specimens were subsequently either fixed in formalin or preserved directly in ethanol. Specimens were also documented in-situ and ex-situ with various digital camera models with waterproof casing (THH – Tan Heok Hui, TN – Tohru Naruse, YF – Yoshihisa Fujita). Abiotic parameters were measured using a hand held PCSTestTM 35 multi-parameter meter.

Specimens are deposited in the following collections: ZRC – the Zoological Reference Collection of the Lee Kong Chian Natural History Museum, National University of Singapore;

QM – the Queensland Museum, Brisbane; and WAM – the Western Australian Museum, Perth. Distributional range of fish species was mainly obtained from Allen & Erdmann (2012). Abbreviation used: SL – standard length measured from tip of upper jaw to base of caudal fin (used for fishes).

RESULTS

CNIDARIA ANTHOZOA HEXACORALLIA ACTINIARIA

Edwardsiella species (Fig. 2)

Remarks: The inner surfaces of the caves not influenced by anchialine waters (West White Cave – Fig. 1, Thunderdome and Thundercliff Caves) at around 30–50 m interior, were covered by mats of numerous soft pliable tube-like structures of less than 5 mm diameter (Fig. 1), which is most likely to be a byproduct of serpulid worms. However, abandoned or empty tubes may in turn be colonised by edwardsiid anemones, which can be distinguished in part by protrusions from the column that do or do not contain certain types of nematocysts (Daphne Fautin, pers. comm.). In this case, members of the genus *Edwardsiella* live in high density and in tubes made by other animals (Marymegan Daly, pers. comm.), which fit the current situation encountered (Fig. 2) in West White Cave.

MOLLUSCA GASTROPODA Neritiliidae Schepman *Laddia traceyi* (Ladd)

Remarks: *Laddia traceyi* was recently reported by Kano & Kase (2008) from the submarine caves of Christmas Island, including Thunderdome Cave. However, this species was not obtained in the present series of expeditions. First described as a fossil from Bikini (Marshall Islands), this species has since been found in caves of disjunct oceanic islands of Japan, Southeast Asia, and Guam (see Kano & Kase, 2008).

Pisulina species

Remarks: *Pisulina adamsiana* Nevill G & Nevill H, and *P. maxima* Kano & Kase, were obtained from Thunderdome and Thundercliff Caves during the present series of expeditions. The former is a rather widespread Indo-West Pacific species

Table 2. Five abiotic parameters measured for selected anchialine caves in 2011 (ppt – parts per thousand; ppm – parts per million).

| Name of associated anchialine cave | pH | Temperature (°C) | Conductivity (μS/cm) | TDS | Salinity |
|------------------------------------|------|------------------|----------------------|----------|----------|
| Runaway Cave | 7.67 | 25.4 | 996 | 707 ppm | 497 ppm |
| Hole 19 Cave | 7.45 | 25.7 | 3930 | 2.78 ppt | 2.10 ppt |
| Freshwater Cave | 7.09 | 25.3 | 1206 | 855 ppm | 608 ppm |
| Whip Cave | 7.24 | 25.4 | 1538 | 1.09 ppt | 777 ppm |



Fig. 3. *Neritopsis radula* trail, photographed in-situ in Thundercliff Cave (YF 2012).



Fig. 4. *Neritopsis radula* with tentacles and foot extended, photographed in-situ in Thundercliff Cave (YF 2012).



Fig. 5. *Microliotia mirabilis* (top) and *Neritopsis radula* (bottom), photographed in-situ in Thundercliff Cave (YF 2012).

while the latter has only been reported from Japan, Guam, and Southeast Asia (see Kano & Kase, 2008). Both have also been previously reported from Christmas Island by Kano & Kase (2000), who also reported a third species, *Pisulina tenuis* Kano & Kase, which we did not find.

Neritopsidae Gray

Neritopsis radula (Linnaeus) (Figs. 3–5)

Remarks: Although widely distributed in the Indo-West Pacific, this species is rarely found alive and appears to be common only in submarine caves (Herbert & Kilburn, 1991; Kase & Hayami, 1992; Lozouet, 2009). Live animals, and many shells empty or inhabited by hermit crabs, were observed in Thunderdome, Thundercliff and West White Caves during the present series of expeditions. The shells seem to be particularly favoured by the larger long-legged cave-dwelling pagurid hermit crabs (Figs. 12–13). To the best of our knowledge, the accompanying figures (Figs. 3–5) are the first published in-situ images of the living animal.

Pickworthiidae Iredale

Discrevinia balba Laseron

Remarks: the original description of *Discrevinia balba* was based on a single specimen from Christmas Island by Laseron (1956). However the habitat and detailed locality information was not mentioned by Laseron, and this species does not seem to have been reported from Christmas Island since (see Tan & Low, 2014). A few shells inhabited by tiny hermit crabs were found in Thunderdome and Thundercliff Caves in the recent expeditions. This species is the type species of *Discrevinia* Laseron, 1956.

Microliotia species

Remarks: Ten species of the family Pickworthiidae are presently known to occur on Christmas Island (Tan & Low, 2014), but only two were observed during the present series of expeditions. These two species are *M. koizumii* Kase, and *M. mirabilis* (Kuroda & Habe) (Fig. 5). The presence of *M. mirabilis* on Christmas Island was only recently mentioned in Takano & Kano (2014), while *M. koizumii* is a new record for Christmas Island (see Tan & Low, 2014). The two species were found in Thundercliff Cave.



Fig. 6. *Antecaridina lauensis* from Whip Cave (THH 2010).



Fig. 7. *Macrobrachium* sp. (female) from Whip Cave (THH 2010).

CRUSTACEA

DECAPODA

CARIDEA

Alpheidae Rafinesque

Metabetaeus minutus (Whitelegge)

Remarks: Anker (2010) treated this taxon and extended the distribution range, based on specimens collected from Runaway Cave (2010). This species is distributed from Ryukyu Islands (Japan), Sulawesi Tenggara, Loyalty Islands East of New Caledonia, and Christmas Island (Anker, 2010).

Atyidae De Haan

Antecaridina lauensis (Edmondson) (Fig. 6)

Remarks: Both Namiotko et al. (2004) and Davie & Ng (2012) mention the presence of this tiny shrimp in the coastal anchialine caves. It is apparently sympatric with both cave-dwelling *Orcovita* species. This tiny shrimp with reduced eyes was obtained from Whip Cave (2010), Hole 19 Cave (2011) and Runaway Cave (2011).



Fig. 8. *Parhippolyte* sp. 1 (female) – large, photographed in-situ from West White Cave (THH 2011).



Fig. 10. *Enoplometopus voigtmanni* photographed in-situ in Thunderdome Cave (THH 2011).



Fig. 9. *Parhippolyte* sp. 2 – small red, photographed in-situ from Thundercliff Cave, foraging on diver's leg (YF 2012).



Fig. 11. *Palinurellus wieneckii* photographed in-situ in Thunderdome Cave (THH 2011).

Palaemonidae Rafinesque

Macrobrachium sp. (Fig. 7)

Remarks: This species had been previously identified as *M. microps* Holthuis, based on juvenile specimens (Humphreys & Eberhard, 2001); however, this is not the case when adults were obtained during this present series of expeditions. The description of this taxon is in progress by Fujita Y and Ng PKL. This large (more than 10 cm total length) depigmented cave shrimp was obtained from Daniel Roux Cave (2010), Whip Cave (2010) and Freshwater Cave (2011). The eggs carried by the female are all very small (less than 1 mm diameter), indicating a pelagic larval stage and indicating a possibly continual coastal anchialine cave system in Christmas Island (Humphreys et al., 2009).

Hippolytidae Bate

Parhippolyte species

Remarks: Both *Parhippolyte* sp. 1 (Fig. 8) and *Parhippolyte* sp. 2 (Fig. 9) were obtained from the deeper recesses of submarine caves. The larger species 1 was the more common species obtained in baited traps left in the caves. The smaller red species 2 was obtained only from secondary cave pool (Hama's Sushi Bar) within Thundercliff Cave, and this species have been observed to forage on diver's legs (Fig. 9).

Enoplometopidae de Saint Laurent

Enoplometopus voigtmanni Türkay (Fig. 10)

Remarks: See earlier paper (Ng & Naruse, 2014) on the new record of this species from Christmas Island and Australia. The single specimen with only one chela was obtained using clove oil about 40–50 m into the Thunderdome cave (2011). This species has also been sighted in the reefs in Flying Fish Cove during night dives (Tiernan B, pers. comm.).

Palinuridae Latreille

Panulirus species

Remarks: See earlier paper (Ng & Naruse, 2014) on the occurrence of *P. femoristriga* (von Martens), and *P. penicillatus* (Olivier) in Christmas Island. Both species were commonly encountered within 20 m from cave mouth and fished for human consumption. They are both widespread species with Indo-West Pacific distribution.

Palinurellus wieneckii (De Man) (Fig. 11)

Remarks: One ovigerous specimen was obtained in a baited trap in Thundercliff Cave (2010) and another specimen hand-picked in Thunderdome Cave (2011, see Fig. 11). See earlier paper (Ng & Naruse, 2014) on the new record of this species from Christmas Island and Australia.



Fig. 12. *Pagurixus nomurai* carrying a *Neritopsis radula* shell, photographed in-situ in Thunderdome Cave (THH 2011).

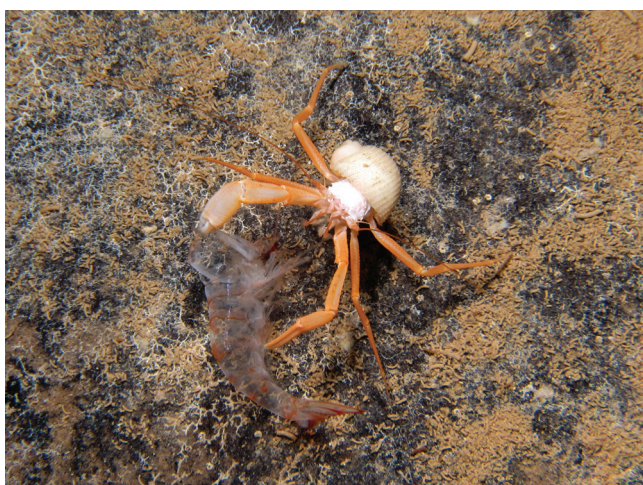


Fig. 13. Pagurid hermit crab carrying a *Neritopsis radula* shell, feeding on shrimp exuviae in Thundercliff Cave (YF 2012).

Scyllaridae Latreille

Parribacus antarcticus (Lund)

Remarks: See earlier paper (Ng & Naruse, 2014) on this species. This species is more commonly encountered on coral reefs and are nocturnally active. This is a widespread species with an Indo-Pacific distribution.

ANOMURA

Paguridae Latreille

Pagurixus nomurai Komai & Asakura (Fig. 12)

Remarks: This taxon was described originally from Kumejima Island (Ryukyu Islands, Japan) by Komai & Asakura (1995), and this represents a new record for this species in the eastern Indian Ocean. This species typically uses the shell of *Neritopsis radula* Linnaeus, in West White, Thundercliff and Thunderdome Caves in Christmas Island.

Paguridae new genus and new species 1 (Fig. 13)

Remarks: This new taxon is now being described by Osawa M and his colleagues. This long-legged, small-eyed pagurid hermit crab is a fast mover that can scramble quickly into



Fig. 14. Pagurid hermit crab carrying a *Microliotia mirabilis* shell, photographed in-situ in Thundercliff Cave (YF 2012).

crevices to avoid capture. It will also discard the gastropod shell being carried over its abdomen to avoid capture (pers. obs.). One specimen had been observed to be feeding on a hippolytid shrimp moult (Fig. 13). This species typically uses the shell of *Neritopsis radula* Linnaeus, in West White, Thundercliff and Thunderdome Caves in Christmas Island.

Paguridae new genus and new species 2 (Fig. 14)

Remarks: This new taxon is now being studied and will be described later by Osawa M and his associates. This species typically uses the shell of *Microliotia mirabilis* (Kuroda & Habe), as it is a smaller-sized taxon. It was collected from West White, Thundercliff and Thunderdome Caves in Christmas Island.

Diogenidae Ortmann

Clibanarius new species

Remarks: The description of this new species is part of the study by Osawa M.

BRACHYURA

Portunidae Rafinesque

Carupa species

Remarks: Both *C. ohashii* Takeda, and *C. tenuipes* Dana, are normally found in crevices and caves (Takeda, 1993; Kawamoto & Okuno, 2009). These species have been recorded from Indo-West Pacific waters.

Christmaplacidae Naruse & Ng

Christmaplax mirabilis Naruse & Ng

Remarks: This whitish crab species is superficially similar to the varunid *Orcovita* Ng & Tomascik, in its colouration, elongated ambulatory legs and reduced eyes, but it is actually a new species of a new genus of the superfamily Pseudozioidea Alcock (described within this volume, see Naruse & Ng 2014). Since it cannot be placed in any of the three pseudozoid families, a new family, Christmaplacidae, is established for it. This species is known from only two

specimens collected from the second anchialine body of the Thundercliff Cave. Its asymmetrical chelae in both male and female as well as the presence of abraded molariform teeth on both immovable and movable fingers suggest that *C. mirabilis* is molluscivorous, feeding on the cave gastropods.

Sesarmidae Dana

Karstarma jacksoni (Balss)

Remarks: This endemic species was originally described from Christmas Island and is widespread throughout the island, having been found in caves, forests, and even in people's homes (pers. obs.). This taxon was also encountered in Thundercliff Cave airpocket during the short trek into the second anchialine cave water (TN pers. obs. 2010). It was encountered in both the Runaway Cave (2010) and the Grotto (2010) climbing on cave walls.

Varunidae H. Milne Edwards

Orcovita species

Remarks: *Oorcovita hicksi* Davie & Ng, and *O. orchardorum* Davie & Ng, had only been recently described based on specimens obtained primarily from Whip, Runaway, Freshwater and Hole 19 Caves (Davie & Ng, 2012); although only *O. orchardorum* had been obtained from the Grotto in 2012. Both of these endemic species are sympatric and most probably have a marine dispersal phase, which explains their continual presence in coastal anchialine caves on the northwestern and southern coasts of Christmas Island (Humphreys et al., 2009).

Xanthidae MacLeay

Atergatis dilatatus De Haan

Remarks: One male of *A. dilatatus* was collected near the air pocket of the left branch of the Thundercliff Cave (2012). This species has been recorded from Indo-West Pacific waters.

Neoliomera cerasinus Ng (Fig. 15)

Remarks: *Neoliomera cerasinus* was originally described based on the specimens collected from Thunderdome Cave, Christmas Island [type locality] and Kumejima Island, Ryukyu Islands, Japan (Ng, 2002). Subsequently, the species has been found from Okinawa Island and Shimoji Island, Ryukyu Islands (Fujita et al., 2013; Naruse T, unpublished data). It is interesting that the carapace width of the specimens from the Ryukyus are 1.6–2.3 times larger than that of Christmas Island (Fujita et al., 2013).

In Christmas Island, *N. cerasinus* had been found in Thunderdome, Thundercliff and West White Caves. In Thundercliff Cave, more than one deposition of crab exoskeleton (from most probably this species) had been encountered during dives conducted there (Fig. 16). It is not clear whether the depositions of exoskeleton came from dead specimens or from moults (though the likelihood is from dead specimens as the discarded exoskeleton is much thicker than from moults).



Fig. 15. *Neoliomera cerasinus* photographed in-situ in West White Cave (THH 2011).



Fig. 16. A deposition of *Neoliomera* exoskeleton photographed in-situ in Thundercliff Cave (THH 2012).

Paramedaeus sp.

Remarks: This specimen was collected from under a limestone rock on a sandy-muddy slope, about 20 m from an entrance of the Thundercliff Cave (2012) at left branch. The cave bent almost perpendicularly just after the entrance, so the habitat was very dark. See earlier paper (Mendoza et al., 2014).

ECHINODERMATA

CRINOIDEA

Mariametridae Clark AH

Lamprometra palmata (Müller)

Remarks: This species was collected from West White Cave and Thunderdome Cave. It is commonly found in the coral reefs at night. This is a widespread species with an Indo-Pacific distribution and has been previously recorded from Christmas Island (Marsh, 2000).

Stephanometra indica (Smith)

Remarks: This species was collected from West White Cave and Thunderdome Cave. It is a nocturnal species and commonly found in the coral reef habitat. This is a widespread

species with an Indo-Pacific distribution and has been previously recorded from Christmas Island (Marsh, 2000).

ASTEROIDEA
Ophidiasteridae Verrill
Leiaster sp. (Fig. 17)

Remarks: A single specimen was collected from Thunderdome Cave. This is apparently a new record for Christmas Island, as it had not been previously listed by Marsh (2000).

Linckia multifora (Lamarck)

Remarks: This species was collected from West White Cave and Thunderdome Cave. This species commonly inhabits outer reef slopes. This species has been previously recorded from Christmas Island by Marsh (2000).

Goniasteridae Forbes
Fromia nodosa Clark AM (Fig. 18)

Remarks: This species was collected from West White Cave and Thunderdome Cave. This species is commonly found in coral reef. This is the first record of this species from Christmas Island.

Mithrodiidae Viguier
Mithrodia clavigera (Lamarck)

Remarks: this species was obtained from West White Cave. It is typically a nocturnal species or inhabiting caves and crevices. It has been recorded previously from Christmas Island (Marsh, 2000).

OPHIUROIDEA
Ophiomyxidae Ljungman
Ophiomora elegans Koehler

Remarks: A single specimen was collected from Thunderdome Cave. The species is known only from one specimen collected from the Fernando Veloso, East African coast (Koehler, 1907). The present specimen is the second record of the species and new record for Christmas Island. Detailed descriptions will be published separately by Irimura et al. (in preparation).

Ophiocomidae Ljungman
Ophiopsila pantherina Koehler (Fig. 19)

Remarks: Aggregations were found in the sandy bottom of Thunderdome Cave and Thundercliff Cave. In-situ observations noted visible green light flashes on their arms, indicating that this species is bioluminescent. Detailed descriptions will be published separately by Irimura et al. (in preparation). This is the first record of the species from Christmas Island.



Fig. 17. *Leiaster* sp. from Thunderdome Cave (YF 2011).



Fig. 18. *Fromia nodosa* photographed in-situ in West White Cave (YF 2011).



Fig. 19. *Ophiopsila pantherina* photographed in-situ in Thunderdome Cave (YF 2011).

Ophiodermatidae
Ophioconis cupida Koehler

Remarks: This species was obtained with a baited trap from Thunderdome Cave. This is the first record of the species from Christmas Island. Detailed descriptions will be published separately by Irimura et al. (in preparation).

HOLOTHUROIDEA
Stichopodidae Haeckel
Stichopus noctivagus Cherbonnier (Fig. 20)

Remarks: This species was observed from Thundercliff Cave. The colour pattern is similar as in previous locations. It is only known from the Pacific Ocean and this is the first record of the species from Christmas Island.

HEMICHORDATA
Enteropneusta
Acorn worm (Fig. 21)

Remarks: The unidentified acorn worm is fairly common on the surface of the substratum in the submarine caves. It appears to secrete a thin mucous covering over itself, and feeds on the superficial layer atop the sandy silty substratum (Fig. 48).

TELEOSTEI
ANGUILLIFORMES
Anguillidae Rafinesque
Anguilla bicolor McClelland (Fig. 22)

Remarks: A single juvenile specimen (267.0 mm SL) was obtained with a baited trap from Daniel Roux Cave (2010). Large adults are commonly sighted in the shallow creeks in the Dales. It appears that *Anguilla bicolor* is a new published record for Christmas Island, despite its presence being reported in the tourism trade and internet resources (e.g., <http://www.masterfile.com/stock-photography/image/848-06821981/Indonesian-Shortfin-Eel-%28Anguilla-bicolor%29-migrating-up-a-freshwater-stream-Christmas-Island-Indian-Ocean-Territory-of-Australia>). This is most often mis-identified as *A. marmorata* which had been recorded from Anderson Dale (Butcher & Hale, 2010). This is a widespread species with an Indo-Pacific distribution.



Fig. 20. *Stichopus noctivagus* photographed in-situ in Thundercliff Cave (YF 2010).



Fig. 21. Acorn worm photographed in-situ in Thundercliff Cave (TN 2012).



Fig. 22. *Anguilla bicolor* (267.0 mm SL juvenile) from Daniel Roux Cave (THH 2010).



Fig. 23. *Congresox talabonoides* (235.0 mm SL juvenile) from Whip Cave (THH 2010).



Fig. 24. *Diancistrus* sp. (about 150 mm SL) photographed in-situ from West White Cave (THH 2011).



Fig. 25. *Photoblepharon palpebratum* (56.2 mm SL) from Thundercliff Cave (THH 2012).

Muraenidae Rafinesque

Echidna unicolor Schultz in Schultz, Herald, Lachner, Welanders & Woods

Remarks: This species was obtained with a baited trap from Whip Cave (2010, 2011). Previously recorded by Allen et al. (2007) from coral reef habitats. This fish species illustrates a definitive link from the Whip Cave to the sea. This is a widespread species with an Indo-Pacific distribution.

Muraenesocidae Kaup

Congresox talabonoides (Bleeker) (Fig. 23)

Remarks: A small individual (235.0 mm SL) was obtained with a baited bottle trap from Whip Cave (2010). This appears to be a new record for Christmas Island. This is a widespread species with an Indo-Pacific distribution.

OPHIDIIFORMES

Bythitidae Gill

Diancistrus sp. (Fig. 24)

Remarks: An individual (about 150 mm SL) was sighted while diving in West White Cave in 2011. This individual was encountered towards the end of the cave in chilled (anchialine) cave waters, amongst the cave crevices. Only a couple of photographs were captured before the fish escaped further into the cave recesses too narrow to dive into. The identity of this fish cannot be ascertained without physical specimens, although up to four dinematchyinine taxa have been recorded in Christmas Island waters, viz. *Brosmophyciops pautzkei* and *Ogilbia* sp. (both recorded by Allen et al., 2007), *Dinematchythus trilobatus* (described from Christmas Island by Möller & Schwarzhans, 2008) and *Paradiancistrus christmasensis* (described from Christmas Island by Schwarzhans & Möller, 2011); but all four species having larger eyes. The present species record is based on in-situ photographs and tentatively belongs to the *Diancistrus erythraeus* group, which are thick-headed and with very small eyes (Schwarzhans W, pers. comm. 2012).

BERYCIFORMES

Anomalopidae Gill

Photoblepharon palpebratum (Boddaert) (Fig. 25)

Remarks: This flashlight fish is a new record for Christmas Island from Thundercliff Cave (2012); and apparently for the eastern Indian Ocean (the rest of the range is mainly the Pacific; Allen & Erdmann, 2012). It was observed during both daytime and night at the second anchialine water body, and only at night near the marine entrance of the cave. It is typically a nocturnal schooling species inhabiting caves and crevices. It also inhabits outer reef habitats along steep slopes (Allen & Erdmann, 2012).

HOLOCENTRIFORMES

Holocentridae Bonaparte

Myripristis vittata Valenciennes in Cuvier & Valenciennes

Remarks: All holocentrid species are typified by having large eyes, a general reddish body colouration with strong dorsal- and anal-fin spines. They are all nocturnally active, usually taking shelter close to reefs, often in caverns, caves or under coral tables. These species (not all identifiable to species) were generally encountered individually or in schools of 5 or more near or within 10–20 m of cave mouths (pers. obs.). There are 13 other holocentrid fish species from three genera, *Myripristis*, *Plectrypops* and *Sargocentron*, recorded from waters around Christmas Island (Allen et al., 2007); having an Indo-Pacific distribution.

PERCIFORMES

Epinephalidae Bleeker

Cephalopholis sexmaculatus Rüppell

Remarks: An individual of about 30 cm SL was observed about 30 m within the Thunderdome Cave (2010). This is a widespread species with an Indo-Pacific distribution.

Kuhliidae Jordan & Evermann

Kuhlia mugil (Bloch & Schneider)

Remarks: This species is common in the shallows in rocky habitats and rocky tide pools, occurring in large schools (Allen et al., 2007). This species was commonly sighted in the Grotto. This is a widespread species with an Indo-Pacific and eastern Pacific distribution.

KURTIFORMES

Apogonidae Günther

Cercamia eremia (Allen)

Remarks: This small species is rarely encountered, as it inhabits crevices and caves (Allen et al., 2007). This is a widespread species with an Indo-West Pacific distribution.

PEMPHERIFORMES

Pempheridae Bleeker

Pempheris oualensis Cuvier in Cuvier & Valenciennes

Remarks: Aggregations of 20 or more were usually encountered near cave mouths (pers. obs.). This is a widespread species with an Indo-Pacific distribution.

GOBIIFORMES

Eleotrididae Bonaparte

Eleotris fusca (Bloch & Schneider) (Fig. 26)

Remarks: This species was only obtained from anchialine caves with baited traps. The caves were Daniel Roux Cave (2010), Whip Cave (2010, 2011), Runaway Cave (2011) and Freshwater Cave (2011, 2012). The cave populations in Christmas Island are typified by a pale body colour, seemingly enlarged pectoral and caudal fins (Humphreys & Eberhard, 2001; pers. obs.). Previously recorded by Humphreys &



Fig. 26. *Eleotris fusca* (66.6 mm SL) from Whip Cave (THH 2010).

Eberhard (2001) and Allen et al. (2007). This is a widespread species with an Indo-West Pacific distribution.

Gobiidae Cuvier

Trimma fasciatum Suzuki, Sakaue & Senou

Remarks: See earlier chapter on the first record of this tiny gobiid fish from Christmas Island (Tan, 2014).

DISCUSSION

In combination, a total of about 150 hours was spent on subtidal sampling in Christmas Island waters (see Tan et al., 2014a for details on the dive locations). Of which slightly more than half (78 hours) of the dives were spent exploring submarine caves (based on four divers' efforts; see Tan et al., 2014b).

The current observations and collections are interesting and represent a preliminary effort to document the macro-fauna occurring in submarine and associated anchialine caves. Within such a small oceanic karstic island, there exist numerous stygobitic and stygophilic macro-fauna, viz. Pisces: dinematchyinine fishes, *Eleotris fusca* and *Trimma fasciatum*; Crustacea: *Antecaridina lauensis*, *Atoportunus gustavi*, *Chrismaplex mirabilis*, *Macrobrachium* sp., *Metabetaeus minutus*, *Neoliomera cerasinus*, *Orcovita orchardorum*, *O. hicksi*, *Procaris noelensis*, two new genera and two new species of Paguridae; Gastropoda: *Discrevinia balba*, *Laddia traceyi*, *Microliotia koizumii*, *Microliotia mirabilis*, *Neritopsis radula*, *Pisulina adamsiana*, *Pisulina maxima*. This demonstrates the possible palaeo-connectivity of this refugium for relict and disjunctly distributed fauna as has been suggested by Humphreys (2000).

Arguably the most exciting find from the present surveys is *Chrismaplex mirabilis* Naruse & Ng (2014), which is a new family, new genus and new species described in this volume. We had not expected such a spectacular blind crab in the anchialine waters of a submarine cave. Its discovery goes a long way to demonstrate that the subterranean and submarine systems in Christmas Island are very extensive and more explorations are needed to understand the diversity there. Clearly, these habitats have been stable environments for a long time to allow a community of diverse cave fauna to evolve.

Despite the concerted efforts in three main submarine caves (Thundercliff, Thunderdome and West White Caves) surveyed using SCUBA, several enigmatic organisms discovered by

previous expeditions were not found. Some of these are *Discrevinia balba* and several other pickworthiids (see Tan & Low, 2014), *Laddia traceyi* (Mollusca), *Humphreysella baltanasi*, *Microceratina martensi* (Ostracoda), and *Atoportunus gustavi* (Crustacea). The endemic ostracod *Humphreysella baltanasi* was described as a species of *Danielopolina* (Humphreys et al., 2009) but subsequently revised and placed under *Humphreysella* by Iglukowska & Boxshall (2013). This enigmatic ostracod was obtained from coastal anchialine caves (Stranglers, Runaway, Whip and Hole 19 Caves). The other endemic ostracod *Microceratina martensi* was described by Namiotko et al. (2004) from Runaway and Hole 19 Caves, again coastal anchialine caves. The swimming crab *Atoportunus gustavi* (described by Ng & Takeda, 2003) is peculiar with elongated limbs and chelae with elongated pincers and teeth, and had been previously obtained from a submarine cave (most likely Thunderdome Cave, Hamanaka T, pers. comm.), but was not sighted or obtained in the present series of expeditions. This could be due to seasonality or rarity of the species (Humphreys & Eberhard, 2001), as it had been collected during the middle of the year.

Another enigmatic crustacean not obtained from the present series of expeditions is *Procaris noelensis* (Procarididae). This relict species was described from the anchialine waters of Runaway Cave based on a single specimen (Bruce & Davie, 2006). Recent attempts to obtain this species using baited traps (of different dimensions and mesh sizes) did not yield any result. The type specimen was obtained in 1998 and during a spell of exceptional drought (Humphreys W, pers. comm.), and that may be the reason for its rarity, or it may be due to seasonality (Humphreys & Eberhard, 2001).

Given the intensity of the present sampling, it may be worth specifically noting species known to be present that were not taken (e.g., *Procaris*, *Humphreysella*, *Microceratina*), indicating that smaller anchialine fauna can be very difficult to sample (Humphreys, 2014). To add onto the difficulties of sampling work in caves, there is presence of salinity stratification of such anchialine caves, which can delimit the distribution and abundance of stenotopic living organisms in the water column (Humphreys et al., 2009).

In the future, with longer survey times and visits at different parts of the year to account for seasonality and different environments, e.g., caves with entrances at further depth, more records can be established with a combination of techniques.

ACKNOWLEDGEMENTS

We would like to express our utmost gratitude to the following: Max Orchard, Michael Misso, Michael Smith, Brendan Tiernan, Tanya Detto (Christmas Island National Park), for logistic support and generous field assistance; Bill Humphreys and Peter Ng, for their speedy and critical reviews of the manuscript, which helped improve the quality greatly; James Reimer, Marymegan Daly, Daphne Fautin, for the preliminary identification of the cave cnidarian; Teruki

Hamanaka (Christmas Island Wet 'N' Dry Adventures), for dive logistics and informative conversations; Lynnie, divemaster extraordinaire and baker of great treats; Lisa Preston (Indian Ocean Experiences), for logistic support and coordination; Bill Humphreys (WAM), for literature resource; Peter Ng, Peter Davie, Tan Kai-xin, Joelle Lai, Jose Christopher Mendoza, Tan Swee Hee, Leo Tan, Shih Hsi-te, for field companionship and assistance; Greasi Simon and Martyn Low, for museum support; Parks Australia Headquarters for research permits AU-COM 2009059, AU-COM 2011096, AU-COM 2012-127, AU-COM 2012-133, and export permits WT2009-6257, 2010-AU-618424, WT2011-1465; funding from LKCNHM and NUS. Last, but not least, Tooheys Extra Dry, for keeping us sane with the clean crisp taste.

LITERATURE CITED

- Allen GR, Steene RC & Orchard M (2007) *Fishes of Christmas Island* (second edition). Christmas Island Natural History Association, 284 pp.
- Allen GR & Erdmann MV (2012) *Reef Fishes of the East Indies*. Volumes I, II, III. Tropical Reef Research, Perth, Australia, 1292 pp.
- Anker A (2010) *Metabetaeus* Borradaile, 1899 revisited, with description of a new marine species from French Polynesia (Crustacea: Decapoda: Alpheidae). *Zootaxa*, 2552: 37–54.
- Bruce AJ & Davie PJF (2006) A new anchialine shrimp of the genus *Procaris* from Christmas Island: the first occurrence of the Procarididae in the Indian Ocean (Crustacea: Decapoda: Caridea). *Zootaxa*, 1238: 23–33.
- Butcher R & Hale J (2010) Ecological Character Description for The Dales Ramsar Site. Report to the Department of Sustainability, Environment, Water, Population and Communities, Canberra, 82 pp.
- Davie PJF & Ng PKL (2012) Two new species of *Orcovita* (Crustacea: Decapoda: Brachyura: Varunidae) from anchialine caves on Christmas Island, Eastern Indian Ocean. *Raffles Bulletin of Zoology*, 60 (1): 57–70.
- Fujita Y, Naruse T & Yamada Y (2013) Two submarine cavernicolous crabs, *Atoportunus gustavi* Ng & Takeda, 2003, and *Neoliomera cerasinus* Ng, 2002 (Crustacea: Decapoda: Brachyura: Portunidae and Xanthidae), from Shimojijima Island, Miyako Group, Ryukyu Islands, Japan. *Fauna Ryukyuna*, 1: 1–9. [in Japanese with English abstract]
- Grimes KG (2001) Karst features of Christmas Island (Indian Ocean). *Helictites*, 37 (2): 41–58.
- Herbert DG & Kilburn RN (1991) The occurrence of *Pisulina* (Neritidae) and *Neritopsis* (Neritopsidae) in southern Africa (Mollusca: Gastropoda: Neritoidea). *Annals of the Natal Museum*, 32: 319–323.
- Humphreys WF (2000) Chapter 30. The hypogean fauna of the Cape Range peninsula and Barrow Island, northwestern Australia. In: Wilkens H, Culver DC & Humphreys WF (eds.) *Ecosystems of the World. Subterranean Ecosystems*. Vol. 30, Elsevier, Amsterdam, pp. 581–601.
- Humphreys WF (2014) Subterranean fauna of Christmas Island: habitats and salient features. *Raffles Bulletin of Zoology*, Supplement 30: this issue.
- Humphreys WF & Danielopol DL (2006) *Danielopolina* (Ostracoda, Thaumatoceprididae) on Christmas Island, Indian Ocean, a sea mount island. *Crustaceana*, 78 (11): 1339–1352.
- Humphreys WF & Eberhard S (2001) Subterranean fauna of Christmas Island, Indian Ocean. *Helictite*, 37(2): 59–74.

- Humphreys WF, Kornicker LS & Danielopol LS (2009) On the origin of *Danielopolina baltanasi* sp. n. (Ostracoda, Thaumatoctypridoidea) from three anchialine cave on Christmas Island, a seamount in the Indian Ocean. *Crustaceana*, 82(9): 1177–1203. DOI:10.1163/156854009X423157
- Iglikowska A & Boxshall GA (2013) *Danielopolina* revised: phylogenetic relationships of the extant genera of the family Thaumatoctyprididae (Ostracoda: Myodocopa). *Zoologischer Anzeiger*, 252: 469–485.
- Kano Y & Kase T (2000) Taxonomic revision of *Pisulina* (Gastropoda: Neritopsina) from submarine caves in the tropical Indo-Pacific. *Paleontological Research*, 4(2): 107–129.
- Kano Y & Kase T (2008) Diversity and distributions of the submarine-cave Neritiliidae in the Indo-Pacific (Gastropoda: Neritimorpha). *Organisms, Diversity & Evolution*, 8(1): 22–43.
- Kase T & Hayami I (1992) Unique submarine cave mollusc fauna: composition, origin and adaptation. *Journal of Molluscan Studies*, 58: 446–449.
- Kawamoto T & Okuno J (2009) Shrimps and crabs of Kume Island, Okinawa. Third edition. Hankyu Communications Co., Ltd., 175 pp. [in Japanese]
- Koehler R (1907) Revision de la collection des Ophiures du Museum d'histoire Naturelle Paris. *Bulletin Sciences de la France et de la Belgique*, 41: 279–351, 5 pls.
- Komai T & Asakura A (1995) *Pagurixus nomurai*, new species, and additional record of *Pagurixus maorus* (Nobili, 1906), hermit crabs from Kume-jima Island, the Ryukyus, Japan (Decapoda: Anomura: Paguridae). *Journal of Crustacean Biology*, 15(2): 341–354.
- Laserson CF (1956) The families Rissoinidae and Rissoidae (Mollusca) from the Solanderian and Damperian zoogeographical provinces. *Australian Journal of Marine and Freshwater Research*, 7(3): 384–485.
- Lozouet P (2009) A new Neritopsidae (Mollusca, Gastropoda, Neritopsina) from French Polynesia. *Zoosystema*, 31(1): 189–198.
- Marsh L (2000) Echinoderms of Christmas Island. *Records of the Western Australian Museum*, Supplement 59: 97–101.
- Meek PD (2001) The history of Christmas Island and the management of its karst features. *Helictite*, 37(2): 31–36.
- Mendoza JCE, Lasley Jr RM & Ng PKL (2014) New records of rock crabs (Crustacea: Brachyura: Pseudoziidae, Xanthidae) from Christmas and Cocos (Keeling) Islands, eastern Indian Ocean. *Raffles Bulletin of Zoology*, Supplement 30: this issue.
- Møller PR & Schwarzhans W (2008) Review of the Dinematchyini (Teleostei: Bythitidae) of the Indo-west Pacific. Part IV. *Dinemactichthys* and two new genera with descriptions of nine new species. *The Beagle, Records of the Museums and Art Galleries of the Northern Territory*, 2008, 24: 87–146.
- Namiotko T, Wouters K, Danielopol DL & Humphreys WF (2004) On the origin and evolution of a new anchialine stygobitic *Microceratina* species (Crustacea, Ostracoda) from Christmas Island (Indian Ocean). *Journal of Micropalaeontology*, 23: 49–59.
- Naruse T & Ng PKL (2014) A new family, genus and species of cavernicolous crab (Crustacea: Decapoda: Brachyura: Pseudoziidae) from Christmas Island, Australia. *Raffles Bulletin of Zoology*, Supplement 30: this issue.
- Ng PKL (2002) On a new species of cavernicolous *Neoliomera* (Crustacea: Decapoda: Brachyura: Xanthidae) from Christmas Island and Ryukyus, Japan. *Raffles Bulletin of Zoology*, 50(1): 95–99.
- Ng PKL & Naruse T (2014) The lobsters of Christmas Island and Cocos-Keeling Island, with new records of *Palinurellus wieneckii* (De Man, 1881) and *Enoplometopus voigtmanni* Türkay, 1989 (Crustacea: Decapoda: Palinuridae, Scyllaridae, Enoplometopidae). *Raffles Bulletin of Zoology*, Supplement 30: this issue.
- Ng PKL & Takeda M (2003) *Atoportunus*, a remarkable new genus of cryptic swimming crab (Crustacea: Decapoda: Brachyura: Portunidae), with descriptions of two new species from the Indo-West Pacific. *Micronesia*, 35–36: 417–430.
- Schwarzhans W & Møller PR (2011) New Dinematchyini (Teleostei: Bythitidae) from the Indo-west Pacific, with the description of a new genus and five new species. *The Beagle, Records of the Museums and Art Galleries of the Northern Territory*, 2011, 27: 161–177.
- Takano T & Kano Y (2014) Molecular phylogenetic investigations of the relationships of the echinoderm-parasite family Eulimidae within Hypsogastropoda (Mollusca). *Molecular Phylogenetics and Evolution*, 79: 258–269.
- Takeda M (1993) A new swimming crab of the genus *Carupa* from submarine caves in the Ryukyu Islands. *Bulletin of the National Science Museum, Tokyo*, series A, 19(4): 145–150.
- Tan HH (2014) A new record of *Trimma fasciatum* Suzuki, Sakaue & Senou 2012 (Perciformes: Gobiidae) from Christmas Island, Indian Ocean, Australia. *Raffles Bulletin of Zoology*, Supplement 30: this issue.
- Tan HH, Tan SK, Tan KX, Lai JCY, Mendoza JC & Tan SH (2014a) Christmas Island and Pulu Keeling Expeditions 2010 to 2012. Field work and locality records. *Raffles Bulletin of Zoology*, Supplement 30: this issue.
- Tan HH, Davie PJF & Ng PKL (2014b) Christmas Island and Pulu Keeling Expeditions 2010 to 2012: expedition report. *Raffles Bulletin of Zoology*, Supplement 30: this issue.
- Tan SK & Low MEY (2014) Checklist of the Mollusca of Cocos (Keeling) / Christmas Island ecoregion. *Raffles Bulletin of Zoology*, Supplement 30: this issue.
- Tierney B & Tierney S (2009) *The Essential Christmas Island Travel Guide*. Edited by Cash L. Second edition. Christmas Island Tourism Association, 192 pp.