BIODIVERSITY SURVEY OF THE HINAGDANAN CAVE

I INTRODUCTION

Anchialine pools, as defined in the 1984 International Symposium on the Biology of Marine Caves, are cave habitats that “consist of bodies of haline waters, usually with a restricted exposure to open air, always with more or less extensive subterranean connections to the sea, and showing noticeable marine as well as terrestrial influences" (Stock *et al.*, 1986; Iliffe, 2000). They can occur in uplifted coralline islands and in coastal lava tubes produced by volcanoes. Organisms living in Anchialine pools located closer to the sea tend to be typical marine species while those living farther inland have fewer species that assume several unusual forms (Iliffe, 2000).

Anchialine caves have limited geographical range and are almost restricted to coastal limestone areas (Iliffe, 2000). They are well studied in Neotropical regions like Australia but less studied in Southeast Asia, the Pacific, and Africa. In the Philippines, anchialine caves have been studied in the islands of Palawan, Samar and Bohol (refer to Ng *et al.*, 1996). More specifically, Bohol anchialine caves, have been intensively studied for their caverniculous crabs and shrimps for the last two decades (refer to Ng *et al.*, 1996; Ng and Guinot, 2001; Ng, 2002; Davie and Ng, 2007; Ng *et al.,* 2008; Cai *et al.*, 2009; Husana *et al.*, 2009; Mendoza and Naruse, 2010; Ng and Shih, 2014).

One anchialine cave located in Panglao, Bohol was recently studied by the Department of Environment and Natural Resources (DENR-CENRO, *unpublished*). The cave known as Hinagdanan Cave was surveyed last May 14, 2015 with the purpose of classifying and determining its utilitarian value (refer to DENR memorandum no. 2007-04). This was followed by a more recent survey conducted by a team of researchers from Silliman University and Marine Conservation Philippines last July 19 to 23, 2015. The survey which is presently the subject of this report focused on the inventory of cave pool inhabitants (stygofauna) not previously studied by the DENR team, the re-inventory of the troglofauna species, the documentation of the physico-chemical characteristics of the cave and the 3D mapping of the cave. The study was funded by the JICA under the Sustainable Environment Protection Project (SEPP) of Panglao.

II DESCRIPTION OF THE PROJECT SITE

The Hinagdanan Cave is found in Sitio Bingag, Barangay Dauis, Panglao Island, Bohol (Fig. 1). The main entrance to the cave can be located by its coordinates 9° 37.527’ N, 123° 48.056’ E. The single entrance (and exit) to the cave is defined by a short narrow vertical passage that descends to about five meters below the ground.

This is proceeded by a wider passage that descends northwards before connecting to the main chamber where an elliptical pool (circa 20m diameter) can be found. Two narrow skylights each measuring around one meter wide provide natural lighting to the main chamber at the northeastern side of the pool. The longest part of the cave measures about 54m long while the widest part is about 30m wide. The highest point of the cave ceiling or roof is approximately 12m high from the pool surface. The pool is connected to a series of meandering underwater tunnels that sometimes contain air pockets or tiny chambers. Some of these flooded tunnels abruptly end up as small underwater openings that can no longer be explored. The proximity of the cave to the sea is about one hundred meters. The ground surface directly above the cave is mostly exposed with some planted trees.

Fig. 1 Tourist destination map of Panglao Island showing the Hinagdanan Cave (Source:www.boholbikers.com). The cave can be located by its coordinates 9° 37.527’ N, 123° 48.056’

The Hinagdanan Cave is presently promoted for ecotourism by the local government of Bingag, Dauis (Fig 2). Several cave infrastructures like concrete steps and artificial lighting are in place to improve accessibility and illumination to the cave. Cave visit average about 200 visitors a day and is open year round (cave guide personal communication). Hinagdanan Cave is about 8 kilometers from Tagbilaran City and can be reached by vehicle via the old Panglao North Road (Fig. 1).

Fig. 2 Gateway to Hinagdanan Cave in Bingag, Dauis. The shed has two concrete benches that can accommodate 8 persons waiting for their turn to enter the cave (Photo source: DENR April 2015 report).

II MATERIALS AND METHOD

The Hinagdanan Cave survey focused on the cave fauna and physico-chemical aspects of the cave. They include the inventory of troglofauna and stygofauna cave inhabitants and the analysis of some physico-chemical parameters that helped describe the conditions of the cave chamber and cave pool. In addition to this, cave mapping was also conducted to elucidate the important features of the cave.

For purpose of classifying cave organisms, the report adopted the Troglofauna and Stygofauna categories which are based on the habitats and life history of the organisms. Terrestrial troglofauna is further categorized as: 1) Troglophile if the animal can complete its life cycle in a cave, but can also survive in above ground habitats; 2) Trogloxene if the animal uses the cave for shelter but does not complete its life cycle in them; and 3) Troglobite if it cannot survive outside its cave environment. On the other hand the aquatic stygofauna is further categorized as: 1) Stygophile if it inhabits both surface and subterranean aquatic environments, but is not necessarily restricted to either; 2) Stygoxene if the animal is like the stygophile but found occasionally or accidentally in subterranean waters. Stygophiles and stygoxenes may live for part of their lives in caves but do not complete their life cycle in them; and 3) Stygobite if the animal is an obligate or strictly subterranean, aquatic animals and complete their entire life in this environment.

1. *Troglofauna sampling method*

Volant animals were sampled using mist nets. The nets were placed vertically above the two sinkholes (skylights) located on the ground surface during daytime and early evenings. Animals captured in the nets were immediately identified, photographed and released. Identification of the birds and bats followed after Kennedy *et al.*(2000)and Ingle and Heaney (1992), respectively.

In addition to this, community roof survey (cave ceiling survey) was also done during daytime inside the cave using headlamps to determine the approximate number of nesting individuals and to determine the number of nests and their locations. Density estimates were made based on the number of individuals counted per square meter (refer to Tababa *et al.*, 2007; Sedlock and Ingle, *unpublished*). The cave was also visited during night time (with the artificial lights out) and surveyed for presence of animals that were active during the period.

2. *Stygofauna sampling method*

Stygofauna was sampled using baited traps. It employed the use of 30 improvised Thiel-Türkay traps (refer to Manning, 1986) fashioned from translucent 1.5 liter plastic soda containers with 21mm openings (Fig. 3). The traps were baited with chopped pieces of sardinella and were carefully laid on the bottom of the pool in a grid–like manner at three meters apart. The trap line or grid was set to represent three distinctive sections of the pool; a shallow and partially lighted (natural lighting from the skylights) section, midsection of the pool which was about 3m deep and in complete darkness and the deepest (circa 4m) section also completely engulfed in darkness. The position of the traps in the different sections of the pool allowed independent analyses of different variables using one-way ANOVA. The traps were retrieved early morning the following day. They were then re-baited and reinstalled in their original positions. Captured individuals were placed briefly on ice to sedate them. They were then measured and photographed and allowed to revive before returning to the pool.

Fig. 3 A Thiel-Türkay trap with captured fish. The trap is made from 1.5 liter plastic soda container fitted with netting material.

mpling of stygofauna was also made using individuals were then photographed and aphs of some species were also taken in the pool and around the cave as part of the documentation.

The identification of crabs followed after Ng *et al.* (1996), Ng and Guinot (2001) and Clements *et al.*, (2006) while identification of gastropods was based on Kano and Kase (2006). Moreover, the identification of fish was based on Inger and Kong (1962) and Fishbase (http://www.fishbase.org).

3. *Ambient air temperature and relative humidity, cave illumination and water analysis*

The cave ambient temperature and relative humidity were monitored twenty-four hours a day using a portable digital hygrometer. The instrument measured the minimum and maximum temperatures and humidity over a 24-hour cycle. It also provided real-time measurements which were also periodically checked. Cave light was measured in terms of illumination (in Lux) from different sources using a photo meter. The cave pool features were measured using portable meters; conductivity meter (in micro siemens), pH meter and Dissolved oxygen meter (in percentage). In addition to this, water temperature (in Celsius) was measured in-situ using a mercury-based laboratory thermometer. Except for the temperature readings, cave pool measurements were made on water samples collected in airtight DO bottles taken from the surface and bottom (circa 4m deep) sections of the pool. All cave pool measurements were taken during low tide.

4. *Cave Mapping*

The dry surface of Hinagdanan Cave was surveyed using the traverse method which employed the use of Engineer's transit and laser distance finder. A total of three stations were established inside the cave. Results of the survey was processed using the Libre@ Office Spreadsheet and Libre@ Computer Aided Design to produce the three dimensional aspect of the coordinates. Final visualization of the map was achieved using the animation software, Blender.@

The main cave pool was mapped out using a portable sonar and laser distance finder while the underwater passages were mapped out by following a line and measuring the distances and bearing between set points using a compass and measuring tape. Air pockets and dry spaces along the passage where estimated based on their relative positions between the set points. In addition to this, the depths of the passages were also noted using a depth gauge. Results of the cave pool survey was integrated into the 3D cave map using the Blender.@

IV RESULTS AND DISCUSSION

1. *Cave fauna*

Troglofauna

The troglofauna inventory yielded at least three species which were all considered troglophiles (Table 1). Two of these species were swiftlets, *Collocalia esculenta* and *Collocalia troglodytes* (Fig.4). The former is considered a widespread species while the latter is endemic to the Philippines. *Collocalia troglodytes* was captured more frequently than *C. esculenta* at a ratio of 5 is to 1, making it the predominant troglofauna (refer also to Photodocumentation at the Appendix). The estimated nesting population of swiftlets was determined at around 300-400 individuals with nest density ranging from 2 to 4 nests per square meter. The most dense cluster of nests was observed on the pool ceiling in spaces formed between stalactites (refer also to the photodocumentation at the Appendix).

Fig. 4 Pygmy Swiftlet, the predominant troglofauna inhabiting the cave. The species can be distinguished from its slightly larger cousin, the Glossy Swiftlet, by its well defined white rump and dark upper part.

TABLE 1 LIST OF TROGLOFAUNA AND STYGOFAUNA AND THEIR RELATIVE ABUNDANCE IN HINAGDANAN CAVE

CAVE ORGANISM	CAVE FAUNA CATEGORY	RELATIVE ABUNDANCE	CAVE LOCATION/ HABITAT
TROGLOFAUNA			
Avifauna *Collocalia esculenta* (Glossy swiftlet) *Collocalia troglodytes* (Pygmy swiftlet)	Troglophile (Widespread) Troglophile (Endemic species)	300-500 (mostly Pygmy swiftlet)	Cave roof or ceiling
Insect Tail-less Whip Scorpion (Amblypygid)	Troglophile	Very few	Cave floor
Herpetofauna *Gekko gecko* (Tokay gecko)?	Trogloxene (widespread)	Very few?	Cave ceiling/wall?

STYGOFAUNA			
Decapoda			
Discoplax rotunda	Stygophile	few	Cave pool and floor
Discoplax gracilipes	Stygophile	few	Cave pool and floor
Orcovita fictilia	**Stygobite**	many	Cave pool
Gastropoda			
Micronerita sp?	Stygoxene/stygobite?	Very numerous	Cave pool (submerged rocks and walls)
Pachychilidae	Stygoxene	Few	Cave pool
Thiaridae	Stygoxene	Few	Cave pool
Fish			
Eleotris fusca	Stygoxene	Few	Cave pool
Bostrychus sinensis	Stygoxene	Few	Cave pool

The third species observed was the insect, Whip Scorpion (Fig. 5). Only a few individuals of this species was observed during the night time visits to the cave. We also heard a Tokay gecko during one of the night surveys but were not able to locate it while searching the cave.

Fig. 5 A tail-less Whip Scorpion in Hinagdanan Cave. This species was observed in very few numbers during the night time visits to the cave.

We did not observe bats in the cave. However, we were able to capture two fruit bat species, *Rousettus amplexicaudatus* and *Cynopterus brachyotis,* on the cave surface (Fig. 6). We think they were inadvertently captured while flying through the area and were not actual inhabitants of the Hinagdanan Cave. Fruit Bats are relatively easy to spot inside the cave because of their large size, distinctive eye shine, and striking behavior when disturbed (ie. noisy and constantly flying). They are also noted to be sensitive to human presence and are easily disturbed by artificial lights (refer to

Tababa *et al.* 2012 ; Alcala *et al.*, 2007). This could explain why they are not found in Hinagdanan Cave which is frequented by tourists and illuminated by artificial lights.

Fig. 6 Two Fruit Bat species, *Rousettus amplexicaudatus* (left) and *Cynopterus brachyotis* (right), captured by mist nets. Although the two species were captured outside the cave, their presence inside Hinagdanan cave is not apparent.

The troglofauna of Hinagdanan Cave appears to be depauperate (very few species) and is dominated by the swiftlets, *C. troglodytes.* Only one species of guano-feeding insect, the Whip scorpion was observed inside the cave. The depauperate condition of the cave may be due to the limited food supply and scarce guano deposit. The latter, however was observed as patches of dark deposits on the bottom of the pool. These guano deposits most likely came from swiftlets nesting above the cave pool.

Stygofauna

The total number of stygofauna observed and recorded was eight species (Table 1). They include the three species of crabs 1) *Discoplax rotunda*, 2) *Discoplax gracilipes* and 3) *Orcovita fictilia;* two species of fish 1) *Eleotris fusca* and 2) *Bostrychus sinensis*; and at least three species of gastropods which include the *Micronerita sp.* and two other gastropods belonging to the family *Pachychilidae* and *Thiaridae* (Table 1; Fig. 7). Refer also to the photodocumentation at the Appendix.

Fig. 7 A mix catch of stygofauna (crabs and fish). Majority of the catch were crabs accounting for more than 90 percent of the animals captured by traps.

The most common species captured in the traps was *Orcovita fictilia* with a total of 234 individuals. This represented 95% of the total catch (Fig. 8). The species is the only stygobite encountered and is considered endemic to the cave (refer to Ng et al., 1996; Clements et al., 2006).

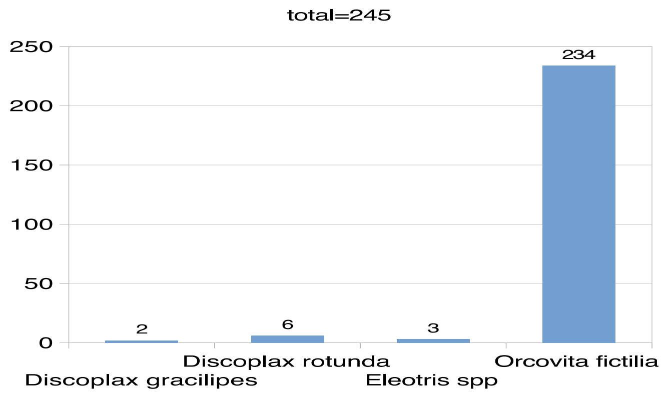

Fig. 8 The number of captured animals per species using Thiel-Türkay traps. Ninety percent of animals captured were from the Varunid crab species, *Orcovita fictilia*. Also captured by the traps were two species of the Gecarcinid crab genus *Discoplax* and a fish belonging to the family Eleotridae.

The comparatively fewer number of *Discoplax gracilipes and D. rotunda* individuals captured in traps may be due to their large size (up to 26mm and above) which prevents the larger and mature adults from entering the small trap openings (Fig. 9). We observed several of these larger individuals swimming in the pool and in some occasion walking on dry surface. On the other hand, we did not capture *Karstama boholano*, a caverniculous crab earlier reported inhabiting the cave (Ng, 2002). Neither did we observe the small shrimp, *Antecaridina lauensis*, also reported to be inhabiting the cave pool (refer to Cai et al., 2009). It is possible that our traps were not designed to capture the species.

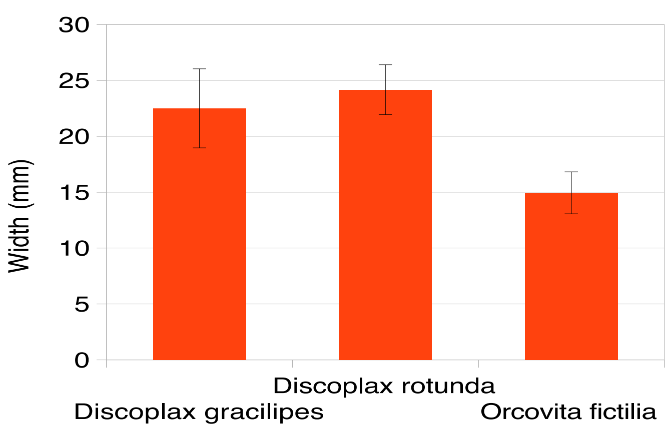

Fig. 9 Graph showing the average carapace width and Standard Deviation for three species of crabs captured in traps. It shows the comparatively smaller *Orcovita fictilia*. Its small size makes it easier for the species to enter the 21mm opening of the trap.

The one-way ANOVA test for dependence of animal diversity and abundance on trap location (zone) showed a p-value of 0.9 for both dependent variables and presents no significant relationship between the trap's location (zone) and abundance of catch. It appears that the present lighting conditions and difference in depth have no effect on the abundance of catch. Moreover, it also appeared that the animals captured were uniformly distributed across the pool.

The observed gastropods include the freshwater species of the family *Pachychilidae* and family *Thiaridae* (Köhler and Glaubrecht, 2003) and the caverniculous micromollusc of the genus *Micronerita sp*. (Fig. 10). The latter appears to be closely related to *Micronerita pulchella*, a submarine species reported in the Panglao area (Kano and Kase, 2008). The slightly transluscent micromollusc was estimated to be less than 2mm. They were found in large numbers in the main pool area but not in the narrow passages. They were also observed feeding on the dark colored organic mats (guano and blue-green algae?) during one late afternoon (refer also to the photodocumentation at the Appendix). A closer examination of the gastropod showed exceptionally long antennae and appeared to have no eye. Further examination of the organism is required to confirm the species.

Fig. 10 Micromollusc of the genus *Micronerita sp*. feeding on guano and blue-green algae(?). The animal has long antennae and appears to have no eye.

At least one species of fish was captured in the traps. This was identified as *Eleotris fusca*. Another species, *Bostrychus sinensis* was also captured in the pool using scoop net. Both species belong to the family Eleotridae and are known to inhabit marine, freshwater and brackish waters (refer to photodocumentation at the Appendix).

2. *Cave illumination and cave lighting*

Sunlight enters the cave via three major openings, the small narrow sinkhole serving as the main cave entrance (and exit) and the two skylights at the main chamber (Fig. 11). Several other smaller or minor openings were also observed in sections along the underwater passages that extend south and northeast of the pool.

The partially exposed and low lighted areas in the main chamber and pool are considered the Twilight zones of the cave. They serve as transitional habitats (between light and dark zones) for some outside organisms to share with the cave inhabitants (Hajenga, 2005). It also allows exchange of energy and materials between the outside and cave environments.

Fig. 11 Twin skylight illuminating the Twilight Zone of the Hinagdanan Cave main chamber. Partially illuminated is the nearby anchialine pool at 1-2 lux.

The main chamber (with the anchialine pool) receives light via the two skylights at around six in the morning and disappears around 5:30 in the afternoon, depending on the time of the year (cave guide pers. comm.). Optimum light (highest illumination of the day) enters the main chamber around noon via the twin skylights (sinkhole) as a pair of vertical pillars of light that illuminate the floor as elongated "spotlights" each measuring 2m long by 1.5m wide (refer to photo-documentation at the Appendix). The range of optimum lighting was measured between 10 to 30 lux with maximum readings towards the center of the spotlight and minimal readings at the periphery. Because the skylights were located close to the pool, illumination was extended up to the pool edge at 1-2 lux before losing illumination. The rest of the pool is devoid of natural lighting. The effective illumination provided by the skylights, therefore ranges between 1 to 30 lux which approximates a "full moon at a clear night" at its minimum and as a "moderately lighted room" at its maximum (refer to Table 2). In comparison, the illumination provided by the artificial lights was measured between 62 to 7 lux, depending on their location.

Table 2 Some examples of illuminance under different conditions (after Schlyter,2009; Bunning et al., 1969)

Illuminance (lux)	Surfaces illuminated
0.0001	Moonless, overcast night sky (starlight)
0.002	Moonless clear night sky with airglow
0.27–1.0	Full moon on a clear night
3.4	Dark limit of civil twilight under a clear sky
50	Family living room lights (Australia, 1998)
80	Office building hallway/toilet lighting
100	Very dark overcast day
320–500	Office lighting
400	Sunrise or sunset on a clear day.

1000	Overcast day; typical TV studio lighting
10000–25000	Full daylight (not direct sun)
32000–100000	Direct sunlight

3. *Ambient cave temperature and relative humidity*

The minimum ambient cave temperature recorded during the duration of the study was 27.9 °C while the maximum ambient temperature was 29.9° C. On the other hand, the minimum relative humidity recorded was 78 % while the maximum relative humidity was 98%. The high temperature and humidity accounts for the warm environment and humid conditions of the cave. This condition allows condensation to occur inside the cave and form water droplets that regularly drip from the ceiling. This makes the cave perpetually wet throughout the year (cave guide personal communication).

4. *Cave water analyses*

The pH readings of the cave pool approximate the seawater (Table 3). However, the temperature and pH readings were higher from samples taken from the surface. Similarly, the Dissolve Oxygen was higher on the surface compared to the bottom. On the other hand salinity and conductance (conductivity tests) were higher on the pool bottom.

Table 3 RESULTS OF THE PHYSICO-CHEMICAL ANALYSES OF THE HINAGDANAN CAVE ANCHIALINE POOL

PARAMETER	SURFACE MEASUREMENTS	BOTTOM MEASUREMENTS (4M)
Temperature (Celsius)	29	28.5
pH*	7.9	7.4
Conductance (microsiemens)	9,800	13,970
Salinity (parts per thousand)	5.1**	7.5**
Dissolved oxygen (%)	62.1	58

*pH range of seawater is 7.5 to 8.4 (water standards: US office of naval research)

**converted from “conductance” (after water quality monitoring: conductivity to salinity conversion. Sourced from:http://www.fivecreeks.org/monitor)

The differences in the conductivity and salinity readings of the surface and bottom samples indicate that the cave pool forms a halocline. Moreover, the low salinity readings (5.1 and 7.5) indicate that the pool water is brackish. In addition to this, we observed that the pool water regularly rise and fall in concurrence with the change in tide. The latter observation suggests that the cave pool is somehow connected to the sea and since seawater periodically moves in and out of the cave it is further assumed that flushing and nutrient turnover can occur. The presence of halocline and influence of seawater are diagnostic features of an Anchialine Cave (Iliffe, 2000).

Although the pH readings of the pool indicate some degree of alkalinity, the slightly lower pH (7.4) and reduced dissolved oxygen (58 %) of the bottom sample indicate presence of organic material and some degree of decomposition. The organic material is most likely contributed by bird droppings as suggested earlier.

5. *Cave mapping*

------------results of the 3D cave mapping

Results of the underwater cave mapping showed that the aquatic environment of Hinagdanan Cave is composed of the main pool (located at the main chamber) and series of channels or passages. The latter forms the northwest, south, and northeast passages (Fig. 6). A small interconnecting channel connects the south passage with the northeast passage. In addition to this, the aquatic environment also has several surface interphases (dry surface or air pockets) which allow cave water to interact with air. The largest dry surface interface is located at the main chamber. Several smaller surface interphases are also found at the Northwest Passage, south passage, and northeastern passage. Moreover, the underwater survey also identified several unexplored areas with small openings (and potential passages). They include the two unexplored openings at the Northwest Passage, one at the main pool, one at the south passage, and at least two at the Northeast Passage. These unexplored areas have the potential to interconnect and even extend the passages further inland or connect to the sea. The two northernmost unexplored points at the northwest and northeast passages are believed to be connected to the sea which is about 100m north of the cave.

Fig. 6. Schematic map of the aquatic pool and underwater passages of Hinagdanan Cave. The sea is about 100m north of the cave.

V RECOMMENDATIONS

Cave monitoring and protection

Anchialine caves are inhabited by cave organisms specifically adapted to the dark aquatic environment. The absence of light and limited amount of food support only a few species and small populations. Anchialine caves are considered fragile and vulnerable to environmental changes and perturbations so that conservative management and maximum precautionary measures should be applied when promoting it for ecotourism.

- Regular monitoring of the cave fauna and chemo-physical conditions of the cave:
  - o Although no immediate threat was observed on the troglofauna, the study recommends continuous monitoring of the cave species. The monitoring of cave fauna and other cave parameters can be facilitated using the simplified checklist developed by Alcala (refer to Appendix). The monitoring, which can be conducted once a year should include estimation of the swiftlet population and the inventory of cave organisms.
  - o Do bi-annual water sampling: include the confirmative *E. coli* test to rule out fecal contamination. The high coliform counts reported by the DENR (April 2015 report) may be attributed to non-enteric species that are not necessarily harmful to the swimmers. In addition to this, tests for alkylbenzene sulfonate and oxidizing agents which are commonly found in soap and disinfectants, respectively, can also be undertaken to check their presence in the pool.
  - o Although the environmental conditions of the cave appears to be stable bi-annual monitoring of the relative humidity and ambient temperature should be done to check for changes.

- Swimming in the pool may have some adverse effects on both the swimmer and resident microorganisms that thrive in the anoxic water column. However, this needs to be further investigated through detailed microbiological studies.

- With regards to reports of "swimmers itch" it may be worthwhile to conduct a parasitological investigation on the possible presence of bird parasite and its intermediate host, aquatic snails. Swimmers Itch or Cercarial Dermatitis has been associated with some bird species and snails with the former serving as host for the adult parasite and the latter serving as host for the larva or cercaria (CDC: http://www.cdc.gov/parasites/ swimmers itch/ biology. html).

- If ever swimming is continued, strict measures should be imposed on the ban of use of soap and other bathing and washing compounds.

- We also recommend the regular collection of garbage in the pool and clean up of the surrounding areas, inside and outside the cave. Individuals entering the cave should be strictly monitored and prevented from littering. Likewise, loitering inside the cave during the close period (night time) should not be allowed.

Cave tour, access and traffic

- Develop an Interpretive walk-through tour that will emphasize the unique cave system (anchialine cave) and cave diversity. Improve on the current information provided by the tour guides by providing additional information that is more accurate. For example, cave guides refer to the nesting birds as swallows which are actually swiftlets. In addition to this, the guides need to provide more information about the pool as oppose to merely referring to it as brackish water. The pool in the anchialine cave forms halocline (layered salt water) that allows unique organisms to live in it.

- Determine the bottlenecks in the passageways (eg. stairway landing near the pool and skylight area). Bottleneck traffic occurs as a result of too many people congregating in one place. This can be ameliorated by limiting the time spent in small places and or expanding these small areas to provide space for individuals to maneuver or wait (refer to cave map).

- Limit the number of visitors entering the cave. Limiting the number of visitors will assure better control and better audience interaction. Too many audiences will not only reduce the effectiveness of the tour but will also cause interference with the talk as the audience become noisy. The best way to determine the effectiveness of the interpretive tour is to interview the visitors after the tour.

Management can experiment on 15 individuals as the optimum number of visitors. This is based primarily on the number of visitors that can be "comfortably' accommodated at the lower stairway (5 pax) and skylight area(5 pax) where most photography and interaction takes place. Another group of five individuals can serve as standby group at the upper part of the walkway near the entrance(5 pax). Since the cave walkway has a total linear length of 40m, each visitor (including the 3 guides) can be provided with at least 2 linear meter of space which is relatively loose and comfortable. The cave can be divided into 3 sections that will allow 3 groups to simultaneously conduct their photograph sessions and short lectures. This will also mean that with the smaller groups of fives, management can utilize three guides at *any time inside the cave. This arrangement, however, does not include couples and single walk-in visitors.*

- Provide a waiting room that doubles as an interpretive and registration center near the entrance. Develop an orientation program (to be conducted by guides) for visitors waiting for their cave tour. The interactive section can have exhibits and materials related to the cave (in general) and more specifically on anchialine cave.

Cave lighting

The present artificial lighting in the cave can be further improved by reducing illumination (at least 2 to 6 lux). Reducing the illumination and limiting it to 12 hrs (or less) a day will help mitigate the effects of too much light on the resident cave animals and cave structures. Too much light can cause photo-decay on some natural structures and materials while the warm light can increase the ambient temperature of the cave.

- Consider the use of Light Emitting Diode (LED) lights and solar power which is more energy efficient and long lasting. LED lights hardly produce heat so it has minimal contribution to cave temperature. On the other hand solar lighting is self-regulating and can be automated, providing lights only during daytime. On the other hand, the conventional lights can still be retained for emergency and maintenance purposes.

- Replace the white lights with low spectrum lights (eg. yellow) particularly in areas near the ceiling where the birds are nesting. On the other hand, the pool area can be illuminated by low intensity colored lights like green and red. An alternative is to install dim switches and dim lights which can be regulated to control light intensity.

- Cover up or camouflage the wirings for aesthetic reasons. Some cave lights can be positioned to focus and accentuate the cave features. Similarly, some light bulbs need to be repositioned to avoid glare to the audience when they look up and view the cave structures. On the other hand, low intensity pilot lights (1-2 lux) set along the walkway can also be used to guide the visitors.

Surface vegetation, sewage and geohazards

- The ground surface above the cave can be further improved by planting more vegetation. More useful are the *Ficus* species (Fig trees) that are known to hold water and produce numerous deep penetrating roots.

- Management should regulate the construction of toilets that have open septic bottoms near the cave area. This type of toilet can easily contaminate the cave pool and surrounding ground water. Similarly, strict monitoring and regulation of sewage canals and other form of drainage should be implemented to make sure that sewage does not enter the cave.

- The cave network formed by the Hinagdanan cave system needs to be thoroughly mapped out using ground penetrating radar (or similar instrument) to determine the weak spots and hollow spaces (cave caverns). Construction of buildings near and above the cave should be avoided to prevent cave-ins. In addition to this, no road should be built over the cave because the vehicle load and vibration can weaken the underlying cave structures (ie stalactites).

COMMENTS ON THE CAVE CLASSIFICATION AND UTILIZATION

Hinagdanan Cave appears to conform with the Class II* classification as defined by the Cave Act. It contains an anchialine pool which is known to be sensitive to perturbations and human disturbance. In addition to this, the pool is inhabited by rare and unique animals that warrant their protection. Restricting all forms of aquatic activity may be prudent at this point until more proof can be obtained to support pool activities.

On the other hand, the cave can still be used for educational tours following some if not all the recommendations proposed by the study.

***Class II**. Caves with areas or portions which have hazardous conditions and contain sensitive geological, archeological, cultural, historical, and biological values or high quality ecosystem. It may be necessary to close sections of these caves seasonally or permanently. It is open to experienced cavers or guided educational tours/visits.*

VI ACKNOWLEDGEMENT

The research team wishes to thank JICA-SEPP especially Shin-ichiro Tanimoto, Team leader of the project for funding the study. We extend our gratitude to Holger Horn of Philippine Fun Divers Bohol for providing us tanks, air, and weights free of charge. We also thank Mr. Joey Gatus of JICA-SEPP for his active participation in the field survey and for his help in arranging our travel and accommodation. Likewise special acknowledgement is extended to Mr. Lito Iyo and Nice Luga for their help and services. Last but not the least we would like to extend our gratitude to the Bingag Local government and officers for allowing us to conduct the study in the Hinagdanan Cave.

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