A baseline study of the critically endangered cave-dwelling catfish (*Clarias cavernicola*)

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A BASELINE STUDY OF THE CRITICALLY ENDANGERED CAVE-DWELLING CATFISH (*CLARIAS CAVERNICOLA*) IN NAMIBIA

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INDEMNITY

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Foreword

This report presents a baseline study of the critically endangered cave-dwelling catfish *Clarias cavernicola*. The aim of this study was to collect baseline information on *Clarias cavernicola*, listed as Critically Endangered by the International Union for Conservation of Nature (IUCN), to introduce measures to protect the species from extinction.

First, we want to thank the Namibian Chamber of Environment for their financial support. We also want to thank the Deputy Director of Inland Fisheries and Aquaculture, Renier Dawid Burger for his valuable input and support. Further, we thank the research divers Chris and Tiffany Steenkamp and Rueben Engel, and the staff at the Farm, especially A.B and S.B for their great help during fieldwork. And finally, we want to thank the Ministry of Fisheries and Marine Resources and the Norwegian Institute for Nature Research for their important financial support and Namibia Nature Foundation for managing the project.

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Introduction

Fish communities established in subterranean habitats, inhabit aphotic zones, which are highly fragmented and tend to contain scarce food resources for the fish (Poulson and White, 1969). There are currently 247 species of cave and groundwater fishes found around the world, with China, Brazil, Southeast Asia and Mexico accounting for 50% of the species (Trajano, 2001; Proudlove, 2010). These fish species are exclusively subterranean and have specializations related to their isolation in the subterranean realm with the most conspicuous being the reduction or loss of melanic pigmentation and partial or full loss of eyes (Holsinger and Culver, 1988). In the Afrotropical Region (Africa n = 5, Madagascar n = 3), eight species of subterranean fishes are described of which six were described between 1921 and 1936, and it is suggested that there are still undiscovered species (Berti and Messana, 2010). From these eight described subterranean fish species, two belong to the Clariidae family, namely *Clarias cavernicola* Trewavas 1936 and *Uegitglanis zammaranoi* Gianferrari 1923.

Clarias cavernicola was known from only one, underground lake in the a Cave north of Otavi and west of Grootfontein, Namibia, making it the rarest fish in southern Africa and one of the most endangered fishes in the world (Skelton, 1990). The origin of this species is unknown, as the nearest rivers are the Kavango and Kunene Rivers situated 250 km and 370 km away, respectively. The closest open water sources, are Lakes Guinas and Otjikoto located at a distance of 26 km and 41 km. *Clarias* species are not naturally found in Lake Guinas or Otjikoto.

In general, the Clariidae family includes about 12 genera and 74 species, of which the genus *Clarias* currently has 61 valid species throughout the continent of Africa (Froese and Pauly 2018). Members of this fish family have pairs of barbels which are used as highly effective sensory organs and have a general eel-like body form which is scaleless (Skelton 2001). *Uegitglanis zammaranoi* is probably the geographically closest epigean congeneric species to *C. cavernicola* on the African continent. There have been no behavioural or ecological studies on *C. cavernicola* (Berti and Messana 2010; Proudlove 2010), and very little information on the basic aspects of their life history have been available until recently. The only available records are few observations about its spontaneous behaviour in both the field and aquarium (Skelton 1990; Bruton 1995). Such knowledge is not only scientifically relevant but also fundamental for the establishment of efficient conservation policies.

Research questions

This study focused around central questions relative to population parameters of *C. cavernicola*:

1) What is the population size of *C. cavernicola* observed using visual census methods?
2) Is recruitment taking place and are there temporal fluctuations in the visual population densities of *C. cavernicola*?
3) What is the habitat use of *C. cavernicola* within the cave habitat?
4) What is the state of the cave environment?
5) Are there any threats to the population of *C. cavernicola*?

Therefore, two SCUBA diving expeditions to estimate the relative population size and habitat utilisation of *C. cavernicola* were done on the 11^{th} February and 25^{th} May 2019. During the second expedition, a new cave entrance along the same fault as the Cave was explored for possible new populated cave pools. The answers to these questions may ultimately lead to the development of conservation measures to ensure the survival of this endemic catfish species.

Materials and methods

Study species

The first recorded encounter of *Clarias cavernicola* Trewavas 1936, may have been between 1917 and 1919 by geologist Jaeger and Waibel (1921), but was first collected by Dr Karl Jordan who visited the cave in 1921 (Trewavas 1936). It was scientifically described from six specimens in 1936 (Trewavas 1936), but the lectotypes assigned by Teugels (1986) from the syntype series of Trewavas (1936) contained only five specimens.

Clarias cavernicola, similar to most cave-dwelling fishes, is devoid of pigment, and the skin colour is creamish flushed with pink or golden-yellow (Figure 1). In some specimens, the eyes are completely absent, but the eyes vary in their development and are often sunk in the socket with the surface skin more or less opaque (Trewavas 1936). While the brain does not show a striking reduction in size as in other cave fishes, the cerebellum is somewhat reduced and the olfactory apparatus is slightly underdeveloped (Hennig 1977). This, however, does not suggest that *C.*

cavernicola has poorly developed olfactory powers (Hennig 1977). Histological sections of some individuals' degenerated eyes confirmed that choroid and retinal layers are disorganised and a few large vacuolated cells are all that remain of the lens whereas no rods or cones were identified (Hennig 1977).

Figure 1: *Clarias cavernicola* is devoid of pigment, and the skin colour is creamish flushed with pink or golden-yellow

The size of the population is unknown, but was previously estimated to contain 150-200 individuals (Sefton et al. 1986), while another estimation of 200-400 individuals was made by C. Hay in 1995 (C. Hay own data). It was suggested that *C. cavernicola* inhabits an area over a shelve near the water surface and that they rarely penetrate deeper than 15 m (Bruton 1995). Trewavas (1936) examined the stomach content of three individuals and found fairly uniform fragments of dark brown exoskeletons of insects which were also found in the excrements of baboons that frequented the cave. Trewavas (1936) concluded that none of the fragments suggested that prey had been taken whole and alive except possibly a flatworm and a crab. It was therefore suggested that it feeds primarily on detritus made up of bat and baboon excrements, animal carcasses and terrestrial insects that fall into the cave (Bruton 1995; Skelton 2001).

Bruton (1995), suggested that the reduction in water level rendered the site inaccessible to wild game as a drinking hole and food sources from animal carcasses and baboon droppings may be less available. It is however, highly unlikely that wild game frequent the cave to make use of the water source, as the topography of the cave entrance does not allow animals to reach the water's surface (Pers. comm. F. Jacobs). Hence, if an animal was to venture into the cave it would probably be trapped and die. There is evidence of this as a Greater Kudu *Tragelaphus strepsiceros* skeleton has been found at a depth of 60 m under the water's surface (Pers. comm. C. Steenkamp).

The suprabranchial organ is still present in *C. cavernicola,* but is greatly reduced. This is probably related to the loss of its functional significance, due to either a lowered oxygen consumption or a high oxygen content of the water or both, since *C. cavernicola* very seldom surfaces to gulp air (Hennig 1977). Under hatchery conditions, C. Hay induced females to produce eggs in 1991 using pituitary extract injections. Each female produced about 50 adhesive eggs, with a near-transparent, greenish yolk, which suggests a more precocial lifestyle for the cave catfish (Bruton 1995). Artificial breeding of *C. cavernicola* was not successful in captivity (C. Hay own data) and has not been observed in the wild.

Study area

The Cave is situated in the carbonate-dominated Otavi Group in the Otavi Mountainland (OML) (Söhnge 1957). The Otavi Group consists of the Abenab and the Tsumeb subgroups which overlay the Nosib group and the Basement Complex (Hedberg 1979). The Tsumeb subgroup, is subdivided into 8 litho-zones (T1 to T8) from the Ghaub formation to the carbonate dominant Maieberg, Elandshoek as well as the Hüttenberg formations. The Cave is a large fault controlled, canyon passage in the Maieberg formation and marks the change from a deep-sea environment observed in the Elandshoek Formation (underlying formation) to a shallow lagoon shelve (Sefton et al.

1986). It consists of a grey bedded basal dolomite, stromatolite rich (T6), overlain by two upper units T7 and T8, marked by pisolite and oolite.

The Cave reaches the surface in five known places through chimneys which allow partial penetration of sunlight into the first section of the cavern and allows circulation of air (Sefton et al. 1986). The passage slopes down for approximately 250 m at a declining angle of -45° and the lake is located -81 m under the surrounding earth's surface (Otavi 1995). The water surface of the lake is 18 m long, 2.5 m wide with the long axis extending approximately northwest to southeast. The depth of the Cave increases precipitously through a shaft into an incompletely mapped cavern system that has been explored to a depth of 100 m (Pers. comm. Chris Steenkamp). The groundwater flows in a northerly direction across the geological strike within the highly permeable dolomites of the Elandshoek and Hüttenberg formations (Jacobs 2018). The groundwater is predicted to move in fold axes, pressure relief joints, faults or on lithological contact zones through this highly karstified area (Jacobs 2018). Due to the high conductivities of the karst aquifers, the water levels are highly dependent on aquifer recharge (Jacobs 2018).

Figure 2: Entrance of the Cave with the long axis extending approximately northwest to southeast.

New Cave pools

The present study made an additional expedition into a new cave opening along the same fault line as the Cave (Figure *3*). The entrance of the cave was already known by the current landowner. To his knowledge (i.e. 30+ years on the land) an expedition into this new entrance was attempted, but due to logistical constraints, they could only descend approximately 34 m (A-D) into the cave and did not come close to the water's surface. The new cave is named Chris Cave after the first person to reach the water level during this study. The Chris Cave entrance is located approximately 120 m from the entrance of the Cave at an altitude of 1350 meters above sea level (masl). The entrance of the cave is a shaft 2 m wide and reaches the first floor approximately 3 m below the entrance and is covered with gravel, boulders and bat guano (J). This chamber slopes gradually due east for approximately 20 m before a vertical drop of 5 m which opens into a massive dome (1342 masl) running on the same northwest-southeast fault as the Cave. The dome is estimated to be > 200 m in length and in some place > 50 m high. The dome's floor which is covered in sand, dust and bat guano slopes steeply in a southerly direction for 23.5 m (B-D). At the end there is a large choke (1316 masl) from where a vertical drop of 17 m leads onto a large rocky platform (D-E). To the left of this rock the chamber descends steeply for 18 m and drops and reaches a third floor which is covered completely in bat guano (± 30 cm thick layer) and very fine sand. From here the floor rises gradually in a northerly direction and is marked by fossil formations which include large helictites. The floor drops steeply for another 32 m over until the water's surface (G-H). The new lake is 2 m wide, 8 m long and narrows in a southeasterly direction (i.e. towards the cave), and continues through cracks in the formation. From this newly discovered cave pool (1263 masl) there is a tight squeeze in a northerly direction which opens up into another cave pool of 9 m in length and 2 m wide (H-I), narrowing towards the northeast. There is no surface connection between these two cave pools, but it is highly likely that they are linked underground. All the cave pools are situated in permanent darkness, thus there is an absence of green plants and of photoperiods, and a more or less constant temperature of 28.1˚C was recorded (Figure *4*). Numerous species of the order Blattodae, Isopoda and Araneae were observed in the bat guano and the walls of the caves.

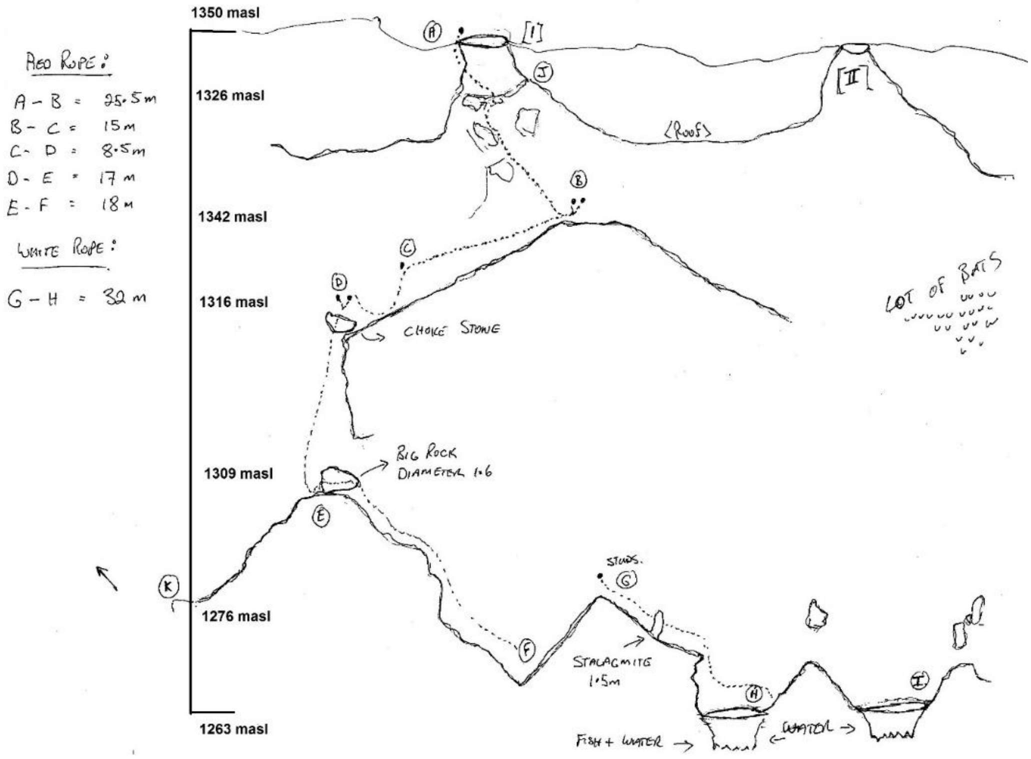

Figure 3: This study made an expedition into a new cave opening along the same fault line as the Cave and discovered two New Cave pools with *Clarias cavernicola*

Figure 4: One visual count from above the surface performed by two counters revealed that the newly discovered cave pool had *Clarias cavernicola*.

Density estimation

The entire water surface area is visible from a specialised platform when using a strong light-emitting diode (LED) flashlight (NITECORE, TM16GT, Guangzhou, China). The dimensions and water clarity (> 15 m) of the Cave allow for visual count (VC) data from above the water using a specialised platform and underwater using SCUBA. Although mark-recapture methods produce more accurate population data, due to the small population size (i.e. population densities too small to obtain a minimum number of marks needed for mathematical treatment) and ecological fragility (i.e. only known population) of *C. cavernicola,* tagging techniques are not advisable (Trajano 2001). Although the use of VC to estimate fish populations has been questioned, the unique characteristics (blind, pink or golden yellow), observed initial behaviour (calm, lethargic) and cave habitat (confined area, clear water, little debris) of *C. cavernicola*, VC is proposed to give approximate *C. cavernicola* populations estimates.

Estimates of population size were therefore performed using the direct-count method from both above the water and under the water. Additional VC data were also obtained by two divers using SCUBA gear during February 2019 and May 2019 (Figure *5*). The same two SCUBA divers were used for both surveys to account for consistency. Each diver was equipped with a fish and habitat datasheet and underwater slate with pencil, and a dive watch. Both divers also carried an underwater digital camera and lighting for taking habitat and fish photos. Upon entering the water the two divers immediately descended to a maximum depth of 40 m. Once they reached the depth of 40 m they used a point circular search pattern where divers were positioned at a distance of 9 m apart which allowed them to have a clear view of the entire cave shaft, then turning in a clockwise 360° rotation, to assess the presence of *C. cavernicola*. If no fish were observed, divers ascended by 5 m until the first fish was observed (Figure *6*). At the location of the first fish, divers used a modified vertical jackstay method, by following a horizontal transect each time ascending by one meter until they reached the surface. The reports indicate a large degree of similarity among the divers' counts. During the first survey in February 2019 individuals were caught using a hand dip net and measured for total length to the nearest mm.

Figure 5: Two professional divers preparing to descend to 40 m to start the visual count survey *for Clarias cavernicola.*

Water quality

Water samples in the Cave were collected using a Niskin bottle at the surface, 5, 10, 15, 30 and 40 m depths for laboratory analyses (Table 1). The water quality of the Cave seems to be relatively stable throughout the measured water column and no major changes for the tested parameters were observed between the surface water down to a depth of 40 m. Water temperature (°C), ORP(mV) , pH, Dissolved Oxygen (%) and salinity (ppt) measured *in situ* during both surveys using a Hach HQ40d portable multi-meter lower to 40 m whereby a reading was recorded every meter (Figure 7, Table 2). One water quality reading for water temperature (°C), ORP(mV), pH, Dissolved Oxygen (%) and salinity (ppt) was also done in the New Cave pools during the May 2019 survey. The multi-meter was calibrated on location, according to the instructions in the manufacturer's manuals to ensure accuracy.

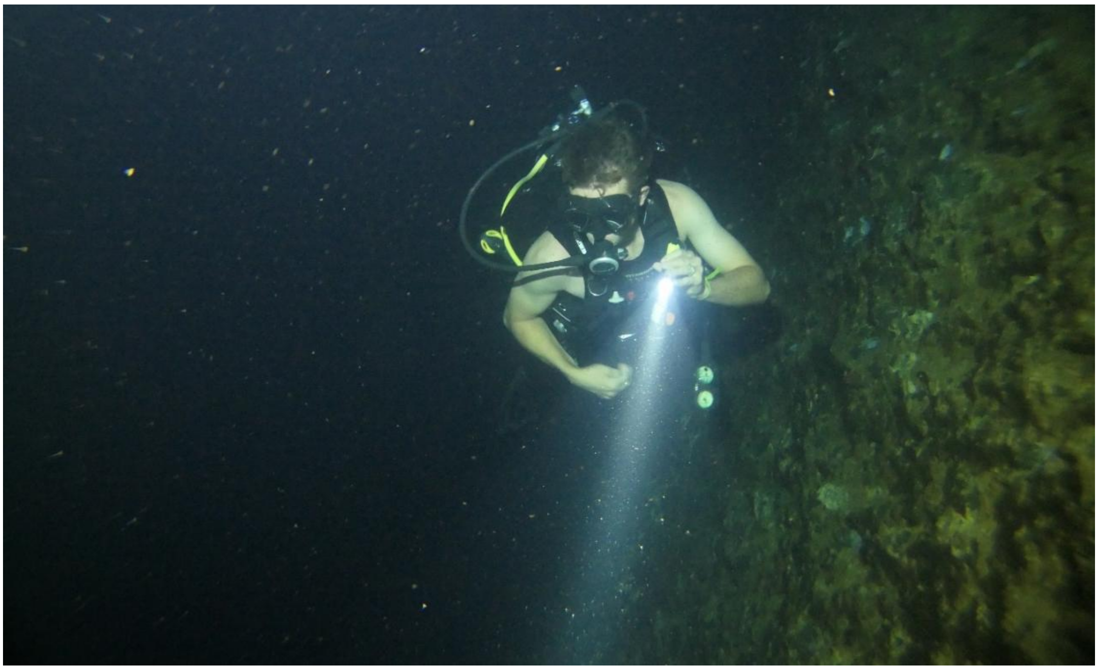

Figure 6: Diver using a flashlight to assess the presence and absence of *Clarias cavernicola* ascending by one meter if no fish is present.

Figure 7: Measuring in situ water quality during both surveys using a Hach HQ40d portable multi-meter lower to 40 m whereby a reading was recorded every meter.

Table 1: Physicochemical properties (Analytical Laboraory Services, Windhoek) of the water at selected depths taken in the Cave on the 9th February 2019.

Parameter	Units	Surface	5 m	10 m	15 m	30 m	40 m
Temperature	ºC	27.2	27.2	27.2	27.2	27.2	27.2
pH		6.9	6.9	7.0	7.0	6.9	6.9
Electrical Conductivity	mS/m	94.6	94.3	94.3	94.2	94.4	94.5
Turbidity	NTU	0.5	0.3	0.5	0.3	0.3	0.8
Total Dissolved Solids (calc.)	mg/l	633.8	631.8	631.8	631.1	632.5	633.2
P-Alkalinity as $CaCO_3$	mg/l	0.0	0.0	0.0	0.0	0.0	0.0
Total Alkalinity as $CaCO_3$	mg/l	460.0	465.0	460.0	465.0	455.0	470.0
Total Hardness as $CaCO_3$	mg/l	515.0	517.5	515.0	505.9	510.9	510.9
Ca-Hardness as $CaCO_3$	mg/l	259.7	262.2	259.7	254.7	259.7	259.7
Mg-Hardness as $CaCO_3$	mg/l	255.3	255.3	255.3	251.2	251.2	251.2
Chloride as Cl^-	mg/l	12.0	10.0	10.0	9.0	10.0	9.0
Fluoride as F^-	mg/l	0.4	0.3	0.3	0.3	0.3	0.4
Sulphate as SO_4^{2-}	mg/l	20.0	20.0	21.0	22.0	21.0	21.0
Nitrate as N	mg/l	2.1	2.1	2.3	2.4	2.3	3.0
Nitrite as N	mg/l	0.3	0.0	0.0	0.0	0.0	0.6
Sodium as Na	mg/l	16.0	16.0	16.0	16.0	16.0	16.0
Potassium as K	mg/l	1.2	1.1	1.2	1.2	1.1	1.1
Magnesium as Mg	mg/l	62.0	62.0	62.0	61.0	61.0	61.0
Calcium as Ca	mg/l	104.0	105.0	104.0	102.0	104.0	104.0
Manganese as Mn	mg/l	0.0	<0.01	0.0	0.0	0.0	0.0
Iron as Fe	mg/l	0.0	0.0	0.0	0.0	0.0	0.0
Stability pH, at 25°C		6.8	6.8	6.8	6.8	6.8	6.8
Langelier Index	Scaling	0.1	0.1	0.2	0.2	0.1	0.1
Ryznar Index	Stable	6.7	6.7	6.6	6.6	6.7	6.7
Corrosivity ratio	no corrosive properties	0.1	0.1	0.1	0.1	0.1	0.1

Table 2: Water temperature (°C), ORP(mV) , pH, Dissolved Oxygen (%) and salinity (ppt) measured *in situ* using a Hach HQ40d portable multi-meter from the surface down to a depth of 40 m with 1 m intervals on the 9th February 2019 and 24th May 2019.

Depth (m)	Temp. (°C) Feb	Temp. (°C) May	ORP(mV) Feb	ORP(mV) May	pH Feb	pH May	Dissolved Oxygen (%) Feb	Dissolved Oxygen (%) May	Salinity (ppt) Feb	Salinity (ppt) May
0	27.2	27.1	270.9	185.2	7.0	7.0	12.4	9.8	0.4	0.4
1	27.2	27.1	255.3	185.3	7.0	7.1	6.7	9.3	0.3	0.4
2	27.2	27.1	276.2	185.1	7.0	7.1	5.4	9.1	0.3	0.4
3	27.2	27.1	276.6	185.0	7.0	7.1	4.9	9.0	0.3	0.4
4	27.2	27.1	276.9	184.8	7.0	7.1	4.7	8.8	0.3	0.4
5	27.2	27.1	277.2	184.9	7.0	7.1	4.6	8.8	0.3	0.4
6	27.2	27.1	277.5	184.9	7.0	7.0	4.5	8.8	0.3	0.4
7	27.2	27.1	277.2	186.3	7.0	7.1	4.8	8.9	0.3	0.4
8	27.2	27.1	278.2	184.0	7.0	7.1	4.4	9.2	0.3	0.4
9	27.2	27.1	278.3	184.3	7.0	7.0	4.3	9.0	0.3	0.4
10	27.2	27.1	277.9	184.3	7.0	7.0	4.4	9.0	0.3	0.4
11	27.2	27.1	278.1	184.3	7.0	7.0	4.3	8.8	0.3	0.4
12	27.2	27.1	278.9	184.3	7.0	7.0	4.3	8.8	0.3	0.4
13	27.2	27.1	278.2	184.3	7.0	7.0	4.3	8.9	0.3	0.4
14	27.2	27.1	278.4	184.3	7.0	7.0	4.1	9.0	0.3	0.4
15	27.2	27.1	278.1	184.3	7.0	7.0	3.7	8.9	0.3	0.4
16	27.2	27.1	277.4	184.3	7.0	7.0	3.8	8.7	0.3	0.4
17	27.2	27.1	277.6	184.3	7.0	7.0	3.6	8.6	0.3	0.4
18	27.2	27.1	277.0	184.3	7.0	7.0	3.7	8.2	0.3	0.4
19	27.2	27.1	276.7	184.3	7.0	6.8	3.9	7.9	0.4	0.4
20	27.2	27.1	276.0	184.3	7.0	7.0	4.0	7.8	0.4	0.4
21	27.2	27.1	275.4	184.3	7.0	7.0	4.1	7.7	0.4	0.4
22	27.2	27.1	275.1	184.3	7.0	7.0	4.1	7.6	0.4	0.4
23	27.2	27.1	275.1	184.3	7.0	7.0	4.1	7.2	0.4	0.4
24	27.2	27.1	275.1	184.3	7.0	7.0	3.3	6.8	0.4	0.4
25	27.2	27.1	277.2	184.3	7.0	7.0	3.3	7.2	0.4	0.4
26	27.2	27.1	277.2	184.3	7.0	7.0	3.2	7.4	0.4	0.4
27	27.2	27.1	276.4	184.3	7.0	7.0	3.2	7.4	0.4	0.4
28	27.2	27.1	275.1	184.3	7.0	7.0	3.1	7.4	0.4	0.4
29	27.2	27.1	273.2	184.3	7.0	7.0	3.1	7.4	0.4	0.4
30	27.2	27.1	269.5	184.3	7.0	7.0	3.0	7.9	0.4	0.4
31	27.2	27.1	269.5	184.3	7.0	7.0	3.0	7.9	0.4	0.4
32	27.2	27.1	269.5	184.3	7.0	7.0	1.9	7.9	0.4	0.4
33	27.2	27.1	269.5	184.3	7.0	7.0	1.8	7.9	0.4	0.4
34	27.2	27.1	269.5	184.3	7.0	7.0	1.9	7.9	0.4	0.4
35	27.2	27.1	272.5	184.3	7.0	7.0	1.8	7.9	0.4	0.4
36	27.2	27.1	272.5	184.3	7.0	7.0	1.8	7.9	0.4	0.4
37	27.2	27.1	272.5	184.3	7.0	7.0	1.6	7.9	0.4	0.4
38	27.2	27.1	272.5	184.3	7.0	7.0	1.5	7.9	0.4	0.4
39	27.2	27.1	272.5	184.3	7.0	7.0	1.6	7.9	0.4	0.4
40	27.2	27.1	272.5	184.3	7.0	7.0	1.4	7.9	0.4	0.4

Table 3: During the expedition into a new cave on the 25th of May 2019 water temperature (°C), ORP(mV) , pH, Dissolved Oxygen (%) and salinity (ppt) measured *in situ* using a Hach HQ40d portable multi-meter in the New Cave pools.

Surface water	Temperature(C)	ORP(mV)	pH	DO(%)	TDS	Salinity(ppt)
New Cave (pool1)	27.1	185.2	7.2	9.8	612.0	0.40
New Cave (pool2)	27.2	184.2	7.1	8.8	607.0	0.38

Results

Population estimates in the Cave

During the VCs in the Cave, the two divers recorded 111 and 119 individuals in February and 35 and 41 individuals in May, which indicate a large overlap in the sightings between the two divers (Figure *8*). During the February VC *C. cavernicola* was found down to a maximum depth of 8 m, whereas 80% (mean n = 93) of the individuals were present in the first three upper meters of water. During the May VC *C. cavernicola* was found to a maximum depth of 17 m whereas 63% (mean n = 25) were found in the first three meters. The difference between the February and May VC was approximately 75 fish. This did indicate that the fish may move to areas outside this single cave pool. During the survey in February 2019, 10 fish were measured (total length, mm). The mean total length was 104 mm ± 44 SD with the minimum sizes being 42 mm and the maximum 153 mm (Figure *9*).

During both expeditions in the Cave, fish were located primarily in two areas. They were found over a shallow rock shelf in the middle of the cave, which is probably the same habitat referred to by Bruton (1995). However, they were also found to aggregate in the extreme north-west and south-east areas of the cave. These areas had a gradual slope (approximately 4 m in length) and gravel substrate. Within these areas, they could be seen hunting the endemic cave-dwelling isopod (*Namibianira aigamasensis*) which was found to be common in the cave (Figure *10*).

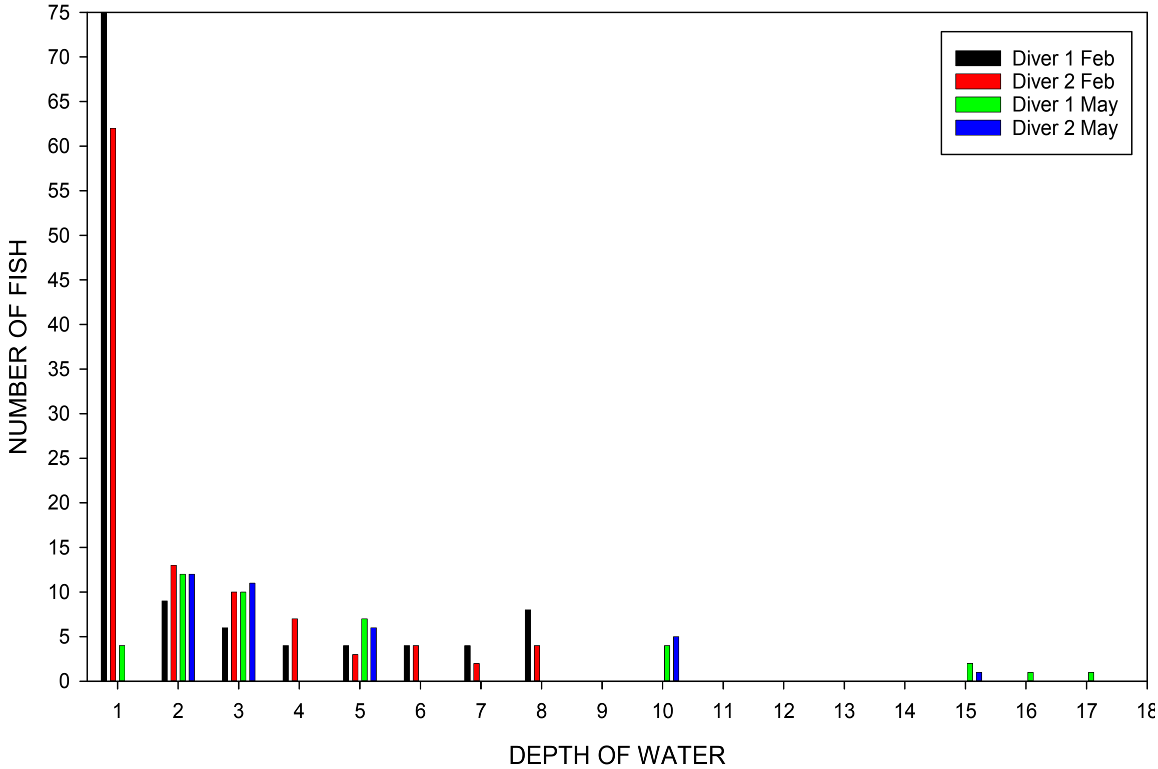

Figure 8: The direct-count method used by two divers. Counts were done at 1 m intervals from a depth of 40 m to the waters' surface. Total population estimate between 111 and 119 individuals.

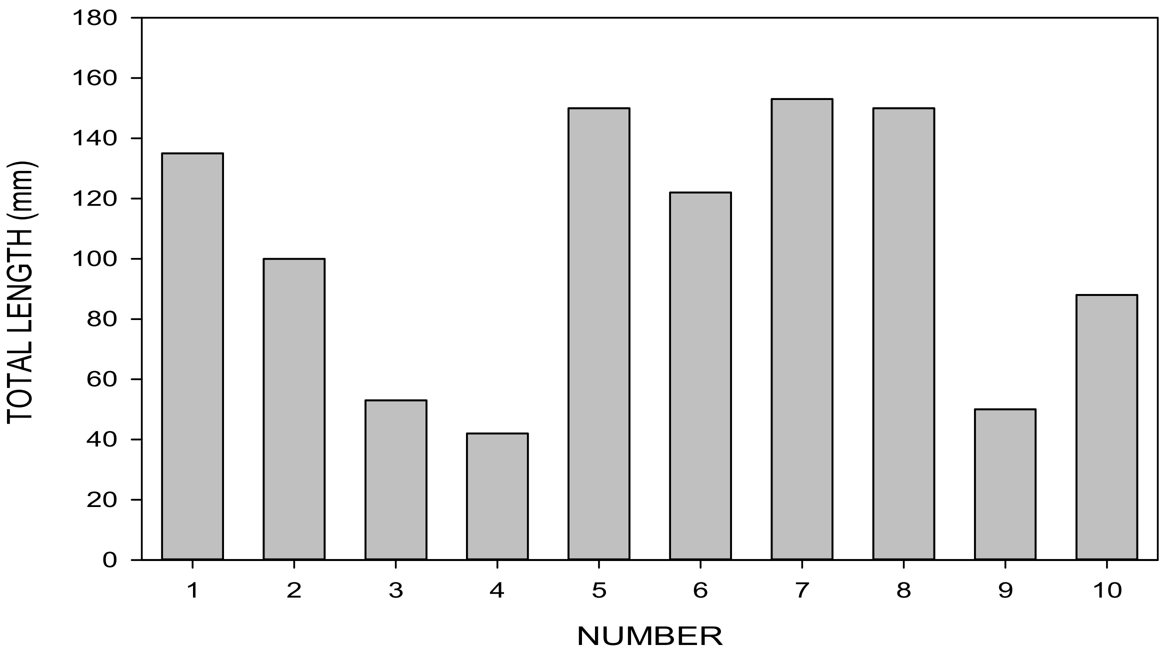

Figure 9: Length measurements of ten *Clarias cavernicola* during the survey in February 2019.

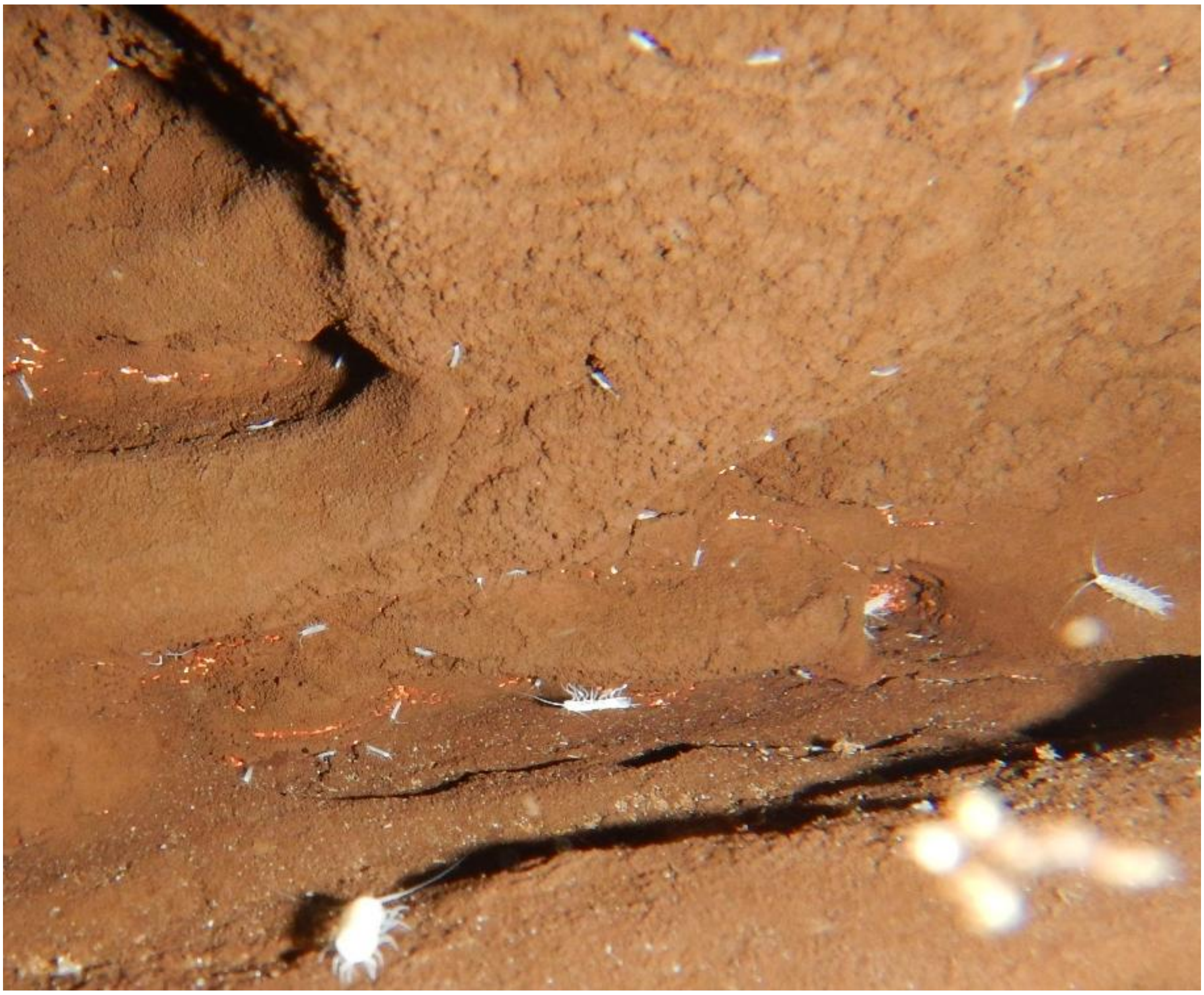

Figure 10: The endemic cave-dwelling isopod (*Namibianira aigamasensis*) which was found to be common in the cave.

Population estimates in the New Cave pools

One visual count from above the surface performed by two counters revealed that the first newly discovered cave pool had 58 and 62 *C. cavernicola* and the second cave pool had 11 and 14. Hence, the range of this species, although, at a small scale has now been extended to three pools in the same fault. The new cave pools are located > 100 m from the Cave pool and no connection between these pools could be seen. It is, however, very difficult to explore narrow cracks < 30 cm wide, but based on the geology of the fault it is expected that these pools are hydrologically connected and, thus, the individuals could be part of a single population. During the two dives, however, no passages from the Cave pool to the new cave pools could be seen down to a depth of 40 m. The absence of more than 60% of fish in the Cave pool during the May VC suggests that *C. cavernicola* may move to other areas in the cave system which has not been previously explored.

Discussion

Despite the fact that *C. cavernicola* was discovered 100 years ago, very little information is available concerning this species. The remoteness, the difficulty in accessing the water in the cave and the fact that this species does not play any role in human food security, such as the fish species in the northeastern rivers, probably contributed to this dearth of information. Namibia, being a signatory to the Rio Biological Diversity Convention compels the Namibian government and therefore the Ministry of Fisheries and Marine Resources who has the mandate, to protect this critically endangered fish species.

This study extended the distribution range of this species, although within the same fault and cave system. This extended range does provide marginally better protection against localized pollution, decline in the food source and water level. However, this updated information does not, in respect of the IUCN criteria, change the status and this species should still be considered critically endangered.

The physicochemical properties of the water are all consistent throughout the water column down to a depth of 40 m, except for oxygen that decreases drastically after 3 m after which it is very consistent with a slight decrease down to 40 m. This may be one of the reasons why the majority of the fish are present in the upper layers with none found deeper than 17 m. This as well as the fact that food is mainly present at the surface. It is most likely that oxygen enters the water column mainly through ventilation between the air and water surface that probably eliminates the possibility of a turnover process within the water column.The low oxygen concentration below 3 m may play a significant role in the movement of the catfish in the cave. If some connections between different parts of the cave are only at great depths, catfish could then be prevented from entering other components of the cave system.

Based on the visual counts, the current population estimate is standing at a minimum of 119 individuals, this suggests that the initial estimate of 150 to 200 individuals could be correct. Although, with the discovery of the new entrance to the cave system and the observed presence of catfish in this part of the cave, may suggest that there might be more individuals in parts that have not yet been discovered. However, at present, there is no reason to suggest that the population size of *C. cavernicola* is much larger than those counted.

The smaller individuals present at around 4 cm, which may be regarded as immature individuals, suggests that successful breeding has recently happened. It is however not evident when this actually took place.

The *C. cavernicola* population is currently considered to be healthy with individuals in a good condition, stable population numbers (compared to the previous estimates), no sign of any disease or skin infections, large water surface with several air connections, relative abundance of food and successful recruitment taking place. Another positive point is the restricted access to the cave enforced by the owner of the farm, however this aspect relies on the goodwill and interest of the current landowner. Unfortunately, some threats to the survival of this species are not in our control such as climate change that will most likely impact on the cave conditions and even the water abundance or any of the physicochemical parameters that currently provides for a very stable habitat.

Recommendations

The following actions are recommended:

- Predetermined interval visits to visually, from above the water, inspect the water clarity/condition, fish condition, for any sign of successful breeding, presence of food and a visual count of individuals.
- Gene sequencing can be done to determine closely related fish species and whether the species in the different parts of the cave are the same species or maybe a subspecies.
- Artificial breeding should be studied to potentially establish a population outside its natural range for restocking if necessary. This, however, should only be done in extreme circumstances as diseases/parasites/fungi can also be introduced into the cave.

- Suba dive counts should be conducted at least every 5 years. This, however, could change considering the variability that climate change is expected to bring.
- Determination of any specific site related conservation measures that might be applied, especially under the provisions of the Protected Areas and Wildlife Management Bill.
- Access to the cave must be controlled by the landowner and the Ministry.
- The cave ecosystem must receive special protection.
- The Minister should by notice in the Gazette declare this species as endangered. This would prevent anyone to catch, retain, kill or injure this species without the written permission of the Minister. This is according to Section 21 of the Inland Fisheries Resources Act (No. 1 of 2003) of Namibia.

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