PRELIMINARY TECHNICAL REPORT FOR THE PROJECT

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

GRANT AGREEMENT

between

The Namibian Chamber of Environment (NCE)

and

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REPORT INFORMATION

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Authors:	Jacobs, Francois; Hay, Clinton; Jacobs, Gerhard and Næsje, Tor
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Foreword

This report was made to summarize the fieldwork done in 2019 and present preliminary results of a baseline study of the critically endangered cave-dwelling catfish *Clarias cavernicola*. The aim is to document baseline information on *Clarias cavernicola*, listed as Critically Endangered by the International Union for Conservation of Nature (IUCN), with the objective to introduce measures to protect the species from extinction.

First, we would like to thank the Namibian Chamber of Environment for their support to this study. We would also like to thank Deputy Director of Inland Fisheries and Aquaculture Renier Dawid Burger for his valuable input and support. Further, we thank the research divers Chris Steenkamp and Rueben Engel, and the staff at Aigamas Farm, especially Axel and Silke Bauer for great help during fieldwork. And finally, we would like to thank the Ministry of Fisheries and Marine Resources and the Norwegian Institute for Nature Research for their important financial support.

30th April 2019
Francois Jacobs
Kamutjonga Inland Fisheries Institute

Introduction

Fish communities established in subterranean habitats and, hence, inhabit aphotic zones, are highly fragmented and tend to contain scarce food sources for fish (Poulson and White, 1969). Strong selective pressures within these communities ensure the survival of relict species which due to their fragility and vulnerability are among the most threatened fishes in the world (Skelton, 1990; Gibert and Deharveng, 2002).

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 reduction or loss of melanic pigmentation and partial or full loss of eyes (Holsinger and Culver, 1988). In Africa, eight species of subterranean fishes are currently 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 in Africa, two are from the Clariidae family namely, *Clarias cavernicola* Trewavas 1936 and *Uegitglanis zammaranoi* Gianferrari 1923.

Clarias cavernicola is known from only one, underground lake in Aigamas Cave (19°27'33.9"S, 17°16'59.3"E) 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, respectively. *Clarias* species are not found within Lakes Guinas.

Aims and objectives

There has been no behavioral or ecological studies on *C. cavernicola* (Berti and Messana, 2010; Proudlove, 2010), and limited data on basic aspects of their natural life-history and behavior have been available up to now. The only available records are a few observations about its spontaneous behavior in both the field and aquarium (Skelton, 1990; Bruton, 1995). Such knowledge is not only scientifically relevant and important but also fundamental for the establishment of efficient conservation policies. The aim of this study is focused around central questions relative to population parameters of *C. cavernicola*:

1) What is the population of *C. cavernicola* observed using visual census methods?

2) Is recruitment taking place today and are there seasonal fluctuations in the visual population densities of *C. cavernicola*?

3) What is the distribution of *C. cavernicola* within the cave habitat?

4) What is the state of the cave environment?

5) Are there threats to the population of *C. cavernicola*?

The answers to these questions will ultimately lead to development of protection measures to ensure the survival of this endemic catfish species. This report is describing the preliminary results obtained from the first dive that was carried out on the 9th and 10th of February 2019.

Materials and methods

Study area

Aigamas 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. Aigamas Cave is a large fault controlled, canyon passage in the Maieberg formation which reaches the surface at five places 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 groundwater generally 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). The water level of the lake rose by 10 m in 2011 after record rainfalls and then receded to its "normal level" again by 2015 (Pers. com. Axel Bauer).

Aigamas Cave is essentially a large fault-controlled canyon passage which reaches the surface in five place (Sefton *et al.*, 1986). These chimneys 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 lake is situated in permanent darkness, thus there is an absence of green plants and of photoperiods. The water surface of the lake is 18 m long, 2.5 m wide with the long axis extending approximately north to south. The depth of Aigamas Cave increases precipitously through a shaft into an incompletely mapped cavern system that has been explored to a depth of 100 m (Pers. com. Chris Steenkamp).

Population estimate

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 Agaimas Cave allows for visual count (VC) data from outside using the specialised platform and under water using SCUBA.

Estimates of population size were therefore performed using the direct-count method from outside and under the water. VC data were obtained by two divers using SCUBA gear during February 2019. The two divers upon entering the water 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 presence of *C. cavernicola*. If no fish were observed, divers ascended by 5 m until the first fish was observed. At 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 (Figure 1). The divers followed each other < 2 m apart counting all the fish horizontally in front of them and to the sides. Both divers counted all fish seen to compare counts afterwards. Individuals were caught using a hand dip net and measured for total length to the nearest mm.

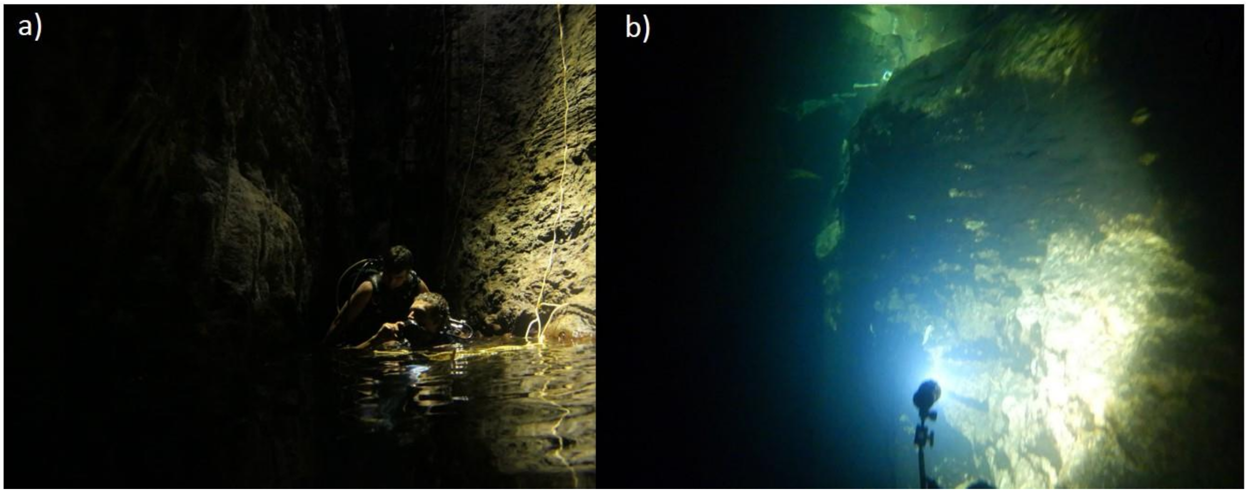

Figure 1: Scuba divers at the waters' surface preparing to descend (a) and scuba divers using dive lights to assess the cave habitat for *C. cavernicola* as part of population estimates (b).

Water quality

Water temperature (°C), pH, conductivity, salinity and dissolved oxygen, were measured *in situ* using a Hach HQ40d portable multi-meter lower to 40 m whereby a reading was recorded every meter. The multi-meter was calibrated on location, according to the instructions in the manufacturer's manuals to ensure accuracy. Water samples were also collected using a Niskin bottle at 5, 10, 15, 30 and 40 m depths for laboratory analyses.

Preliminary results

Population estimates

Despite the cave being more than 100 m deep, *C. cavernicola* was only found to a maximum depth of 8 m. However, the majority of the fish was located at 1 m depth. Fish were located primarily over a shallow shelf where they seem to aggregate most of the time. The total population estimate varies between 111 and 119 individuals (according to separate counts from both divers). Eighty percent of the individuals were present in the first three meters of water in the cave (Figure 2). During this survey, 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 3). The endemic cave-dwelling isopod (*Namibianira aigamasensis*) was also found to be common in the cave and were located to a depth of 15 m.

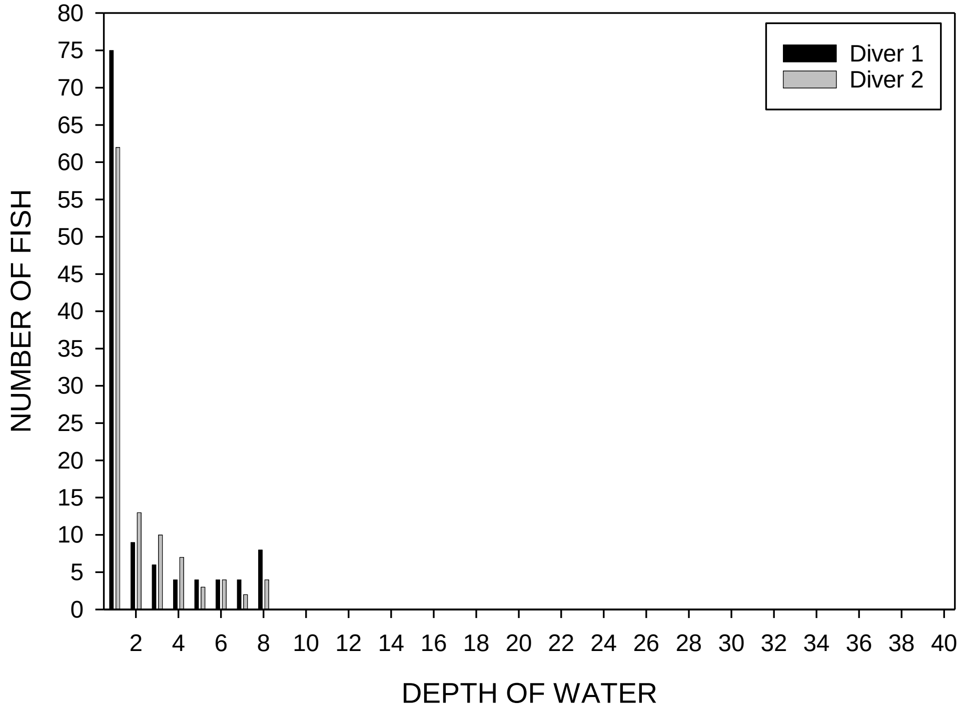

Figure 2: The direct-count method used by two divers. Counts were done at 1 m intervals from a depth of 40 m to the waters' surface. Total population estimate between 111 and 119 individuals.

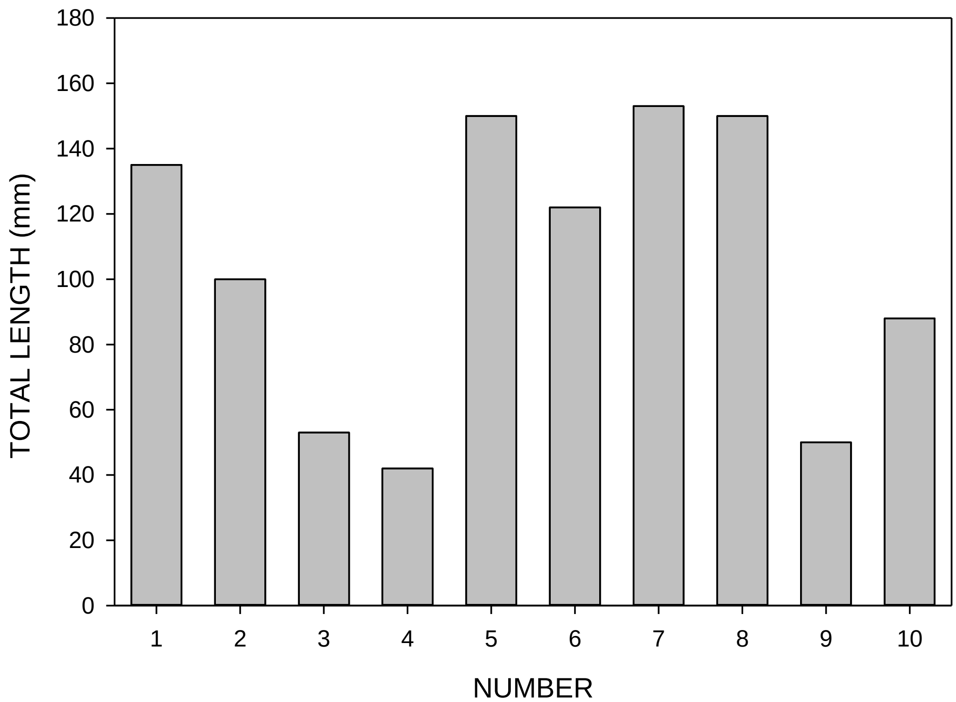

Figure 3: Length measurements of ten *Clarias cavernicola* during the survey in February 2019.

Water quality

Table 1 and 2 list the physicochemical properties of the water at selected depths down to 40 m. All readings are very consistent from the surface down to 40 m except for oxygen that decreased significantly down to 3 m after which it stabilizes.

Table 1: Physicochemical properties (as analysed in the laboratory in Windhoek) of the water at selected depths taken in Aigamas cave on the 9th February 2019.

Parameter	Units	0 m	5 m	10 m	15 m	30 m	40 m
Temperature	°C	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), pH, conductivity and dissolved oxygen 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.

Depth(m)	ORP(mV)	pH	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Salinity(ppt)
0	270.9	7.0	12.4	8.2	0.4
1	255.3	7.0	6.7	4.5	0.3
2	276.2	7.0	5.4	3.6	0.3
3	276.6	7.0	4.9	0.3	0.3
4	276.9	7.0	4.7	0.3	0.3
5	277.2	7.0	4.6	0.3	0.3
6	277.5	7.0	4.5	0.3	0.3
7	277.2	7.0	4.8	0.3	0.3
8	278.2	7.0	4.4	0.3	0.3
9	278.3	7.0	4.3	0.3	0.3
10	277.9	7.0	4.4	0.3	0.3
11	278.1	7.0	4.3	0.3	0.3
12	278.9	7.0	4.3	0.3	0.3
13	278.2	7.0	4.3	0.3	0.3
14	278.4	7.0	4.1	0.3	0.3
15	278.1	7.0	3.7	0.3	0.3
16	277.4	7.0	3.8	0.3	0.3
17	277.6	7.0	3.6	0.2	0.3
18	277.0	7.0	3.7	0.3	0.3
19	276.7	7.0	3.9	0.3	0.4
20	276.0	7.0	4.0	0.3	0.4
21	275.4	7.0	4.1	0.3	0.4
22	275.1	7.0	4.1	0.3	0.4
23	275.1	7.0	4.1	0.3	0.4
24	275.1	7.0	3.3	0.2	0.4
25	277.2	7.0	3.3	0.2	0.4
26	277.2	7.0	3.2	0.2	0.4
27	276.4	7.0	3.2	0.2	0.4
28	275.1	7.0	3.1	0.2	0.4
29	273.2	7.0	3.1	0.2	0.4
30	269.5	7.0	3.0	0.2	0.4
31	269.5	7.0	3.0	0.2	0.4
32	269.5	7.0	1.9	0.2	0.4
33	269.5	7.0	1.8	0.2	0.4
34	269.5	7.0	1.9	0.2	0.4
35	272.5	7.0	1.8	0.1	0.4
36	272.5	7.0	1.8	0.1	0.4
37	272.5	7.0	1.6	0.1	0.4
38	272.5	7.0	1.5	0.1	0.4
39	272.5	7.0	1.6	0.1	0.4
40	272.5	7.0	1.4	0.1	0.4

Follow-up survey

The next survey is planned for the 24th of May 2019 and will include a replicate of sampling techniques and additional exploration into a nearby cave opening to see if *C. cavernicola* is present in other areas within the same cave system. Numerous breaks occur on the same cave system and it may be plausible that sub-populations of *C. cavernicola* are still undiscovered which needs investigation (Figure 4).

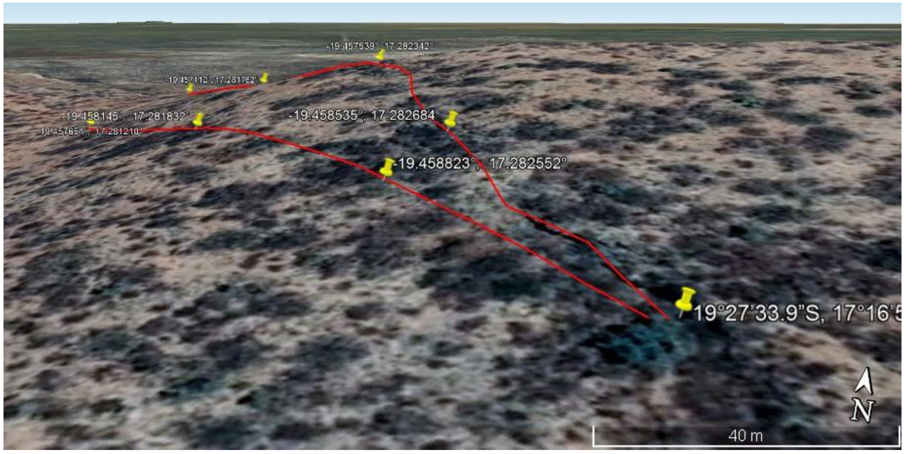

Figure 4: Possible entrances to the same water body along the Aigamas ridge line which will be investigated during the next survey in May 2019

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