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Fish Assemblages and Habitat Use in the Upper Nakambe Catchment, Burkina Faso

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Abstract

This study analyses fish assemblages and their habitat use in the Upper Nakambe catchment of Burkina Faso located in the central part of West Africa. The study gives an overview on the available habitat conditions and their effect on fish community composition and abundances as well as on habitat use of single species. Furthermore the conducted fishing methods, electric fishing and the traditional cast net fishing are compared and their pros and cons are discussed. To answer these questions we sampled 157 fish habitats, caught 18,335 individuals and recorded a total number of 16 families, 35 genera and 70 species in four different river reaches. There are lists provided with the spatial distribution of the caught species, ranges for different habitat parameters and usage curves of four key species; i.e. *Labeo cubie* shows a coarser substrate usage than *Bagrus bajad;* and the habitat of *Chelaethiops bibie* exhibits high occurrences for Xylal. The results of this research make important contribution to general knowledge on habitat use and ecology of fish in semi-arid areas of Africa. They can be used as a management tool for a healthy ecosystem and a sustainable fishery which in turn contributes to food security.

Keywords: Fish, Habitat, Cast net, Electric fishing, Freshwater*, Labeo cubie, Bagrus bajad, Chelaethiops bibie, Lates niloticus*, Burkina Faso, West Africa

Content

1. Introduction

Burkina Faso is a sub Sahelian landlocked country located in the central part of West Africa. It is one of the poorest and least developed countries in the world, with the fifth last ranking in the human development index (UNDP, 2013), showing the urgent need for sustainable development. This is on one hand challenged by natural conditions like long dry seasons with chronic water scarcity and frequent floods and droughts. On the other hand there are several socioeconomic constrains: The population has grown six fold in the past hundred years and is still growing fast. Moreover almost half of the people is at poverty level, only one third of the children complete primary school (INSD, 2009) and more than 40% of the five year old children suffer from chronic malnutrition.
As a consequence food security is a central goal in the national development policies and strategies (DGPSA, 2007).

Burkina Faso is drained by three large river basins (64% Volta, Niger 30%, Comoé 6%) The largest and most important is the Volta Basin with over 120,000 km². There are three major rivers, the Mouhoun, Nakambe and Nainon (former Black-, White-, and Red Volta) which finally all flow into Lake Volta in Ghana.

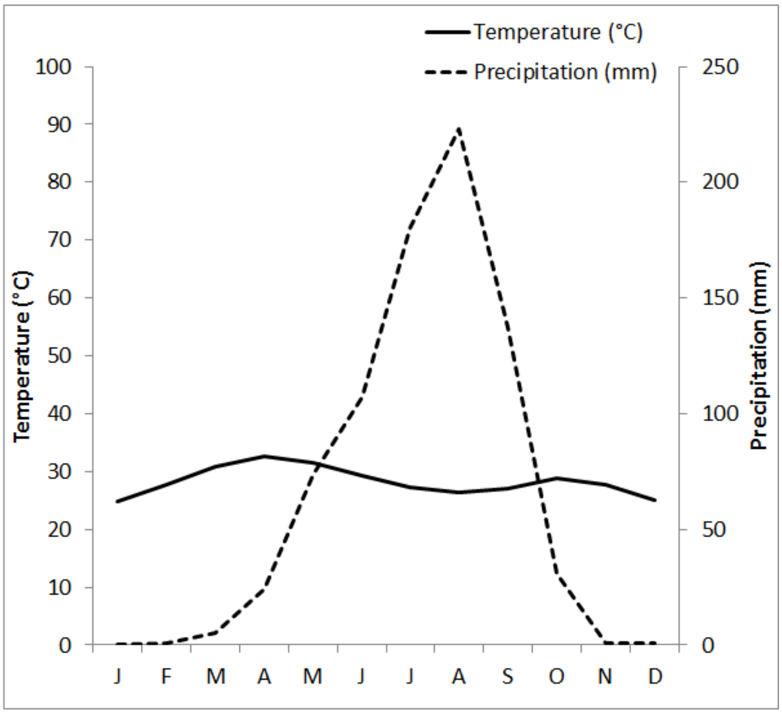


Figure 1.1. Mean annual Temperature (°C) and Precipitation (mm) of Ouagadougou (modified from GDV, 2013).

The country has a tropical climate with two seasons. In the rainy season, which lasts approximately four months, from May/June to September, the country receives between 600 and 1000 mm of rainfall per year (Figure 1.1). In the dry season the high temperature (up to 45°C) results in massive loss of water due to high evaporation rates (2000 mm/year) (Manson and Knight, 2011; Ouedraogo, 2010; Baijot et al., 1994).

As a reaction to severe droughts more than 1400 reservoirs were built since 1950 which are mainly used for agriculture, livestock and fisheries (Ouedraogo, 2010). The construction of reservoirs increased fishery landings by 15 times since 1950, employing more than 30,000 fishermen and several thousand women processing and selling the fish (Ouedraogo, 2010) and fish has become an important protein source (FAO-MAFAP, 2011).

However, loss of habitat and human pressures led to a decline of the fish population in terms of total population, biodiversity and average fish size (Ouedraogo, 2010; Melcher et al. 2012)

The lack of reliable data in Africa concerning fish, ecology as well as general information is well known as mentioned by many authors (Tito de Morais, 2001; Willem and Andrea, 2005; Ouedraogo, 2010) , furthermore the IUCN red list status is not available for one third of the species we caught. To close this gap, we made a list of potential fish species for Burkina Faso by comparing species lists of Roman (1966), Paugy et al. (2003) and Ouedraogo (2010). In the last decades it has been an important aim to find relations between ecological variables and environmental data (Brosse and Lek, 2000). The specific composition of communities is mainly influenced by the interaction between animals and their biotic and abiotic environment (Schoener, 1974). Concerning fish, habitat is regarded as one of the key factors (Werner et al., 1977). This fish habitat encompasses the variety of physical, biological and chemical features of the environment that affects assemblages, populations and individuals (Hubert and Bergersen, 1999). The knowledge on essential fish habitat, for spawning, breeding, feeding or growth to maturity is important to support a healthy ecosystem (WPFMC, 1998) and provides a management tool for a sustainable fishery (Rosenberg, 2000). This in turn contributes to food security and as an economic resource, especially for low income people (Kent, 1998).

This study focuses on natural habitats of fish and, therefore deals with rivers, tributaries and outflows of reservoirs. The work was written within the framework of the SUSFISH

(Sustainable Management of Water and Fish Resources in Burkina Faso) project. The APPEAR (Austrian Partnership Programme in Higher Education & Research for Development) project SUSFISH is funded by the Austrian Development Agency, implemented by the OEAD (Austrian Agency for International Cooperation in Education and Research) and coordinated by Dr. Andreas Melcher from the University of Natural Resources and Life Sciences in Vienna.

The SUSFISH project is a program for higher education with the overall goal to build capacity, monitor and manage sustainable fisheries.

The objectives of the SUSFISH project are to build capacity to study, monitor and manage sustainable fisheries (overall goal) to develop water management and assessment methods based on fish, appropriate for Burkina Faso;

1) to identify, evaluate, and prepare existing data for fish, environment and pressures for a national database;
2) to analyze the relationships between pressures (incl. overfishing, land use, continuity) and the dynamics in fish assemblages and in water quality;
3) to develop ecological awareness by using appropriate case studies to demonstrate the importance of ecological services and biodiversity to the nation's food security and health care;
4) to support the implementation and dissemination of project results by (a) integration of the project results in the education policies and on-going national programs, (b) workshops and international conferences. (Susfish, 2012)

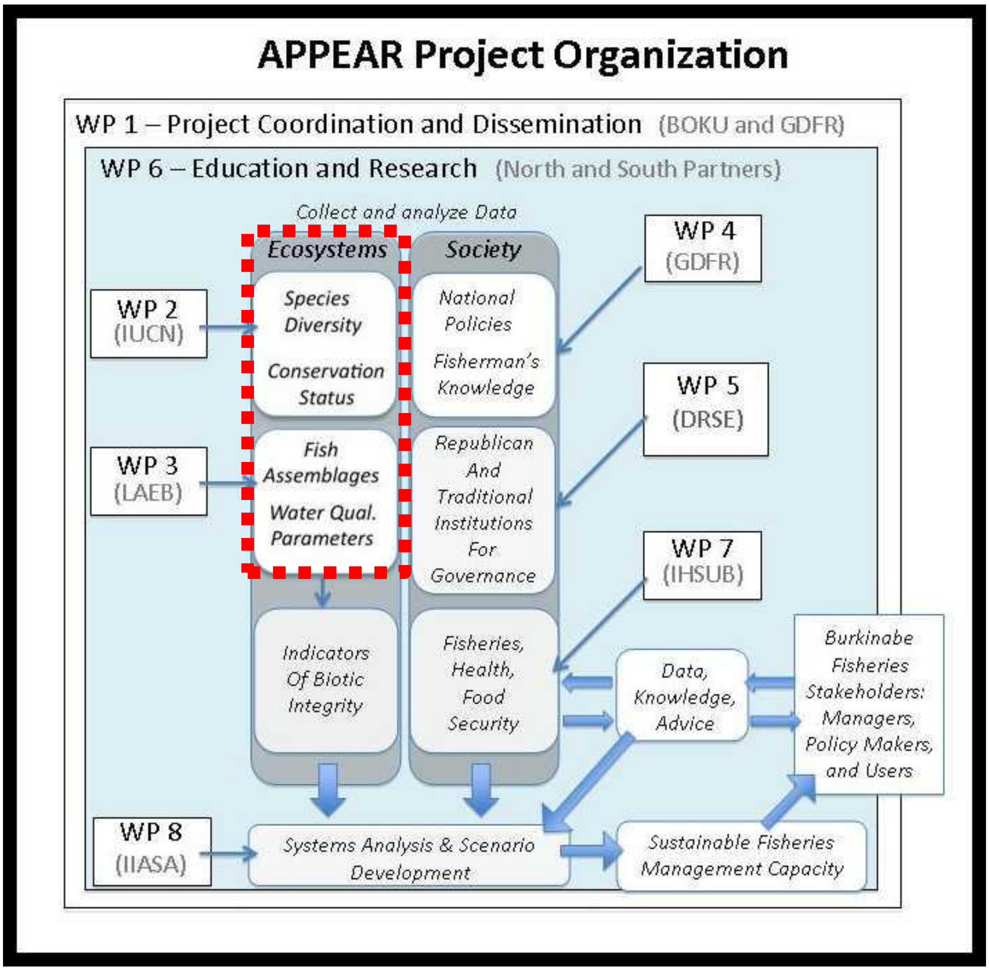


Figure 1.2. Appear Project Organization (Susfish, 2012).

The project is organized in eight work packages and this thesis is situated within WP2 (Basic tools – environment and biodiversity) and WP3 (Quality of waters –risk assessment) (Figure 1.2).

Picture 1.1. Susfish fishing team in Burkina Faso

The overall objective of this study is to gain knowledge on habitat use of fish in general and for key species in the Upper Nakambe catchment and to compare the conducted methods (traditional cast net fishing and electric fishing).

The specific objectives are:

1) to analyze fish assemblages and their spatial distribution
2) to discuss the appropriate fishing method and make recommendations for further fish sampling activities in Burkina Faso,
3) to quantify the available habitat conditions,
4) to assess the effect of habitat parameter on species richness and abundances,
5) to analyze habitat use of four key species namely *Labeo cubie*, *Chelaethiops bibie*, *Bagrus bajad* and *Lates niloticus* and their populations structure.

For this purpose, as well as for the purpose of knowledge transfer, we spent three months in Burkina Faso for Data collection together with our Burkinabe colleagues. The results of this thesis can be implemented into the PhD study of a Burkinabe student using fish communities for assessment of the ecological status of aquatic ecosystems in Burkina Faso, and can therefore be an important contribution to conservation and food security.

2. Methods

This chapter describes the sampling sites, the fish and habitat sampling and the used methods. It was written and conducted in cooperation with Sebastian Stranzl.

2.1 Sampling site selection

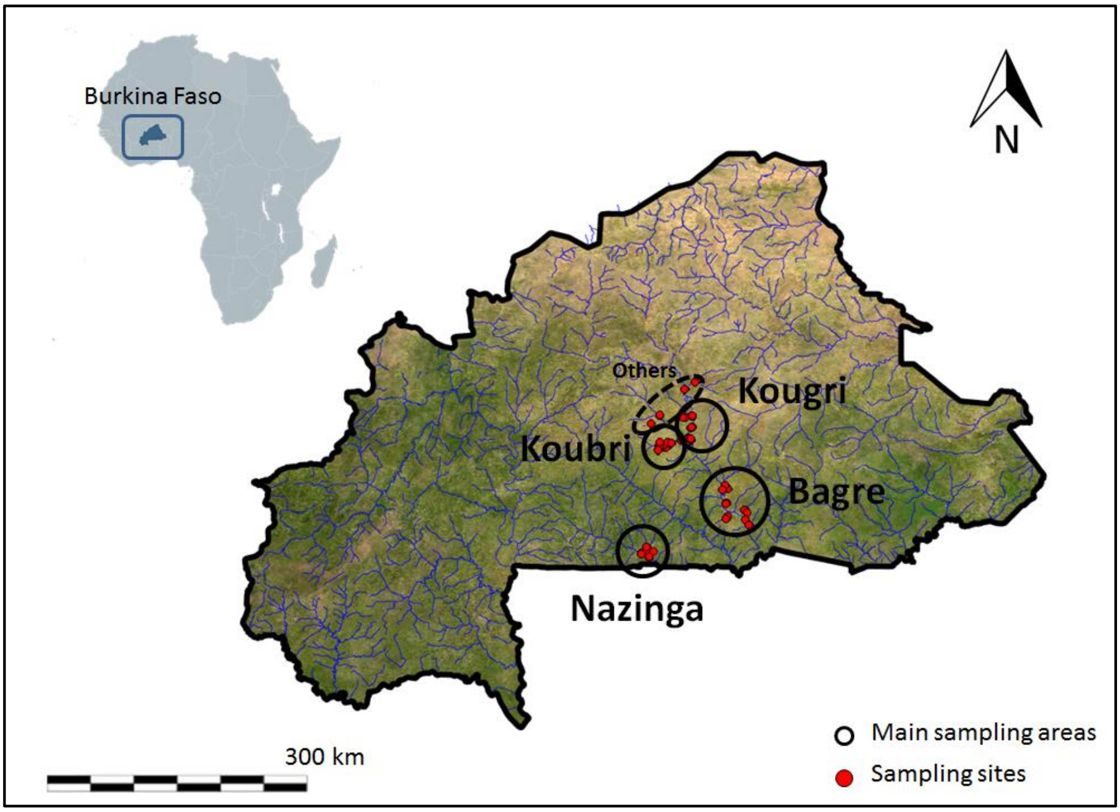


Figure 2.1. Burkina Faso, overview of the main sampling areas (black circle) and sampling sites (red spots) (modified from Google Earth, 2013).

The study area is located in the Nakambe catchment in Burkina Faso between the reservoir of Korsimoro, north of Ouagadougou, and the border of Ghana in the south. The sampling took place between October and December 2012 in the first period of the dry season. Sampling areas were selected visually by means of GIS and expert judgment of our supervisors, local fishermen, the Ministry of Environment and the University of Ouagadougou. Decision criteria for selection were water availability, accessibility, different human stressors, spatial variability, security and travelling costs. Due to the war in Mali (2012/2013) and for security reasons we could not sample in the north of the country. Each area was subdivided into different sites. A site is the entity of all nearby and accessible habitats. Figure 2.1 gives an overview of the sampling sites, Figure 2.2 shows detailed maps of the sampling areas.

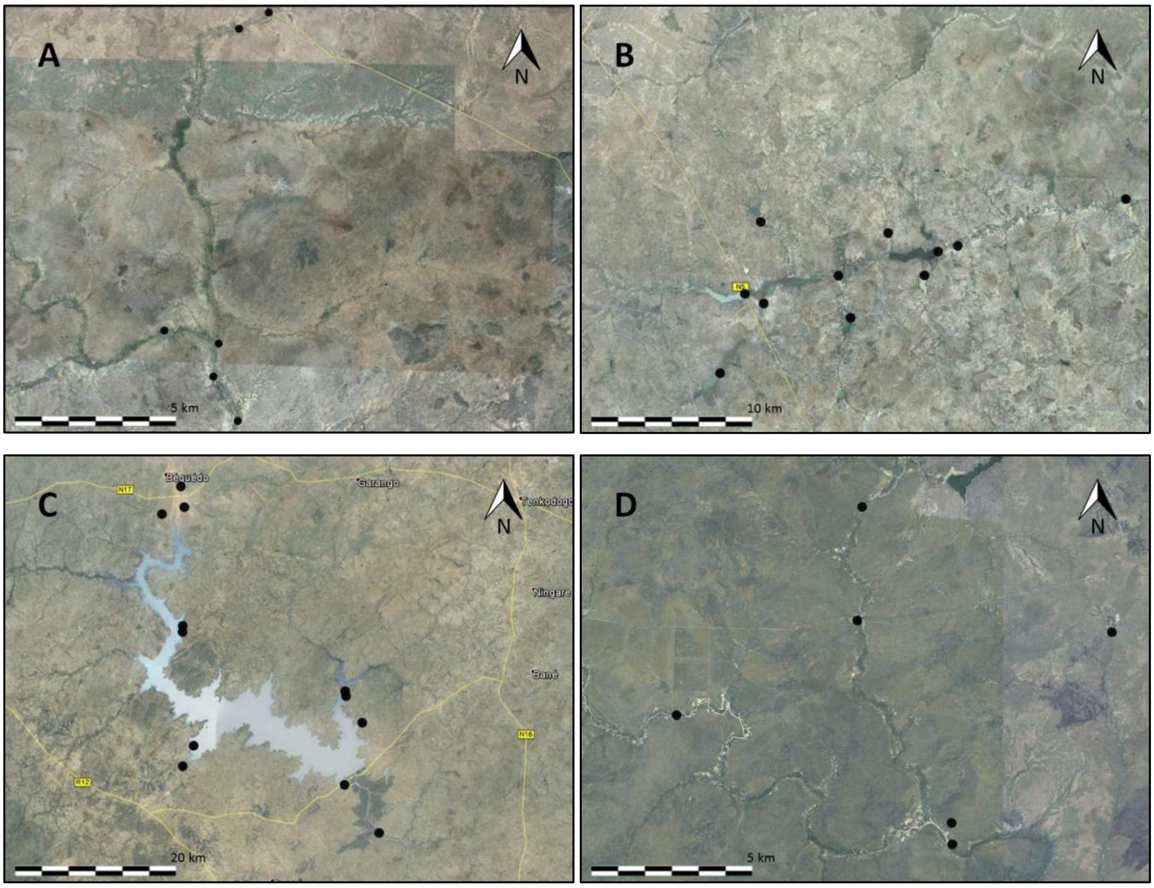


Figure 2.2. The area of Kougri (A), Koubri (B), Bagre (C) and Nazinga (D) with all sampling sites (black dots) (modified Google Earth, 2013).

Kougri is located at the Nakambe River in the east of Ouagadougou. Figure 2.2 (A) shows the Nakambe flowing from the north to the south. The Nariale, a tributary is flowing in from the east.

The moderately impacted area of Koubri (Figure 2.2 B) consists of 15 Reservoirs and belongs to the mentioned Nariale catchment (Ouedraogo, 2010; Melcher et al., 2012).

Bagre (Figure 2.2 C) is the biggest Reservoir in Burkina Faso and was constructed to reinforce irrigation and for providing hydroelectricity. This large shallow Reservoir was built in 1994 by Damming the Nakambe River (Villanueva, 2005).

The protected game ranch of Nazinga (Figure 2.2 D) is located in the south to the border of Ghana and was created 1979. It is characterized by low population density, no economic activities such as agriculture, livestock breeding or wood usage. There is one natural pond and additionally 11 small reservoirs were built to provide wildlife with water. (Ouedraogo, 2010; Melcher et al., 2012)

Table 2.1. Study site names, number of fished habitats, elevation and GPS-Coordinates (WGS 84, Decimal Degrees).

Sampling Location	Number of fished habitats	Longitude	Latitude	Elevation (m)
Kougri (A)	23			
Kougri	5	-1.080785	12.378996	259
Nakambe Barrage	5	-1.089082	12.245099	251
Nakambe under Nariale	3	-1.098804	12.256668	250
Nakambe/Masili	4	-1.09619	12.268317	256
Pitioko	6	-1.116612	12.26906	265
Koubri (B)	53			
Ancien	1	-1.354739	12.226753	282
Arzoum Baongo	7	-1.29724	12.221255	280
Naba Zana	8	-1.351469	12.204276	280
Noungou	5	-1.304137	12.204209	269
Pedga	5	-1.341553	12.180401	291
Peele	4	-1.190097	12.249763	268
PK25	2	-1.402519	12.192986	279
Naba Zana pond	3	-1.392333	12.187168	281
Segda	4	-1.284121	12.223419	268
Stream koubri (Nagreongo)	1	-	-	-
Tolguin	3	-1.322209	12.229311	280
Tyokin	3	-1.396337	12.235285	291
Wendbila	7	-1.415616	12.151827	292
Bagre (C)	34			
Bagre (Djerma/Boussouma)	1	-0.746512	11.773999	238
Bagre Tributary	1	-0.538301	11.533057	239
Bagre-Bangako	2	-0.554605	11.461552	232
Djerma/Boussouma	5	-0.862597	11.675352	248
Fungu	5	-0.731184	11.497439	237
Lengho	3	-0.742808	11.622711	236
Nakambe	2	-0.515558	11.409616	212
Niagho	3	-0.777061	11.757274	224
Béguédo	4	-0.725718	11.769889	232
Béguédo 2	4	-0.752621	11.807014	244
Zangoula	4	-0.557837	11.562785	240
Nazinga (D)	22			
Bodjero	6	-1.504391	11.091481	269
Kouzougou	3	-1.531004	11.154303	266
Naguio	8	-1.583241	11.128345	274
Talango	5	-1.528114	11.188797	270
Others	25			
Korsimoro	5	-1.148269	12.475053	274
Nakambe Bissiga	6	-1.14811	12.475041	276
Zigga	3	-1.076134	12.492104	269
Loumbila	11	-1.397884	12.493584	285
Total	157			

2.2 Field sampling

2.2.1 Development of Field Protocol

The field assessment sheet was developed by adjusting others (Barbour, 1999, NGP, 2010; FAME, 2004) to the conditions and requirements in Burkina Faso. After two initial runs it was adapted to fit to the conditions and to elevate the available and necessary Burkinabe habitat characteristics. The final habitat assessment sheet is attached in the Appendix (Figure 6.1).

Table 1.2. Variables and parameters of the field Protocol for sampling fish and environmental data.

Variables	Description/Unit
Methodological	
Writer	Name of clerk
GPS-Coordinates	Latitude and longitude
Run/Throw nr.	Number of runs for electro fishing/Number of throws with cast net
Start time	Starting time of fishing for each habitat
End time	Ending time of fishing for each habitat
Photo nr.	Photo number of the fished habitat
Weather	Weather at starting time
Sampling method	Conducted fishing method, electro, cast net, gill net
Blockage	Blockage in the fished water body, natural, artificial and non
Sampled area (m^2)	Estimated fished area for electric fishing
Fish	
Species name	Scientific name of the caught fish
Abundance	Abundance of the caught fish
Length	Total length of each fish
Sample number	Number of sample bottle for fish kept for determination
Physicochemical	
Conductivity	In µS/cm
Temperature	In °C
Oxygen	In % saturation and mg/l
pH	Value
Pressures	
Land use	Surrounding land use: Savanna, rice, cotton, vegetables, agriculture, livestock, settlements, roads, forest, protected
Pressure	Visible pressure on the water body, fishing, mining, water abstraction, deforestation, nutrients, washing
Dam	Location of the next dam, upstream, downstream, free flowing
Habitat	
Wetted width	In meter
Water depth	In meter
Velocity	Flow velocity in meter per second
Structure	In the water column, tree, xylal, rock, water plants, reed
Shading	Shading of the sampled water body in % of surface area
Water body type	Reservoir, running, connected sidearm, dead sidearm, pond, dissipation basin, channel, artificial

2.2.2 Fish sampling

Fish were sampled in all water bodies within one sampling site using mainly two types of equipment-electric fishing (EF) and cast net (CN) (Figure 2.3). Additional at some sites a gill net (GN) was used.

For EF the backpack-generator ELT60-IIH from Hans Grassl (Grassl, 2012) was applied. The generator has 1.3 kW and can be switched between 300 V and 500 V. Due to low conductivity all except of one habitat were fished with 500 V. The anode ring has a diameter of 30 cm with a net of 5 mm mesh size in the center. Each habitat was fished in one run by at least three people, one carrying and operating the generator, one landing the fish and a third for security reasons and carrying a bucket to empty the net. Elapsed time was recorded and fished area was estimated to make the results comparable. Small water bodies were fished completely, while big ones were point sampled. EF was always performed by wading. (Compare Reid, 2011; Brousseau et al., 2005; Schmutz et al. 2001; Peter and Erb, 1996)

Figure 2.3. Fishing methods: Electric fishing (left) (Trauner, 2012), Cast net (right)(Koblinger, 2012).

Two professional local fishermen were recruited to conduct the ‘traditional’ CN fishing method. Two different kinds of nets with 10/25 mm mesh size and a diameter of 4.3/4.5 m were used. Number of throws was noted for comparison. Most of the time the fishermen were wading, for some deeper areas they used a boat. (Compare Edo, 2007) There is a video available explaining how to throw the CN by Noufou Bonkoungou, one of the fishermen with 40 years’ experience [www.susfish.boku.ac.at](Susfish, 2012).

The GN was also conducted by our fishermen. It had a mesh size of 50 mm and was placed for two to five hours.

When possible, electric fishing and cast net were applied to the same habitats. Fish were kept in separate buckets for determination, length measurements (total length) and were released afterwards.

2.2.3 Habitat sampling

At each habitat we used measuring tape and a Zeiss laser distance meter to measure the river width and depth at randomly selected transects. Flow velocity was measured using the Global Water Flow Probe FP111. Width, depth and velocity were measured at seven randomly selected points. The number of measurements is empirically chosen as the smallest statistically relevant quantity (Parasiewicz, 2007).

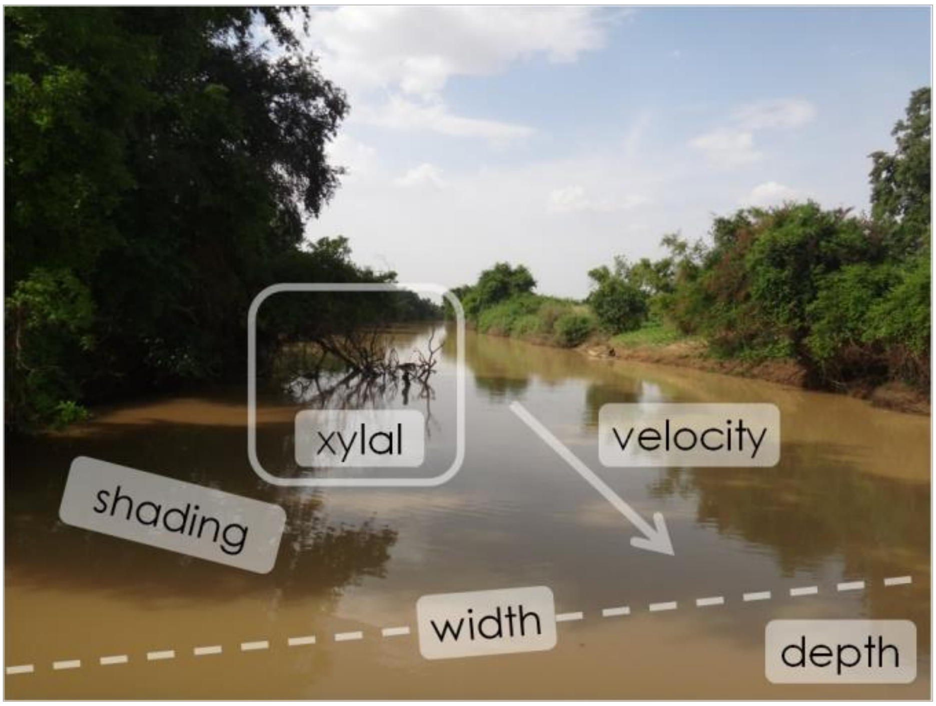


Figure 2.3. Selection of sampled habitat parameters (velocity in m/s, width and depth in m, shading in %, presence-absence of in-stream structures).

The degree of surface covered with shading was estimated and noted. Presence-absence of in-stream structures like Xylal, rocks, water plants, trees, reed and out-washed bank were recorded. Figure 2.3 illustrates these recorded data. The substrate distribution was estimated and dedicated to the different classifications (Pelal<6um, Psammal 6um-2mm, Akal 2-20mm, Mikrolithal 20—63mm, Mesolithal 63-200mm, Macrolithal 200-400mm, Megalithal>400mm, Primary rock and Concrete) according to Austrian ÖNORM 6232. Basic

physicochemical parameters were measured with a WTW Multi 340i Gear namely pH, O_2, temperature and conductivity.
In addition for each habitat adjacent land use and obvious stressors were categorized and noted (Stranzl in prep.). For selected sites we took water samples and sent them immediately to a laboratory for chemical analysis.

2.3 Data analysis and fish determination

Based on the list of potential fish species (Appendix, Table 6.1), which was compiled with literature research and in cooperation with IUCN (Afrique centrale et de l'ouest), and the determination key by Paugy et al. (2003) a hotkey was developed for determination in the field. All animals that were questionable or not possible to determine to species level were collected and preserved in 70% alcohol for further analyses. At the moment of submitting this thesis, determination was still not finished. For this reason some specimens were left at genus or family level for the analyses.

Statistical analyses and data management were achieved by using SPSS and Excel.
To analyze fish assemblages and spatial distribution descriptive statistic was used to create cross tabulation. For visualization boxplots and a Venn diagram (Mamakani et al., 2012) were compiled. For the illustration of the population structure, length frequency diagrams are used showing the relation between length classes and relative frequency. A Rarefaction Curve was plotted to present the amount of species as a function of the number of samples (Gotelli, 2001). This relation can be expressed by the polynomial function

[1] $$y= -0.0589x^2+2.6227x+22.766 \qquad (R^2=0.946).$$

Available habitat conditions were quantified through histograms and boxplots. Its effects on species richness and abundances are shown in a combination of line plots and histogram.
To analyse habitat use of selected species, available habitat and usage curves were developed for selected parameter using frequency-of-use graphs (FUG, Raleigh et al. 1986) as normalized probability function ranging from 0 to 1 (Melcher and Schmutz, 2010).

[2] $$FUG_i = \int_i \; / \int_{[max]}$$

3. Results

A total of 157 water bodies in eight different areas were investigated. The main focus was put on Kougri, Koubri, Bagre and Nazinga. Due to the low number of sampling points Bissiga, Korsimoro, Loumbila and Zigga were summarized for further analyses (Others). If not mentioned otherwise all fish length are meant as total length.

3.1 Fish assemblages

We took 157 fish samples in the considered areas. For all fishing methods and habitats together we caught 18,335 fish specimens and recorded a total number of 16 families, 35 genera and 70 species (Table 3.1 and 3.2).

Table 3.1. Overview of the caught number of families, genera and species for all sampling sites together.

Family (N=16)	Number of genera	Number of species
ALESTIDAE	5	12
ANABANTIDAE	1	1
BAGRIDAE	1	2
CENTROPOMIDAE	1	1
CICHLIDAE	5	7
CITHARINIDAE	1	1
CLARIIDAE	2	3
CLAROTEIDAE	2	3
CYPRINIDAE	4	14
DISTICHODONTIDAE	1	1
MALAPTERURIDAE	1	1
MOCHOKIDAE	1	8
MORMYRIDAE	6	11
POLYPTERIDAE	1	1
PROTOPTERIDAE	1	1
SCHILBEIDAE	2	3
Total	35	70

The number of species varied between 33 in Kougri and 47 in Nazinga. The number of exclusive species reports the number of species which were caught exclusively in this area and ranges up to 12 for Nazinga. Table 3.2 summarizes abundance, number of caught species, the number of exclusive species, conducted sampling days and average caches, number of fished habitat and the mean total length of the fish separated for the different areas.

Table 3.2. Sampling effort and fish community metrics for all study areas in the Nakambe catchment.

	Kougri	Koubri	Bagre	Nazinga	Others	Total
Number of individuals	2,738	5,040	2,567	5,643	2,347	18,335
Number of species	33	45	33	47	33	70
Number of exclusive species	2	11	1	12	0	26
Sampling days	4	11	4	4	3	26
Number of fished habitat	23	53	34	22	25	157
Abundance per sampling day	685	458	642	1411	799	799
Mean Total length (mm)	73.5	76.1	61.1	123.8	78.8	86.9

Figure 3.1 illustrates the spatial distribution and the relation between the number of species and the four main areas. 21 species were caught in all areas, while 14 species only occurred in Koubri and another 14 only in Nazinga. These two areas together share 27 species (3+1+21+2).

Picture 3.1 Dangerous fish, Hydrocynus forskali (left)(Koblinger, 2012) and the electrifying Malapterurus electricus (right)

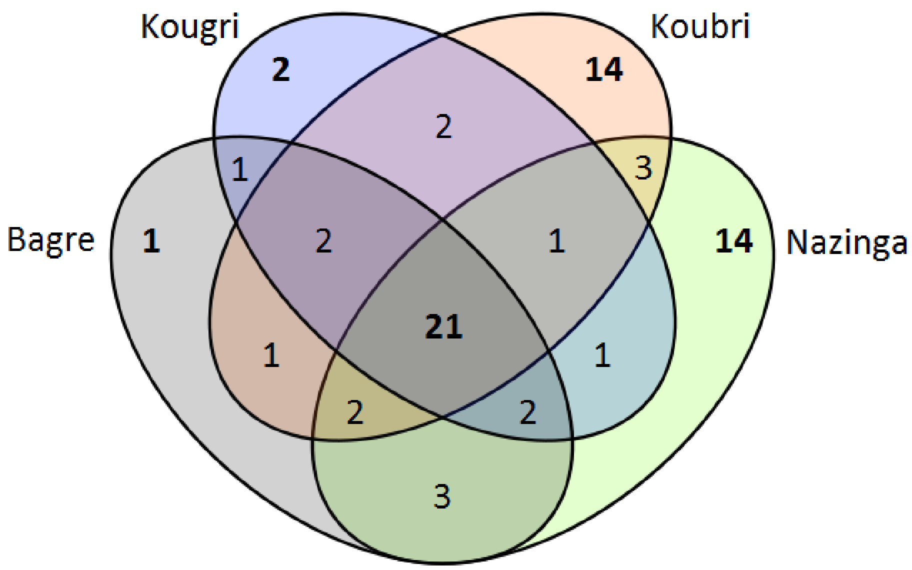


Figure 3.1.Venn diagramm summarizing the relations between the areas and the number of fish species they have in common and exclusively for the main sampling areas.

At fish community level (all sampled fishes and all species), Nazinga shows a higher mean length (123.8mm) than the other Areas (Table 3.2, Figure 3.3). Furthermore abundances per minute electric fishing shows in Nazinga the highest values (Figure 3.2).

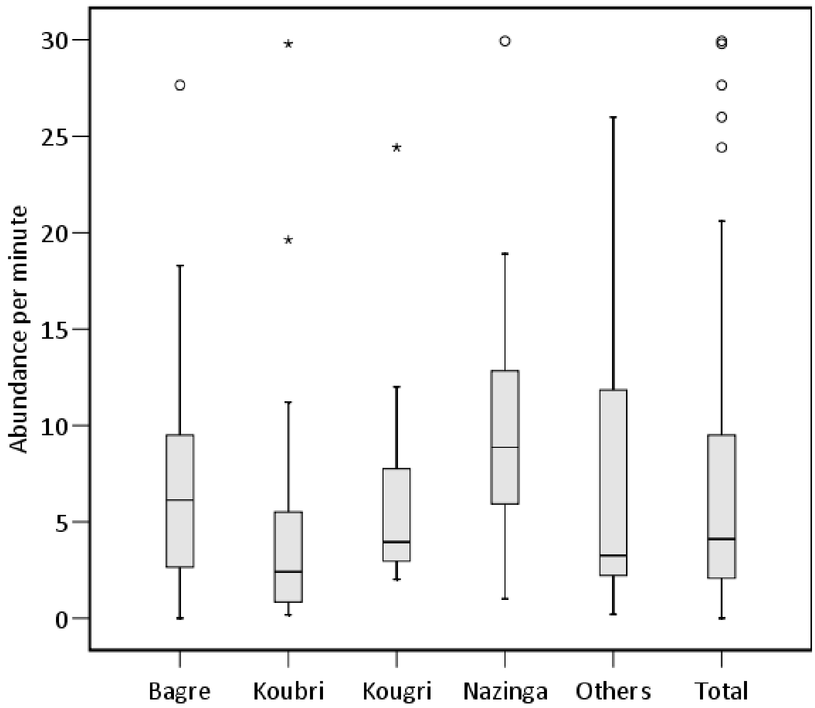


Figure 3.2. Abundances per minute electric fishing for all areas.

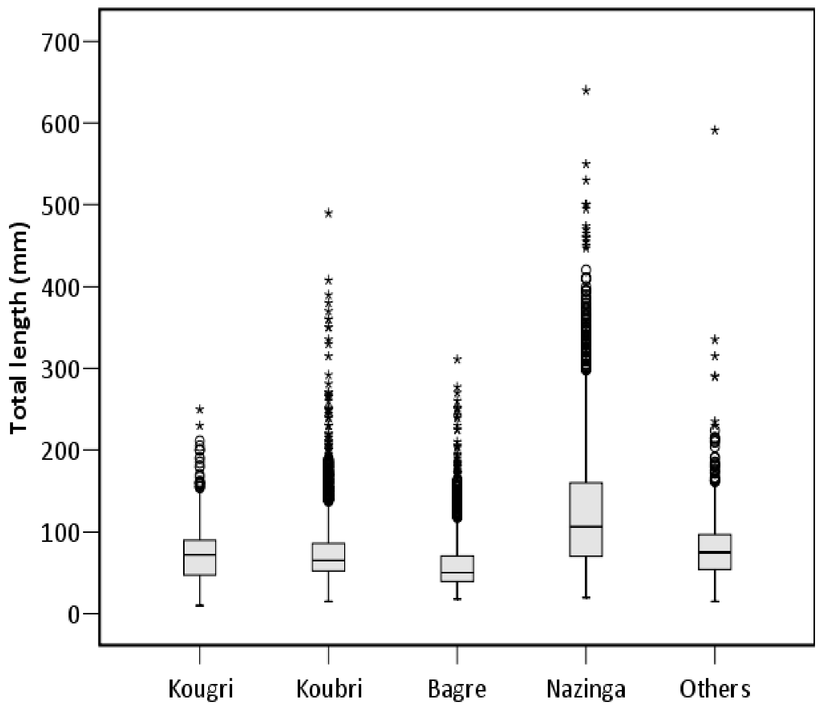


Figure 3.3. Mean total fish length of all caught individuals per sampling Area.

In Table 3.3 a full list of the relative frequencies of the caught species and their red list status is available.

Picture 3.2. ***Hippopotamyrus pictus, Hemichromis bimaculatus, Synodontis nigrita, Protopterus annectens***

Table 3.3. Relative frequency (%) of fish species and their spatial distribution in the investigated areas and Red List status (na=not available, LC= Least Concern), highlight of species >10% relative frequency (bolt), *highlight of exclusive species (cursive).*

Nr.	Species	Total	Kougri	Koubri	Bagre	Nazinga	Others	Red List
1	*Barbus sp.*	**11,72**	**13,11**	8,65	**18,47**	6,08	**23,78**	na
2	*Barbus macrops*	**10,14**	**13,04**	**13,93**	**16,31**	4,07	7,33	LC
3	*Marcusenius senegalensis*	8,68	1,06	2,22	0,89	**22,60**	5,03	LC
4	*Oreochromis niloticus*	8,19	6,94	**15,40**	5,82	5,15	4,01	na
5	*Sarotherodon galilaeus*	8,13	**12,20**	**10,18**	5,35	3,31	**13,59**	na
6	*Brycinus nurse*	6,59	**10,70**	1,09	**18,00**	5,74	4,26	LC
7	*Tilapia zillii*	6,48	1,53	**15,60**	1,95	2,15	7,84	LC
8	*Alestes sp.*	5,75	3,91	4,50	**11,34**	6,41	3,37	na
9	*Clarias sp.*	5,26	2,19	9,23	4,63	4,85	1,96	na
10	*Schilbe intermedius*	5,13	**10,92**	4,64	0,51	5,25	3,75	LC
11	*Chelaethiops bibie*	3,61	**12,49**	1,29	4,71	1,16	3,11	LC
12	*Synodontis schall*	2,63	2,78	0,85	0,76	5,67	0,68	LC
13	*Petrocephalus sp.*	1,63		0,04		5,13		na
14	*Pollimyrus isidori sp.*	1,46				*4,61*		na
15	*Synodontis sp.*	1,16	1,21	2,32	0,93	0,64	0,13	na
16	*Labeo coubie*	1,08	0,95	0,02	0,89	1,70	2,17	LC
17	*Barbus ablabes*	0,94	0,66				6,52	LC
18	*Hyperopisus bebe*	0,92	0,15	0,54	0,17	2,25	0,09	LC
19	*Mormyrus rume*	0,90	0,55	0,54	0,51	1,59	0,81	na
20	*Hemichromis bimaculatus*	0,88	0,22	1,37	0,04	0,19	3,15	LC
21	*Pollimyrus isidori*	0,74	0,73	0,20	0,93	0,31	2,77	na
22	*Lates niloticus*	0,68	0,07	0,48		1,70	0,04	LC
23	*Bagrus bajad*	0,68	0,62	0,30	0,38	1,27	0,43	LC
24	*Cichlide sp.*	0,58		0,08	2,85	0,19	0,98	na
25	*Labeo senegalensis*	0,57				1,75	0,13	LC
26	*Micralestes occidentalis*	0,52	0,11	1,83				LC
27	*Parailia pellucida*	0,44	0,55	1,25	0,08		0,04	LC
28	*Alestes baremoze*	0,41	0,26		0,59	0,92	0,04	LC
29	*Marcusenius sp.*	0,37				*1,16*		na
30	*Synodontis punctifer*	0,36		0,62			1,45	LC
31	*Auchenoglanis occidentalis*	0,36		0,12	0,04	1	0,04	LC
32	*Hemichromis fasciatus*	0,32				0,61	0,98	LC
33	*Petrocephalus bovei*	0,31	0,04	0,58	0,64	0,02	0,47	na
34	*Micralestes sp.*	0,27	*1,83*					na
35	*Schilbe mystus*	0,26			0,13	0,78		LC
36	*Chrysichthys nigrodigitatus*	0,25		0,02	1,87			LC
37	*Heterobranchis bidorsalis*	0,20	0,04			0,62		LC
38	*Bagrus docmak*	0,19	0,11		0,51		0,85	LC
39	*Alestes dentex*	0,18	0,33	0,46				LC
40	*Brycinus leuciscus*	0,18		*0,63*				LC
41	*Synodontis membranaceus*	0,13	0,47	0,16	0,04		0,09	LC
42	*Synodontis nigrita*	0,11	0,11	0,18	0,04	0,12		LC

Table 3.3. Continued.

	Species	Total	Kougri	Koubri	Bagre	Nazinga	Others	Red List
43	*Barbus leonensis*	0,07		*0,24*				LC
44	*Distichodus rostratus*	0,07	0,04		0,42	0,02		LC
45	*Polypterus senegalus*	0,06		0,06		0,12	0,04	na
46	*Hydrocynus forskali*	0,05				*0,17*		LC
47	*Hemichromis sp.*	0,04		0,02		0,12		na
48	*Hyperopisus sp.*	0,04				*0,12*		na
49	*Mormyrus sp.*	0,03			0,04	0,09		na
50	*Barbus pobeguini*	0,03		*0,10*				LC
51	*Ctenopoma sp.*	0,02				*0,07*		na
52	*Malapterus electricus*	0,02		0,04			0,09	LC
53	*Citharinus sp.*	0,02				0,05		na
54	*Labeo sp.*	0,02			0,04	0,03		na
55	*Mormyrus hasselquisti*	0,02				*0,05*		LC
56	*Synodontis ocellifer*	0,02	*0,11*					LC
57	*Synodontis vermiculatus*	0,02		*0,06*				LC
58	*Brycinus sp.*	0,01		*0,04*				na
59	*Chrysichthys auratus*	0,01		*0,04*				LC
60	*Euchenoglanis sp.*	0,01				*0,03*		na
61	*Hydrocynus sp.*	0,01				*0,03*		na
62	*Labeo niloticus*	0,01			*0,08*			LC
63	*Mormyride sp.*	0,01		*0,04*				na
64	*Pollimyrus sp.*	0,01				*0,03*		na
65	*Barbus punctitaeniatus*	0,01		*0,02*				LC
66	*Leptocypris niloticus*	0,01		*0,02*				LC
67	*Micralestes pabrensis*	0,01		*0,02*				LC
68	*Mormyrops anguilloides*	0,01				*0,02*		LC
69	*Polypterus sp.*	0,01				*0,02*		na
70	*Protopterus annectens*	0,01		*0,02*				LC
	Total number of species	**70**	**33**	**45**	**33**	**47**	**33**	

3.2 Sampling methods

In total 66 species were caught with electric fishing (8,822 individuals), 61 species with cast net (9,199 individuals) and 19 species with gill net (227 individuals). Table 3.4 compares our main methods, electric fishing and cast net. EF caught 18 species that CN did not and CN caught 11 that EF did not. All species caught by GN were also caught with other methods. The mean total length of fish caught with CN (106.5mm) was bigger than with EF (66.95mm) (Figure 3.4). In average we caught 11 specimens per minute with EF and 14 specimens per throw with CN. In Total we estimated a fished Area of 12,000 m² for EF and calculated an area of 10,000m² for CN. (Table 3.4)

Table 3.4. Comparison of the conducted methods, electric fishing and cast net.

	Electric	Cast net
Number of individuals	8822	9199
Number of species	66	61
Exclusive species	18	11
Mean total length (mm)	66,95	106,5
Time (minutes)	815	
Captures /min	11	
Throws		666
Captures /throw		14
Area (m²)	12343	10131
Number of fished habitat	93	54
Average per habitat	9 minutes	15 throws
Average per habitat (m²)	132,72	187,6

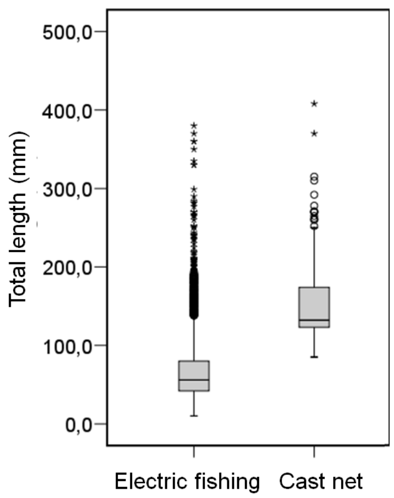


Figure 3.4. Mean total fish length of all caught individuals per sampling gear (Electric fishing and Cast net).

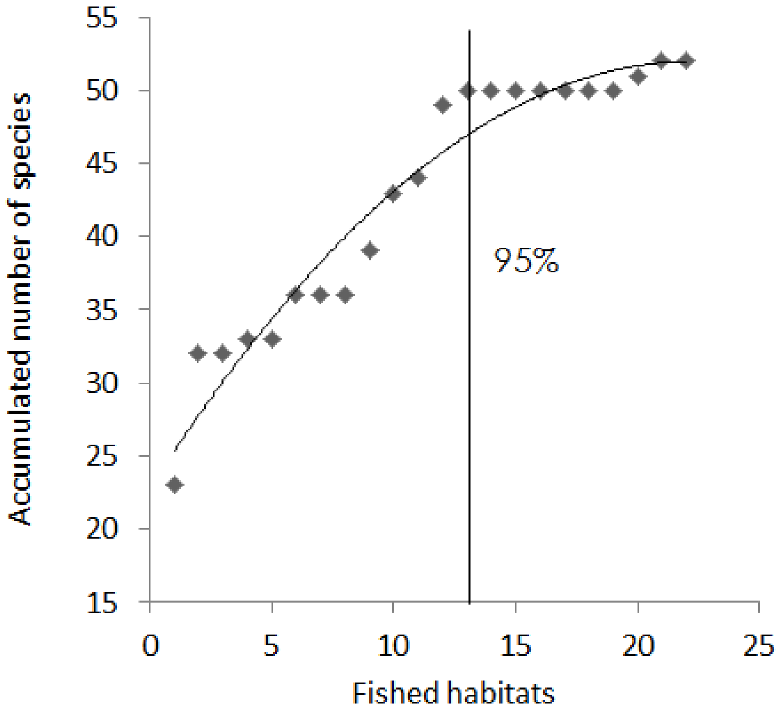


Figure 3.5. Rarefaction Curve, relationship between the number of fished habitat and the accumulated number of species, vertical line indicates that after 13 fished habitats 95 % of the species are caught.

Figure 3.5 displays a Rarefaction Curve, showing the relation between the number of fished habitats and the accumulated number of species. After 13 fished habitats at one site, 95% of the species are caught. This relation can be explained by a polynomial function [1].

Picture 3.3. Some other traditional fishing methods

3.3 Available habitat characteristics

3.3.1 Substrate

In total the distribution of the substrate is dominated by fine fractions as Pelal (44.5%) and Psammal (30.4%). The other fractions share the last quarter (7% Akal, 2.5% Mikrolithal, 1.7% Mesolithal, 3.6% Makrolithal, 2.6% Megalithal, 2% Primary Rock and 5.7% Concrete) (Figure 3.6).

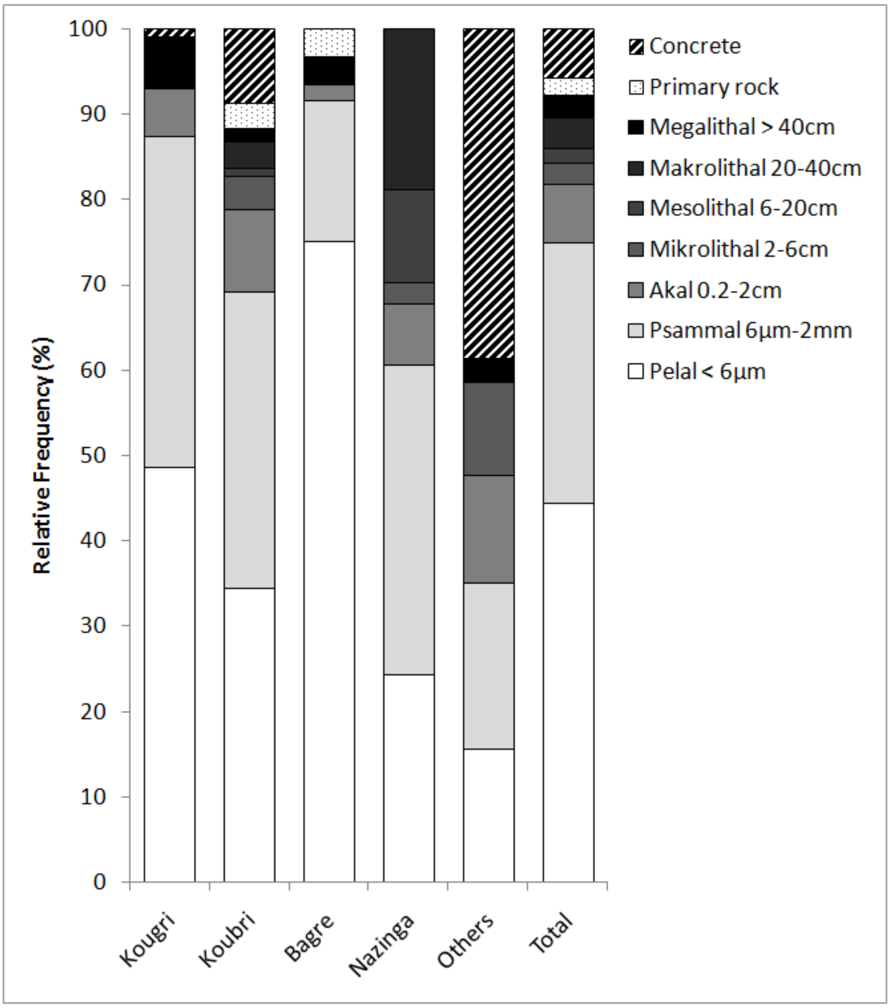


Figure 3.6. Relative frequency of substrate distribution for the sampling areas and in total.

This distribution varies between the areas. In Kougri the fine fractions (Pelal and Psammal) make up 87%. The coarse material as Mikro-, Meso- and Makrolithal is missing completely.

The area of Koubri covers all different fractions. The emphasis is placed on the fine fractions (69%) and shows remarkable high proportions of Concrete (8.7%). Bagre exhibits the largest shares of fractions smaller than 2mm (92%). Nazinga shows a different picture, there are only 61% of fine fractions and a big spare of coarse material (18.7% Makrolithal and 10.9% Mesolithal) (Figure 3.6).

3.3.2 Structures

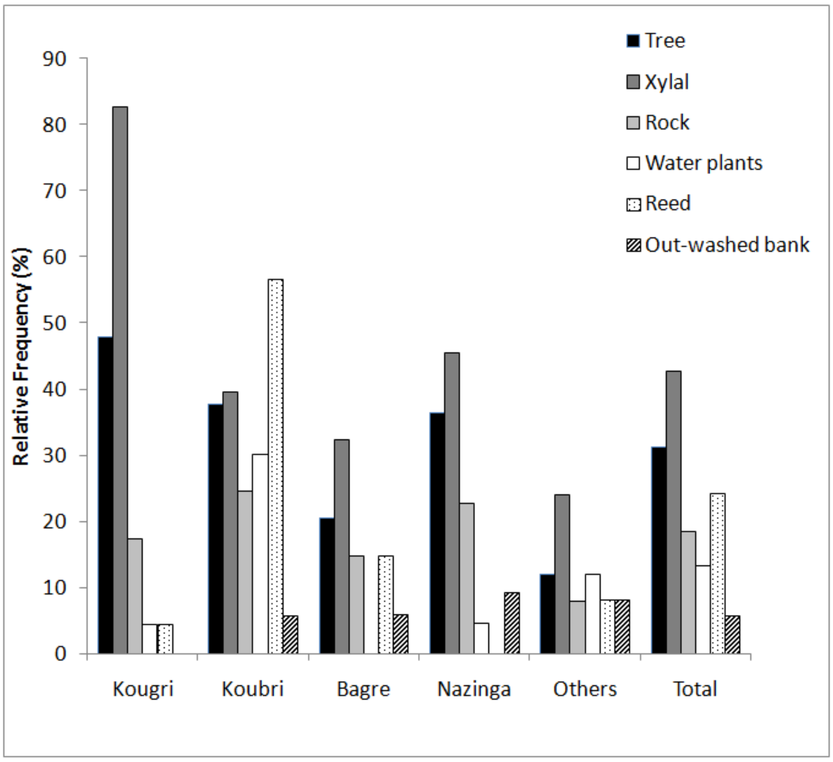


Figure 3.7. Structure occurrence in the different areas and in total.

In total Xylal is the most common structure element for the investigated water bodies (42.7%), followed by trees (31.2%), reed (24.2%), rocks (18.5%), water plants (13.4%) and out-washed bank (5.7%).

Kougri shows a relative high frequency of trees (47.8%) and Xylal (82.6%). Koubri stands out with its high occurrence of reed (56.6%) and water plants (30.2%). In Bagre water plants are missing. Nazinga shows the highest occurrence of out-washed bank (9.1%) but no reed (Figure 3.7)

3.3.3 Physicochemical Parameters

Conductivity ranges from 36.8 µs/cm to a maximum of 271 µs/cm with an overall mean value of 92 µs/cm. In Bagre the highest mean value (134.3 µs/cm) and the widest variation (standard deviation 66.9 µs/cm) was found. Figure 3.8 shows that the values of all the other areas are in a smaller range.

The sampled pH-values cover a range from 6.4 to 10.1 (Mean 7.8). These two extreme examples were both measured in Koubri (Figure 3.8).

Temperature distribution can be divided into two major groups. In Bagre and Nazinga mean values of 26.9°C and 25.5°C were measured with a maximum not exceeding 31°C. While in the other areas the mean temperature is around 32°C and maximum reached 35.1°C (Figure 3.8).

Figure 3.8 shows that the oxygen saturation varies from 18% to 158% with a mean value of 76.3%. There are big differences found in Koubri (18% - 135%) and the most similarity in Nazinga (75% - 90%).

Table 3.5. Measured physicochemical parameters for all areas.

	Conductivity (µs/cm)			Temperature (°C)			pH			O_2 (%)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Kougri	58.6	271	97.8	28.0	35.1	31.7	7.2	9.8	7.9	43	158	75.8
Koubri	42.5	267	95.7	29.2	35.1	31.8	6.4	10.1	7.6	18	135	78.2
Bagre	48.2	219	134.3	24.0	31.0	26.9	6.8	9.0	8.3	46	131	73.7
Nazinga	67.2	102	77.7	23.3	30.2	25.5	7.6	8.6	7.8	75	90	85.6
Others	36.9	270	64.9	28.2	35.0	32.5	7.2	9.6	7.8	48	80	58.0
Total	36.9	271	92.0	23.3	35.1	30.1	6.4	10.1	7.8	18	158	76.3

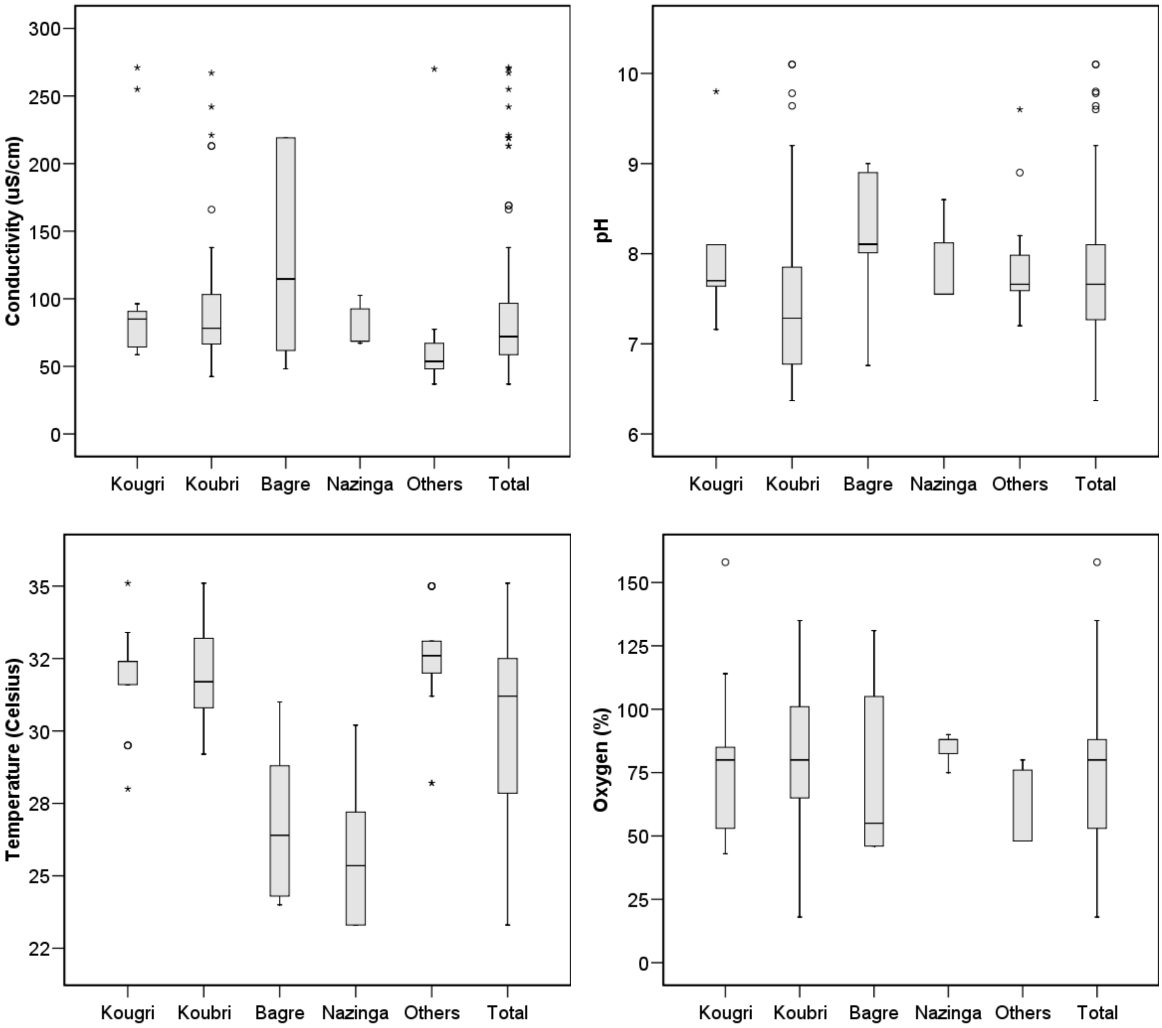


Figure 3.8. Available physicochemical habitat condition of all areas (conductivity (µs/cm), pH, temperature (°C) and oxygen (%)).

Picture 3.4. Taking physicochemical parameters (Stranzl, 2012).

3.3.4 Further measurements

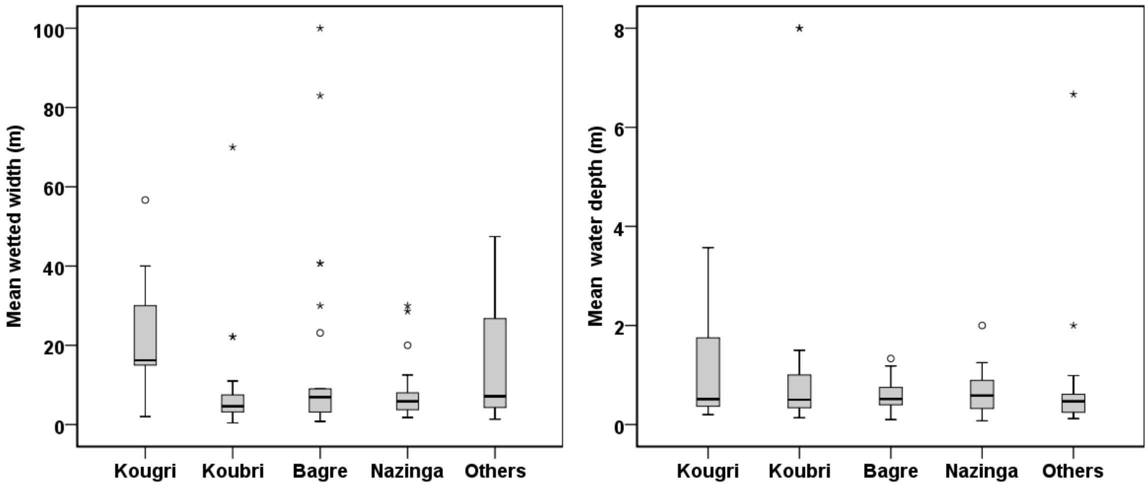


Figure 3.9. Mean wetted width (m) and water depth (m) for all sampling areas.

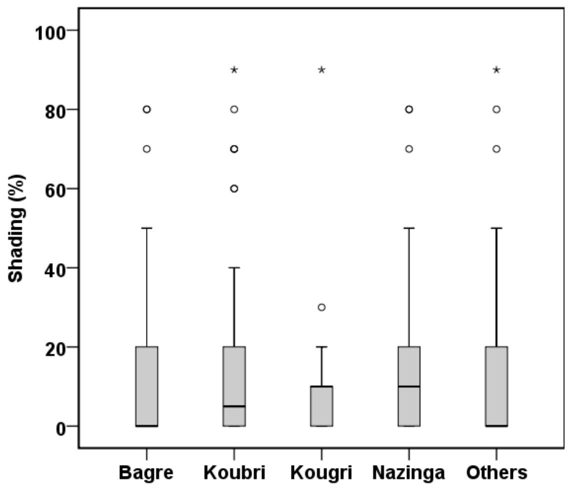


Figure 3.10. Mean shading in % of water surface for all areas.

Figure 3.9 shows that Bagre has deeper and wider water bodies than the other areas. Kougri, Koubri and Nazinga have similar measures. Regarding the mean shading of the water surface, Nazinga exhibits the highest value (Figure 3.10).

3.4 Habitat use at community level

For the calculated mean abundance per m², only fish caught with EF were selected for a standardized comparison. One outlier was excluded for the further analyses (Habitat in the Nakambe).

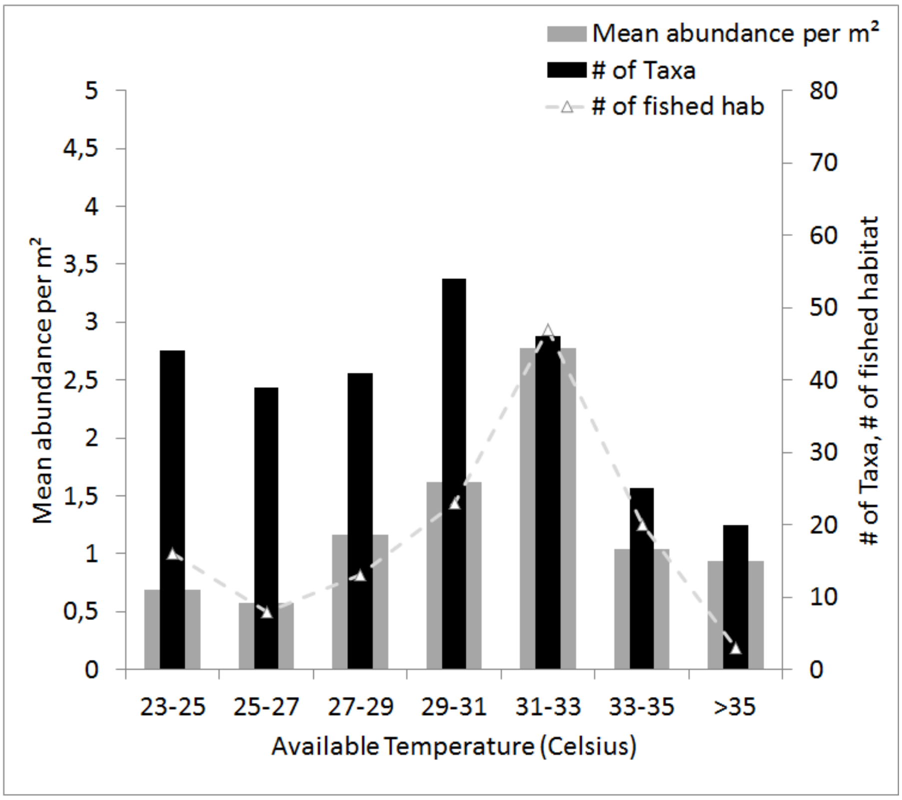


Figure 3.11. Effect of temperature on abundance and diversity.

With an increase of the temperature, abundance and the number of species increases as well. Highest number of species is found in a temperature range of 29-31°C. The fish community is most numerous in a temperature range of 31-33°C. After 33°C abundance and diversity breaks down to a lower level (Figure 3.11).

Habitat with a pH value from seven to eight displays most species. With an increase of the pH, diversity decreases, but abundance increases. Highest diversity can be found in waters with conductivity lower than 120 µs/cm. There is no clear correlation between abundance and measured conductivity (Figure 3.12).

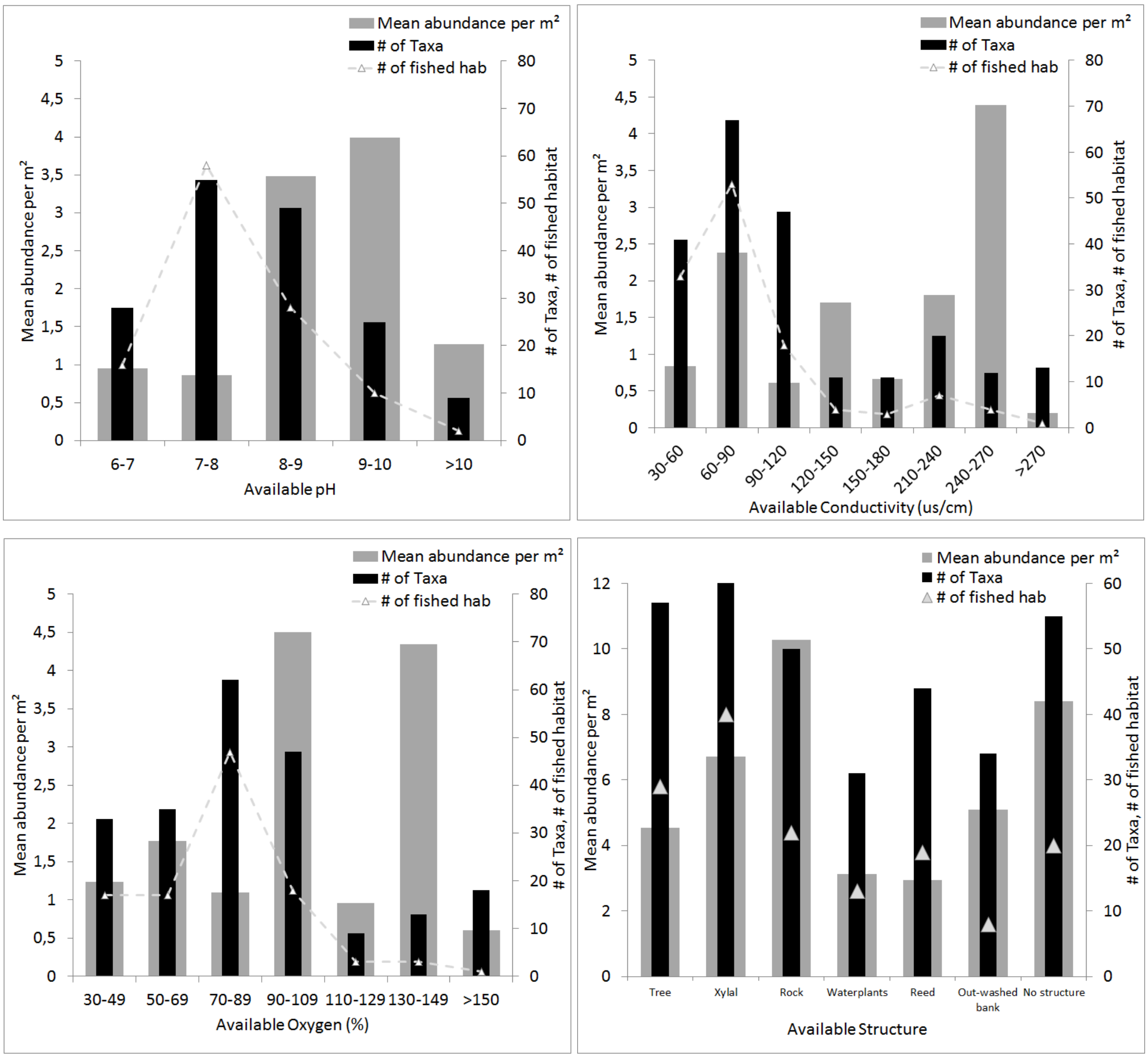


Figure 3.12. Effect of pH, conductivity (µs/cm), oxygen (%) and structures (presence/absence) on abundance and diversity.

Up to 110% of oxygen saturation the number of species increases. More than 110% leads to a decrease of species. Abundance reaches its maximum between 90 % and 150% (Figure 3.12).

There is no clear correlation that the occurrence of certain structure elements have an influence on the number of species or the abundance at community level (Figure 3.12), especially when regarding the high values without any structural element (8.4 mean abundance per m² and 55 species).

3.5 Habitat use at species level

Below some key species were analyzed according to their habitat use. The light grey bars represent the mean available habitat conditions, while the black lines and bars indicate the mean habitat use of the species. Decision criteria for species selection were high abundances (*Chelaethiops bibie*), high value for fishery (*Bagrus bajad* and *Lates niloticus*) and possible indicator species (*Labeo cubie*).

3.5.1 Labeo Cubie

Labeo coubie (Figure 3.13 and 3.14) is a benthopelagic and potamodromous species. It inhabits rivers and lakes (Skelton 1993). It is a bottom feeder, on mud, plant debris and diatoms (Azeroual, 2010). It shows clear preferences for coarse substrate. In its average habitat, substrate is dominated by fractions larger than 6 cm (73%) (Figure 3.16).This is also reflected in the occurrence of structures. Rocks are typical for its habitat (Figure 3.17).Figure 16 shows that its habitat is characterized by some velocity (0.37 m/s) and oxygen saturation around 90% not falling under 43% (Table 3.6, Figure 3.19). It was caught mainly in shallow areas with depths less than 0.3 meter and reaching a maximum size of 150 mm (Figure 3.18). Maximum reported size is 750 mm standard length (Lévêque, 1984).

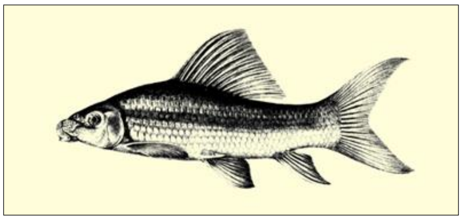


Figure 3.13. Drawing of *Labeo cubie* (from Boulenger, 1907, in Paugy et al., 2004).

Figure 3.14. Photo of *Labeo cubie.*

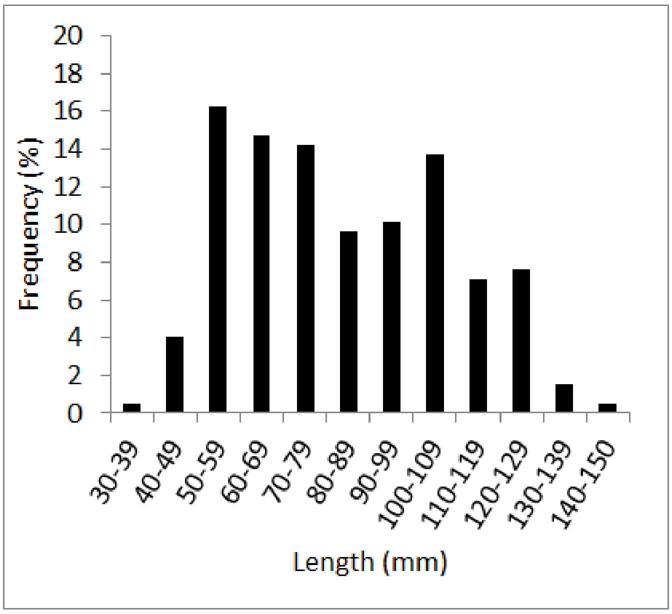
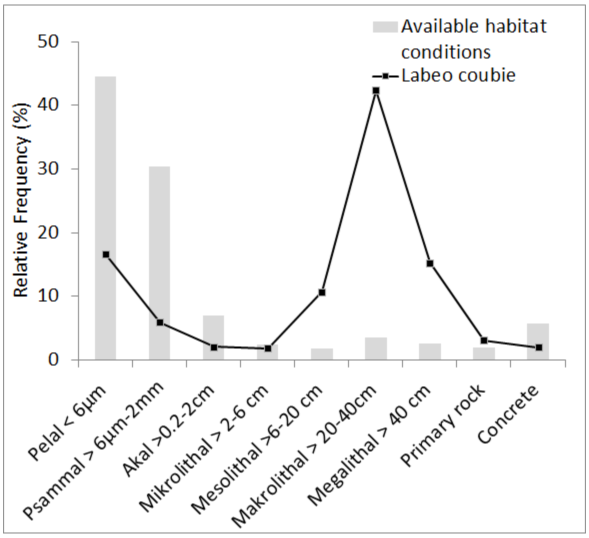


Figure 3.15. Length frequency distribution of *Labeo cubie* (N=197).



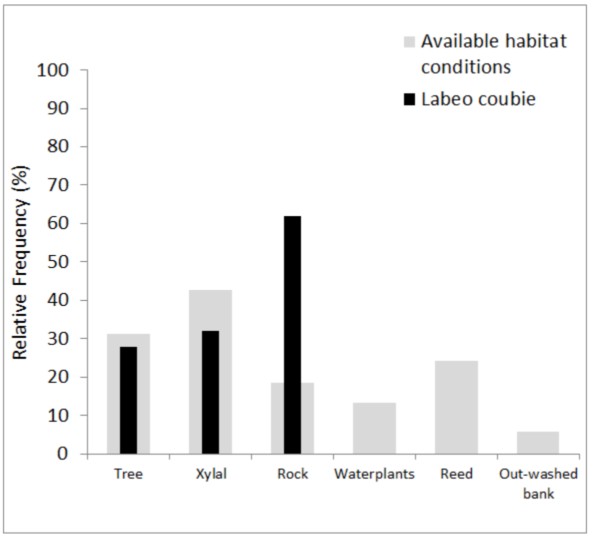
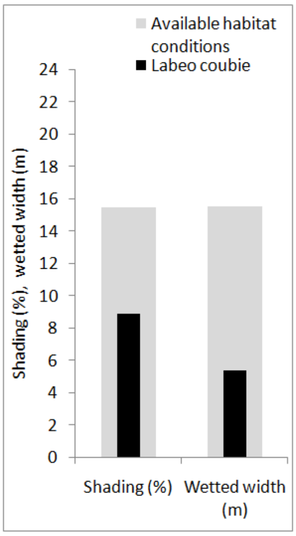


Figure 3.16. Relative frequency of mean substrate distribution for the habitat of *Labeo cubie.*

Figure 3.17. Relative frequency of structure occurrence for the habitat of *Labeo cubie.*



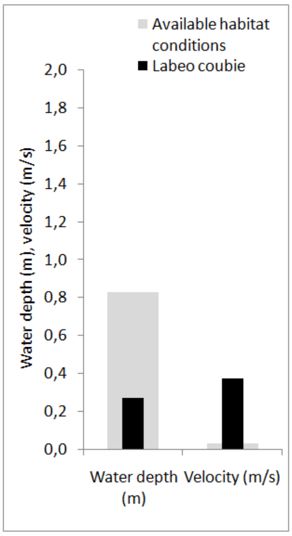


Figure 3.18 Mean values of shading (%), velocity (m/s), wetted width and water depth (m) for *Labeo cubie.*

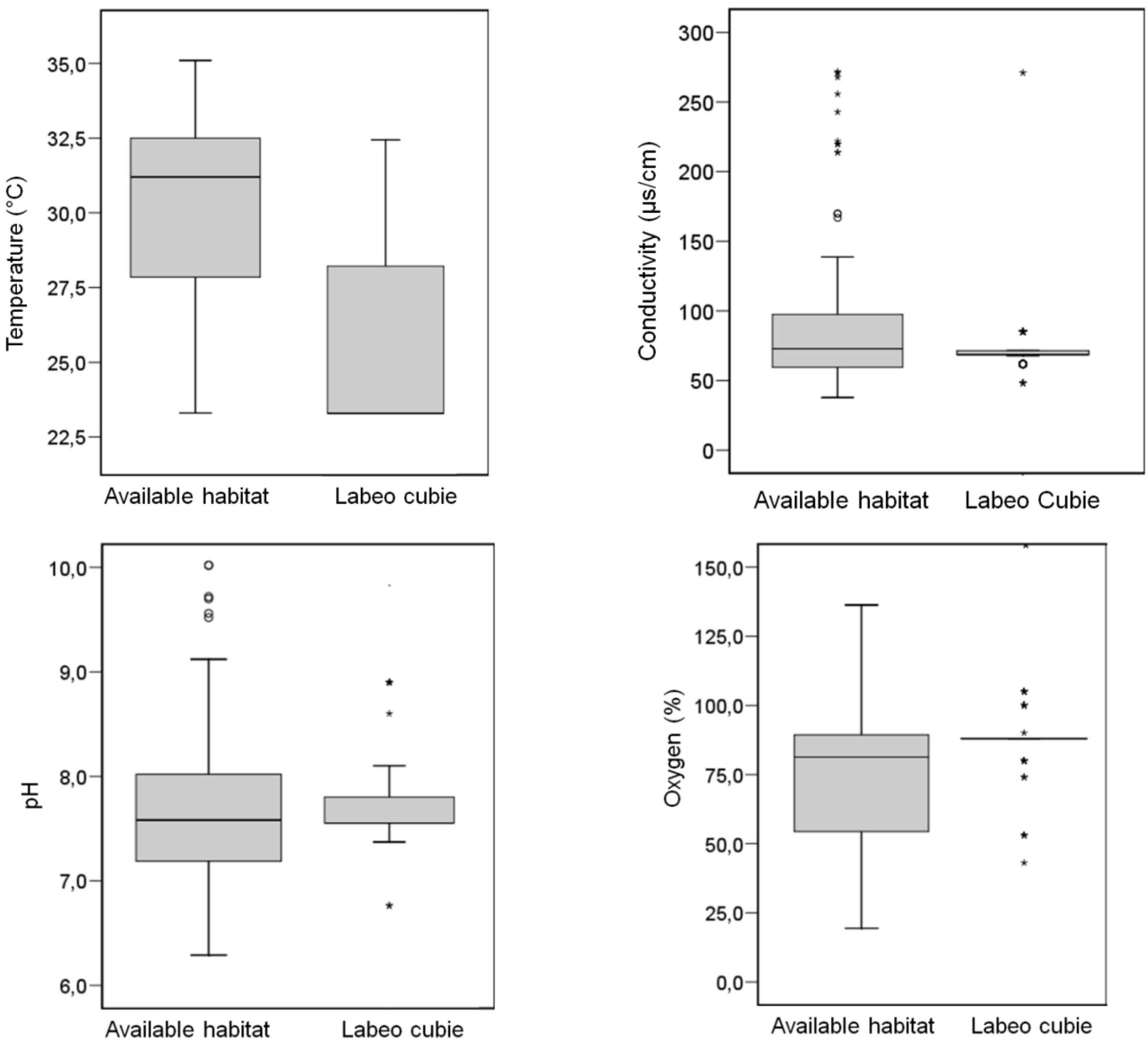


Figure 3.19. Physicochemical parameters for Labeo cubie.

3.5.2 Chelaethiops bibie

Chelaethiops bibie (Figure 3.20 and 3.21) feeds mainly on terrestrial insects (Hickley and Bailey 1987) and seeds at the surface (Bailey 1994). In more than 90 % of its habitat Xylal occurred as a structure element (Figure 3.24). It mainly uses habitats with a dominance of fine substrate (80% < 2mm) (Figure 3.23). It was caught mainly in areas with a mean wetted width around 18 m and depths smaller than 0.6 m (Figure 3.25). Temperature ranges between 23.3 and 35.1 °C (Table 3.6). The length frequency distribution shows that 70% of the caught fish range between 40 and 50 mm with a maximum of 60 mm (Figure 3.22).

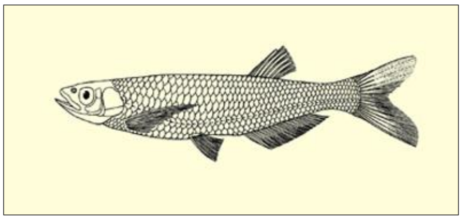


Figure 3.20. Drawing of *Chelaethiops bibie* (from Lévêque et al., 1990, in Paugy et al., 2004).

Figure 3.21.Photo of *Chelaethiops bibie*.

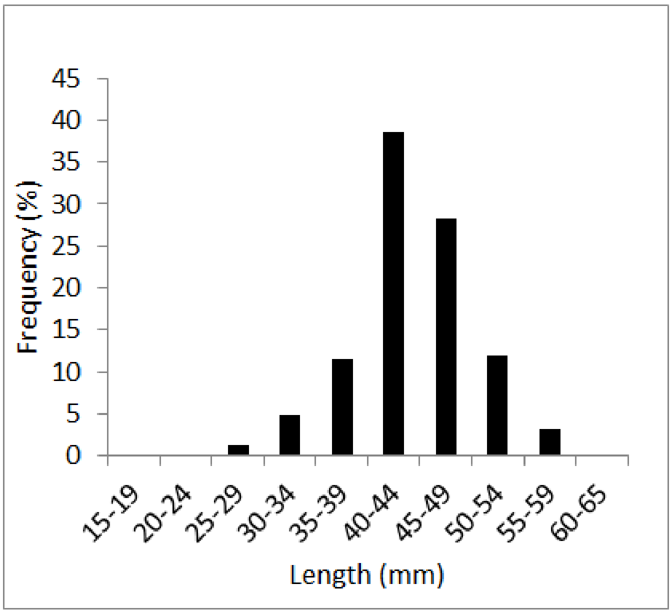
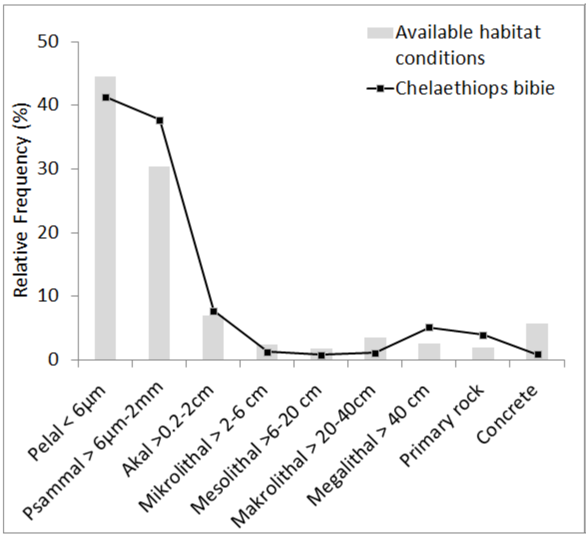


Figure 3.22 Length frequency distribution of *Chelaethiops bibie* (N=585).



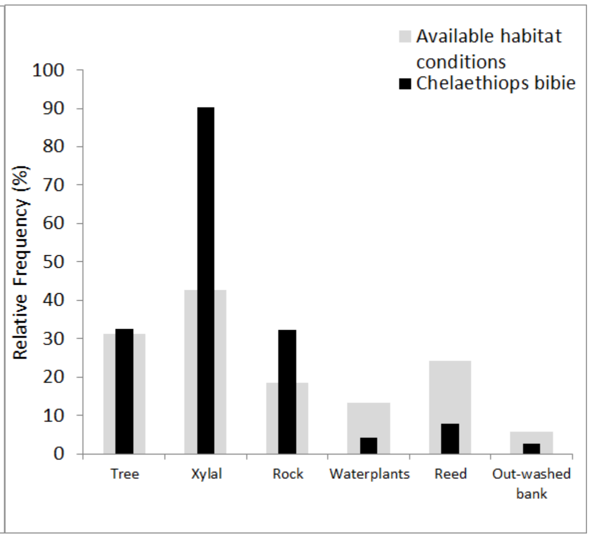


Figure 3.23. Relative frequency of mean substrate distribution for the habitat of *Chelaethiops bibie* .

Figure 3.24. Relative frequency of structure occurrence for the habitat of *Chelaethiops bibie.*

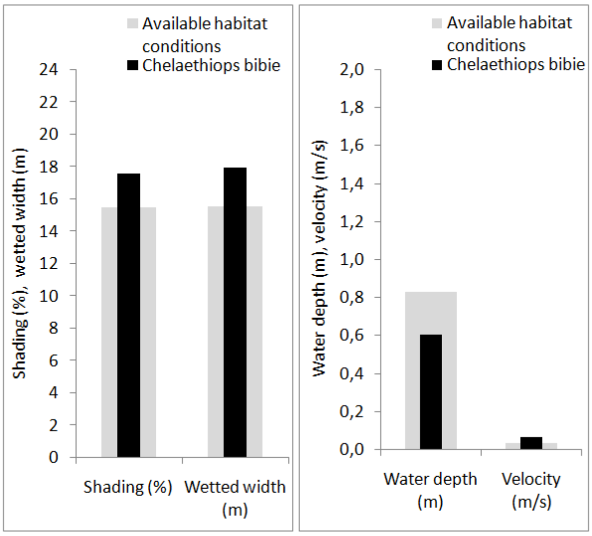


Figure 3.25 Mean values of shading (%), velocity (m/s), wetted width and water depth (m) for *Chelaethiops bibie.*

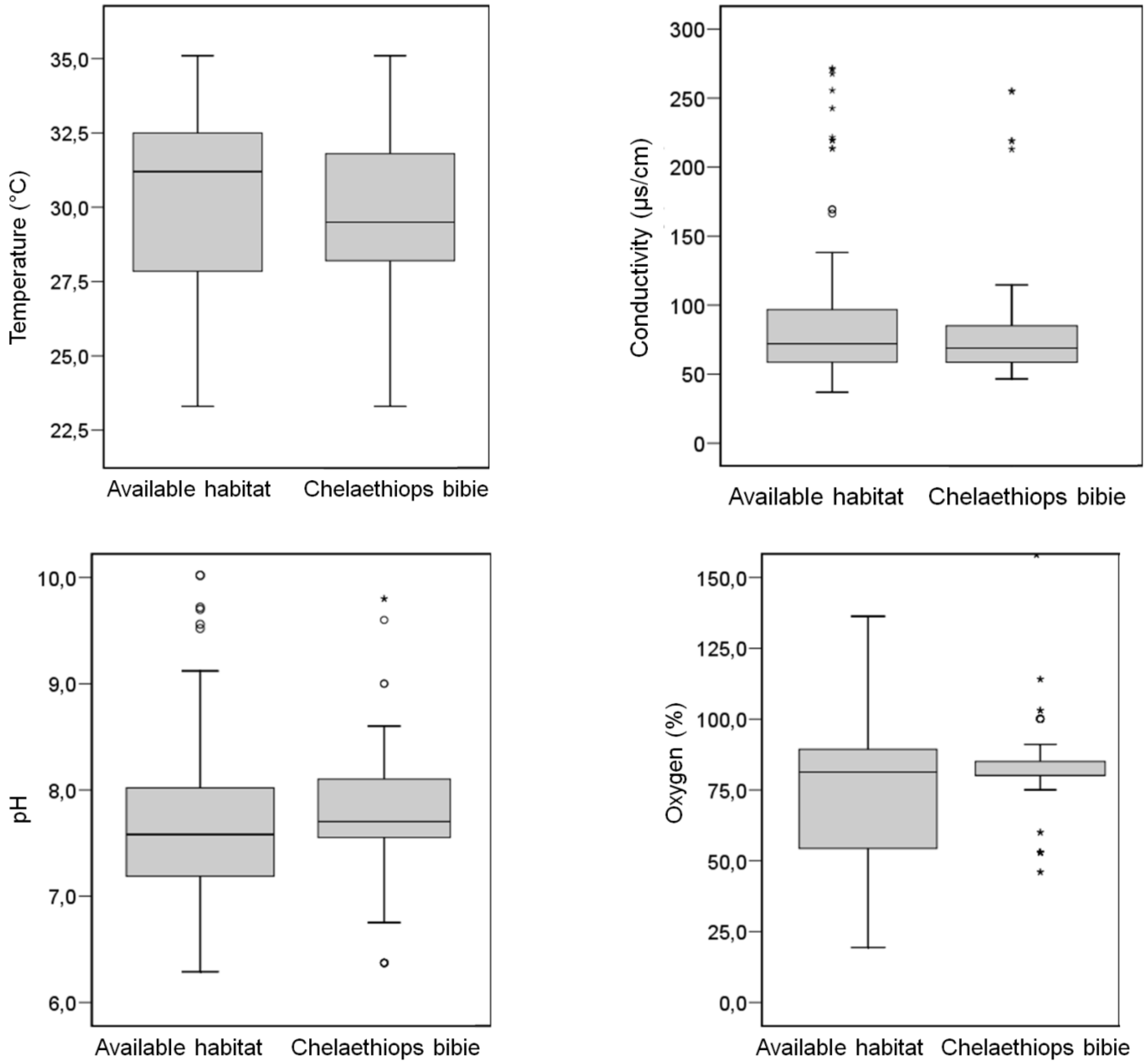


Figure 3.26. Physicochemicall parameters for *Chelaethiops bibie.*

3.5.3 Bagrus bajad

Bagrus bajad (Figure 3.27 and 3.28) lives and feeds on or near the bottom (Lewis, D.S.C., 1974). It feeds on insects, crustaceans, mollusks, vegetable matter (Bailey, R.G., 1994) and adults are exclusively piscivorous (Olaosebikan, B.D. and Raji, A., 1998). It was mainly caught in larger water bodies, with an average depth of 1.8 meter and a width of 22 meter (Figure 3.32). Worthington reported depth until 60 m (Worthington, E.B. and C.K. Ricardo, 1936). The length frequency distribution shows more or less same frequencies of length classes between 110 mm and 350 mm (Figure 3.29). Our biggest measured specimen had 420 mm, but there are reports about maximum lengths of 1,120 mm fork length (Abdel-Latif, A.-F., 1974).

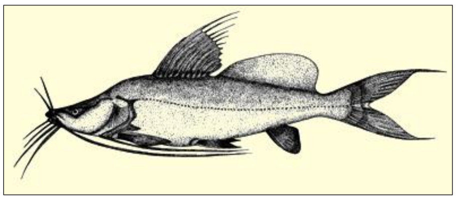


Figure 3.27. Drawing of *Bagrus bajad* (from Blache et al., 1964, in Paugy et al., 2004).

Figure 3.28. Photo of *Bagrus bajad.*

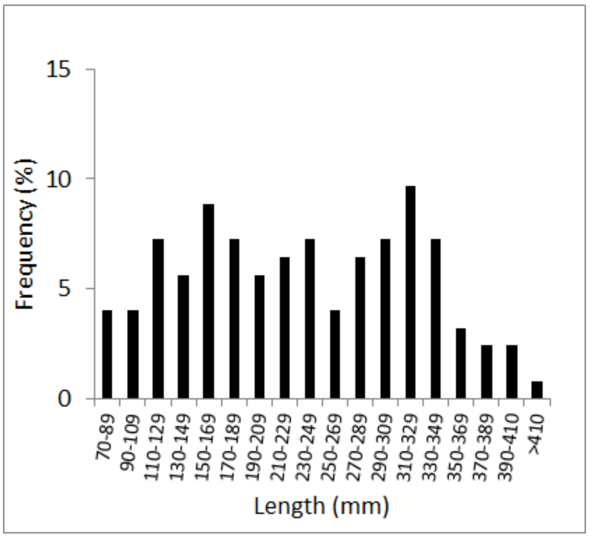


Figure 3.29. Length frequency distribution of *Bagrus bajad* (N=124).

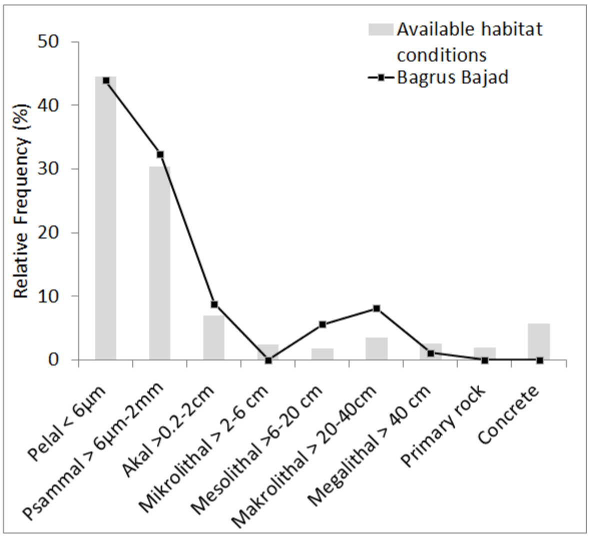


Figure 3.30. Relative frequency of mean substrate distribution for the habitat of *Bagrus bajad.*

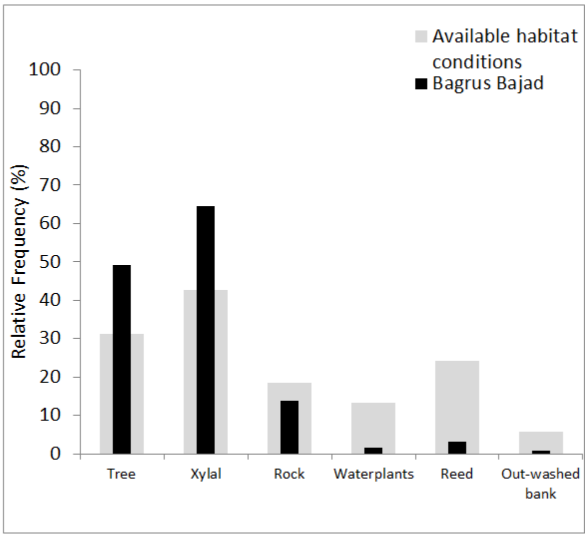
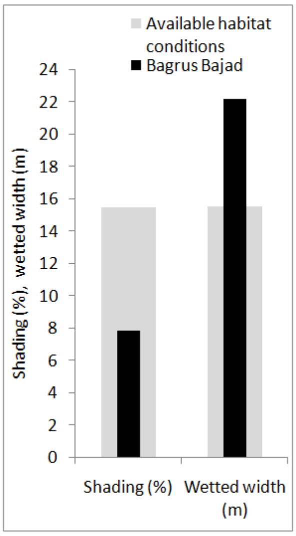


Figure 3.31. Relative frequency of structure occurrence for the habitat of *Bagrus bajad.*



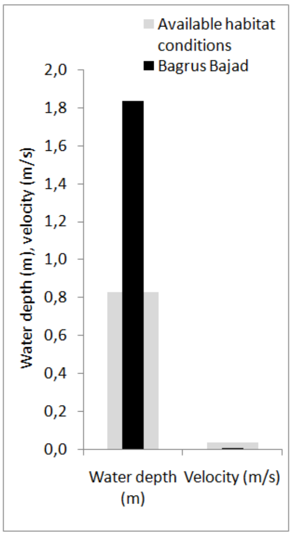


Figure 3.32 Mean values of shading (%), velocity (m/s), wetted width and water depth (m) for *Bagrus bajad.*

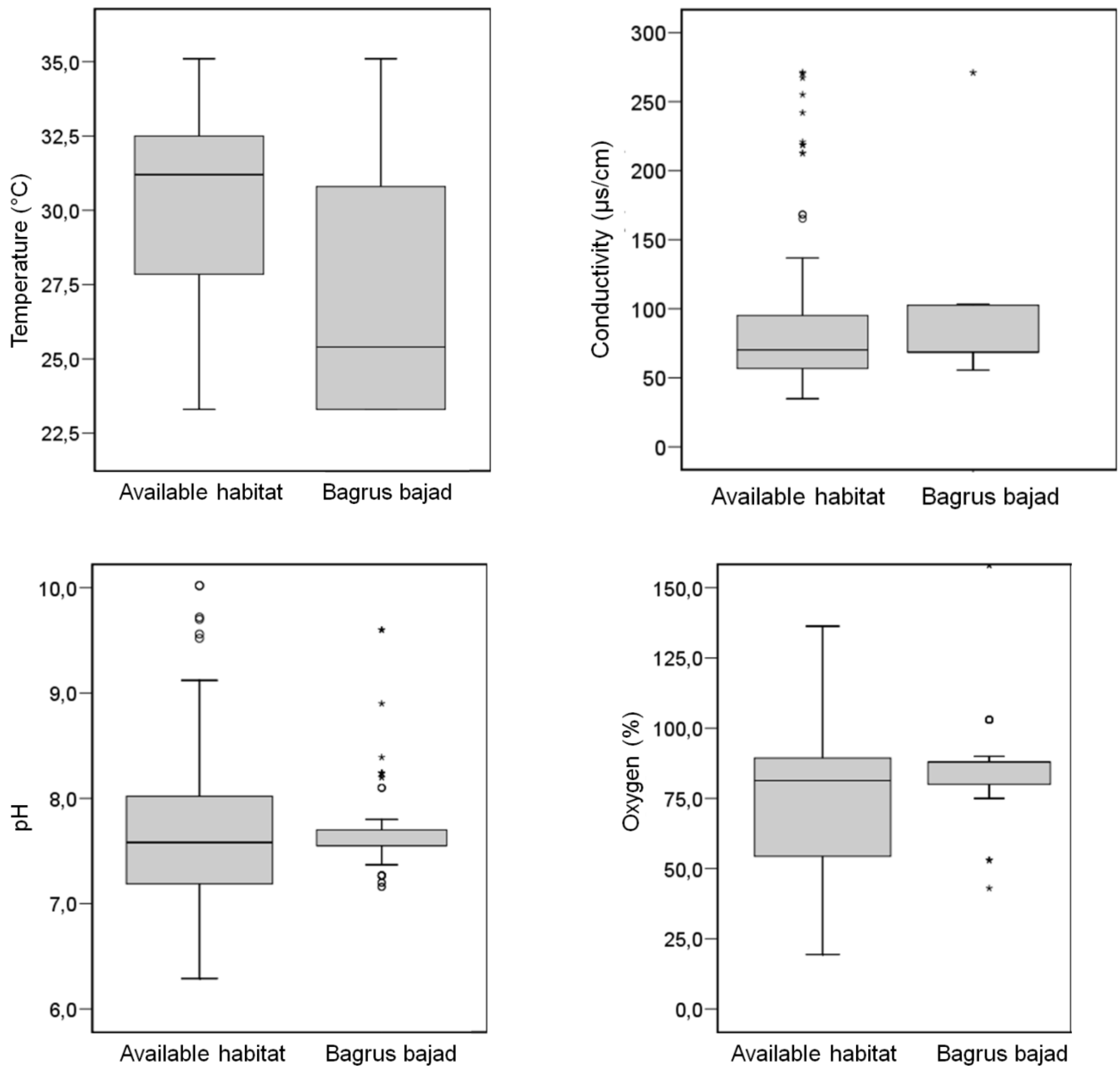


Figure 3.33. Physicochemical parameters for *Bagrus bajad*.

3.5.4 *Lates niloticus*

Lates niloticus (Figure 3.34 and 3.35) inhabits streams, lakes and irrigation channels. Adults inhabit deep water, while juveniles are found in shallow water. It feeds on fish especially *Clupeids* and *Alestes (*Reed, W. et al., 1967). Smaller example also feed on larger crustaceans and insects. Juveniles are planktivorous (Bailey, R.G., 1994). The length frequency distribution shows three peaks. One is around 100 mm, a second one around 190 mm and a third one around 260 mm (Figure 3.36). Maximum reported length is 2,000 mm (Stone, R., 2007.). It shows similar habitat use characteristics as *Bagrus bajad*. *Lates niloticus* seems tolerant against low physicochemical parameters like oxygen saturations under 20 %, temperature maximum of 35 °C and pH values above 10. Compared with the others it was caught in waters with relative low maximums of conductivity (<120 µs/cm) (Table 3.40). Figure 3.38 shows relative high occurrence of trees and Xylal.

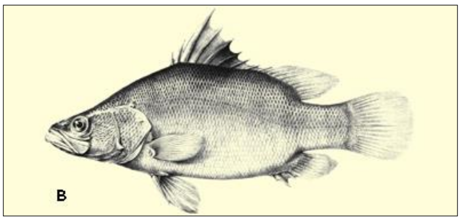


Figure 3.34. Drawing of *Lates niloticus* (from Boulenger, 1907, in Paugy et al., 2004).

Figure 3.35. Photo of *Lates niloticus*.

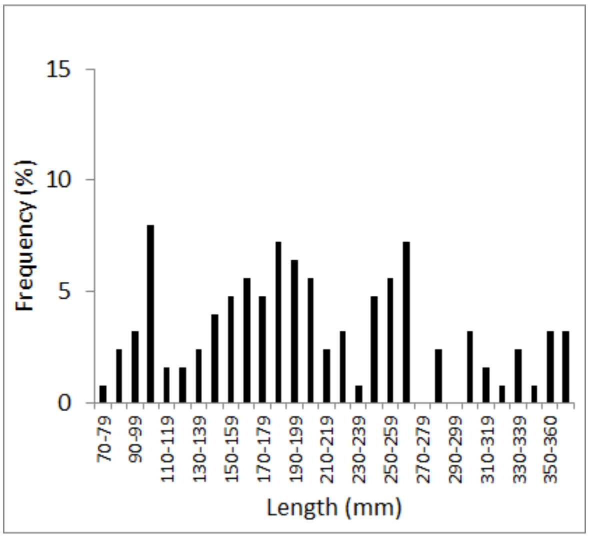


Figure 3.36. Length frequency distribution of *Lates niloticus* (N=125).

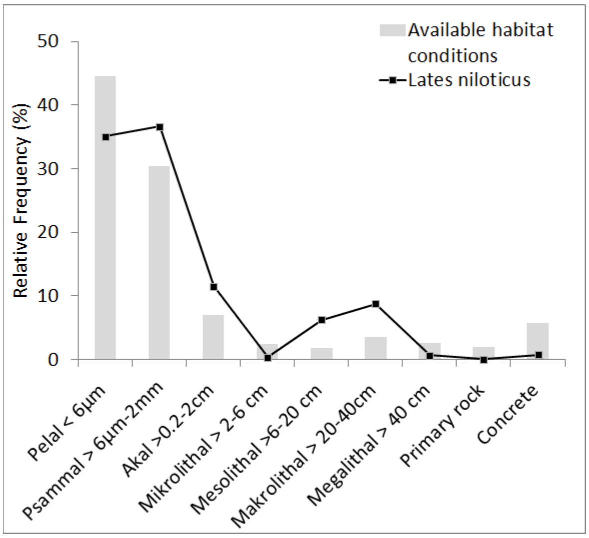


Figure 3.37. Relative frequency of mean substrate distribution for the habitat of *Lates niloticus.*

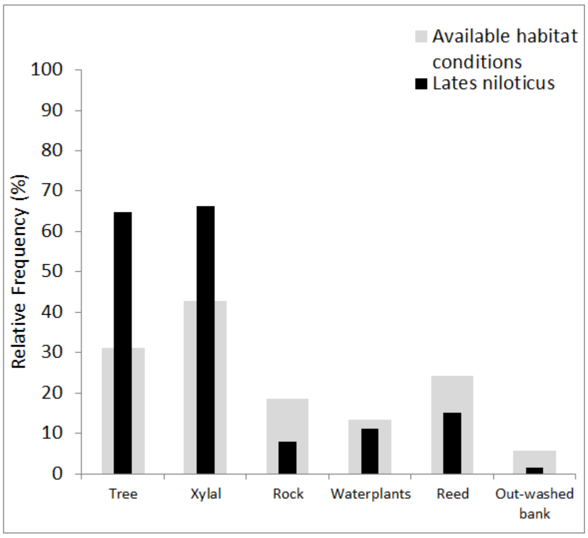


Figure 3.38. Relative frequency of structure occurrence for the habitat of *Lates niloticus.*

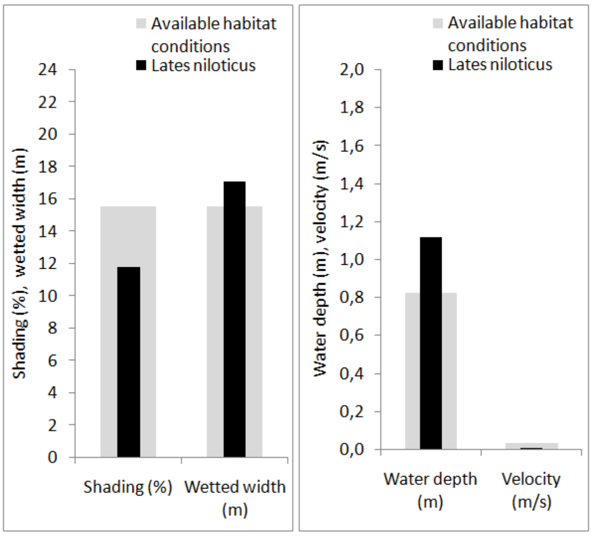


Figure 3.39. Mean values of shading (%), velocity (m/s), wetted width and water depth (m) for *Lates niloticus.*

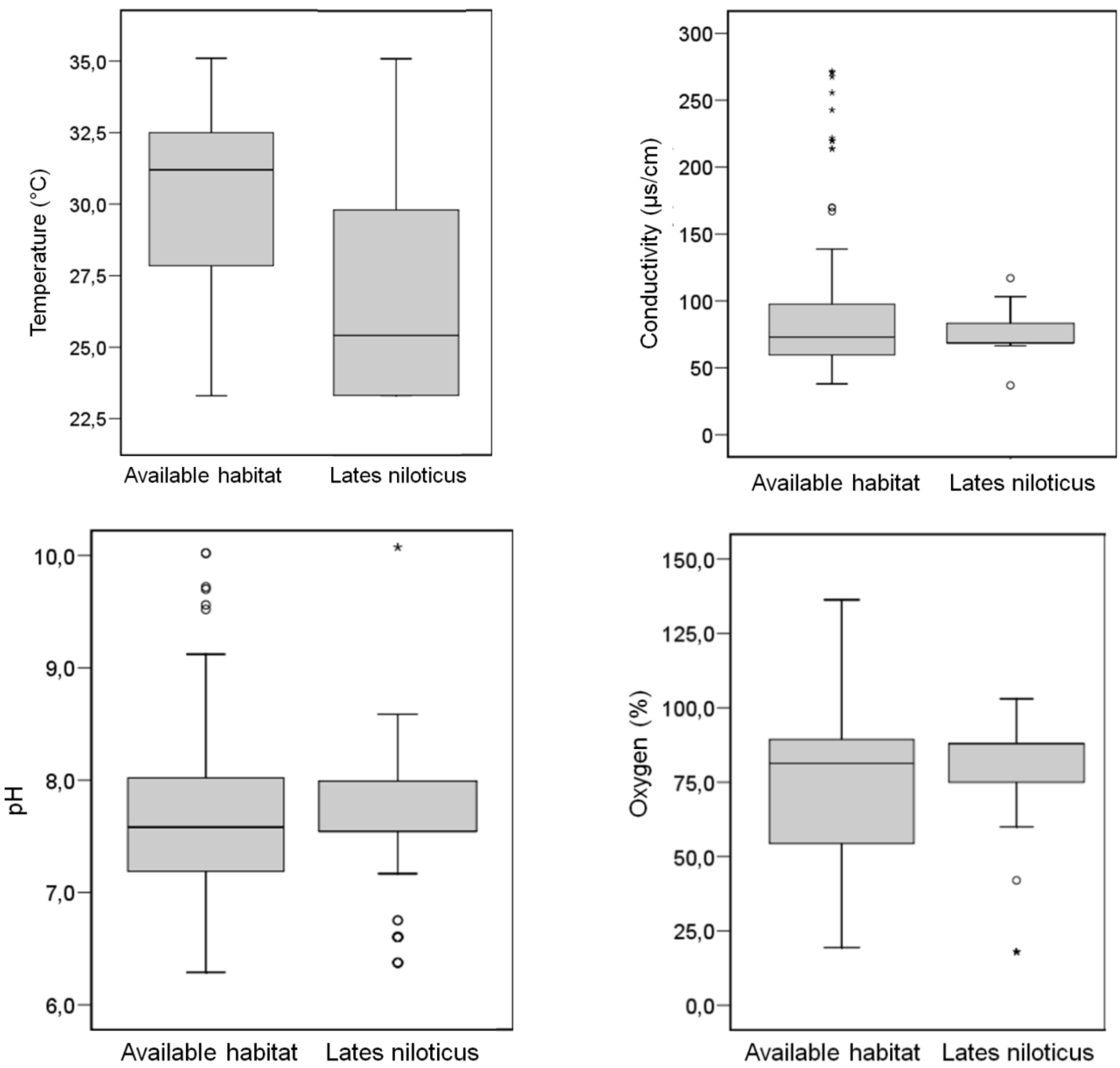


Figure 3.40. Physicochemical parameters for *Lates niloticus.*

Table 3.6. Physicochemical parameter ranges of *Bagrus bajad, Chelaethiops bibie, Labeo cubie* and *Lates niloticus.*

	Oxygen (%)			Temperature (°C)			pH			Conductivity (us/cm)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Bagrus bajad	43	158	86.6	23.3	35.1	27.0	7.2	9.6	7.7	55.6	271	79.3
Chelaethiops bibie	46	158	80.1	23.3	35.1	29.7	6.4	9.8	7.7	46.5	255	74.9
Labeo cubie	43	105	87.2	23.3	32.4	26.2	6.8	8.9	7.8	48.2	271	71.9
Lates niloticus	18	103	80.3	23.3	35.1	26.7	6.4	10.1	7.6	36.9	117	75.6

Table 3.7. Selected habitat parameters of *Bagrus bajad, Chelaethiops bibie, Labeo cubie* and *Lates niloticus.*

	Velocity (m/s)			Water depth (m)			Shading (%)	Wetted width (m)		
	Min	Max	Mean	Min	Max	Mean	Mean	Min	Max	Mean
Bagrus bajad	0	0.4	0.01	0.12	8.00	1.8	7.8	1.79	142.00	22.18
Chelaethiops bibie	0	0.7	0.06	0.11	8.00	0.6	17.6	0.80	142.00	17.95
Labeo cubie	0	0.6	0.37	0.08	1.75	0.3	8.9	0.88	100.00	5.39
Lates niloticus	0	0.4	0.01	0.11	8.00	1.1	11.8	1.79	28.60	17.06

4. Discussion

4.1 Fish assemblages

According to Table 3.3 there are no dominant species shown in the fish assemblage distribution. This was also explained by Melcher et al. (2012) and Ouedraogo (2010). The most frequent species have a share of 10 % of all individuals. Kougri, Koubri and Bagre have four to six of these species. In Nazinga *Marcusenius senegalensis* accounts for 20 % of all caught individuals. This outlier of 750 fish was caught with one single throw by Noufou Bonkoungou (Figure 4.1).

Regarding the results it is immediately clear that Nazinga differs from the other areas. There we found higher abundances, larger mean length and the highest diversity as well as most exclusive species. The reason for this is the protection state of this area and the resulting minor human impacts on the water bodies (Melcher et al., 2012; Ouedraogo, 2010; Stranzl in prep.)

The relative high number of species in Koubri can be explained by the greater sampling effort which was more than double compared with the others (Table 4.1). This argument can be supported by looking at the rarefaction curve (Figure 3.5), which highlights the relation between the number of samplings and the number of caught species (Gotelli et al., 2001). Depending on the research question, it gives a hint how much sampling effort is necessary to gain i.e. 95 % of the species. In this case 13 habitats per site are enough. If your interest is on the rare species you have to sample more intensively.

Table 4.1. Sampling effort, number of species and caught fish for the investigated areas.

	Kougri	Koubri	Bagre	Nazinga	Others	Total
Number of individuals	2,738	5,040	2,567	5,643	2,347	18,335
Number of species	33	45	33	47	33	70
Number of exclusive species	2	11	1	12	0	26
Sampling days	4	11	4	4	3	26
Number of fished habitat	23	53	34	22	25	157
Abundance per sampling day	685	458	642	1,411	799	799
Mean Total length (mm)	73.5	76.1	61.1	123.8	78.8	86.9

Comparing species lists and potential fish lists demonstrates some problems as a result of changing of nomenclature. Some species like Brenimyrus niger have multiple classifications, synonyms or changed their name a few times (Table 4.2). This indicates the need for further studies. There is a master thesis in progress from Adelphe Diloma Hema supervised by the University of Ouagadougou and the IUCN dealing with this issue and also supported by our results.

Table 4.2. Different classifications and synonyms for Brienomyrus niger (adapted after Paugy et al. 2004,Froese and Pauly, 2011).

Name	Author	Year
Brevimyrus niger	Günther	1866
Gnathonemus niger	Günther	1866
Mormyrus niger	Günther	1866
Marcusenius lhuysi	Steindachner	1870
Pollimyrus lhuysi	Steindachner	1870
Mormyrus lhuysi	Steindachner	1870
Gnathonemus baudoni	Pellegrin	1919
Marcusenius macularius	Fowler	1936
Brienomyrus (Brevimyrus)	Taverne	1971
Brienomyrus niger	Taverne	1971

Looking at the red list status of the species in Table 3.3, you can see that one third is not yet classified, which indicates a clear demand for further studies.

4.2 Sampling methods

It is important to use the appropriate fishing method for the investigated water bodies to get meaningful and consistent results on diversity and abundances (Jawad, 2006; Manel, 2005). The study shows pros and cons of EF and CN methods. Some of the limitations are already named by Melcher et al. (2012) and they can be confirmed. Table 4.3 summarizes the limitations and disadvantages for each method. Concerning water depth, both methods have limitations: in water deeper than 1 m EF by wading is not possible, while CN needs a minimum depth of 0.2 m (oral comment by Noufou Bonkoungou). For EF equipment and spare parts are needed, which are not always available in developing countries. It is the second time EF was conducted in Burkina Faso. Other limitations arise with low conductivity and high turbidity. Furthermore EF can be selective for species and size (Peter and Erb 1996, Schmutz et al., 2001). CN fishing is not possible at a certain velocity. Structures like Xylal, rocks or reed can also not be fished. Furthermore a minimum wetted width to throw the CN is required caused by its diameter. Last but not least an experienced fisherman is needed to perform effective fishing (Figure 4.1).

Table 4.3. Limitations of Electric fishing and Cast net fishing.

Electric fishing	Cast net fishing
Max. water depth 1 m	Min water depth 0.2 m
Conductivity	Velocity
Turbidity	Structures (rocks, xylal…)
Equipment/spare parts	Min wetted width 4 m
3 People	Experience
Species selective	
Size selective	

Figure 4.1. Illustration of the importance of experience for cast net fishing; Noufou Bonkoungou (left) catching 750 individuals, Paul Meulenbroek (right) catching one individual.

18 species were only caught with EF and 11 exclusively with CN. During our field work, EF and CN were approximately conducted the same time frame and both methods captured

around 9,000 specimen. Keeping in mind that EF needs three people and CN only one, CN appears more efficient. The two methods complement each other. Due to the limitations and the exclusive species caught by each method I recommend using both for future sampling in sub Sahelian countries like Burkina Faso.

4.3 Available habitat conditions

The collected data on the available habitat conditions represent a picture at a certain time which is strongly influence by the seasonality (Melcher et al. 2012), i.e. one scouted river in Koubri dried out and disappeared within 2 weeks completely and sampling was not possible anymore.

4.3.1 Substrate

Every side is dominated by fine fraction. The heavily impacted and obstructed area of Koubri shows a big spare of concrete caused by reservoirs and irrigation channels which are also used as fish habitat mainly by *Barbus macrops, Clarias sp., Oreochromis niloticus* and *Tilapia zillii*. This indicates the tolerance of this species against obstructions. The protected area of Nazinga exhibits coarser substrate conditions. Possible reasons are less reservoirs and more free flowing sections (Ouedraogo, 2010; Melcher et al. 2012). The high portion of fine fractions in Bagre can be explained by the selection of the sampling points which are mostly located at tributaries to the Reservoir which deposit high sediment loads. This is also shown in high conductivity values for these sites.

4.3.2 Structures

In stream structures are very important for diverse fish communities (Peter and Erb, 1996, Jungwirth et al. 2003) Due to that, it is necessary to assess the available structure elements. The relative high frequency of reed (56 %) and water plants (30%) in Koubri are caused by intensive agriculture with high nutrient input. Regarding Figure 3.7 it is clear that the Burkinabe waters don't have a lack of in-stream structures as in Europe. These elements can be necessary as an essential fish habitat for spawning, feeding, breeding or hiding for certain species (Jungwirth et al., 2003, WPFMC, 1998).

4.3.3 Physicochemical parameters

There are 12 habitats with a higher conductivity than 200 µm/cm. Half of them are located in Bagre and at the other sites constructions was going on nearby the water bodies.

pH value ranges from 6.4 to 10.1 with a mean value of 7.8. The lowest and highest value was measured in Koubri (Table 4.3). These extreme values can be explained by the high agricultural and livestock activities in this area (Bellingham, 2009; Melcher et al., 2012; Ouedraogo. 2010; Stranzl, in prep.).

Table 4.4. Measured temperature (°C) and pH value for all areas.

	Temperature (°C)			pH value		
	Min	Max	Mean	Min	Max	Mean
Kougri	28.0	35.1	31.7	7.2	9.8	7.9
Koubri	29.2	35.1	31.8	6.4	10.1	7.6
Bagre	24.0	31.0	26.9	6.8	9.0	8.3
Nazinga	23.3	30.2	25.5	7.6	8.6	7.8
Others	28.2	35.0	32.5	7.2	9.6	7.8
Total	23.3	35.1	30.1	6.4	10.1	7.8

There are noticeable temperature differences between Bagre/Nazinga and Kougri/Koubri (Table 4.3). The reason is the influence of reservoirs and the selection of the sampling points. In Kougri and Koubri most of the sampling points are located downstream of reservoirs, while in Bagre we mainly sampled tributaries. Nazinga in general shows a lower density of reservoirs than Koubri (Melcher et al., 2012). Nearly all reservoirs have a spill over which releases the warm water from the surface and therefore heats up the waters downstream (Allan and Flecker, 1993).

4.4 Habitat use at community level

The results of the effect of certain habitat parameter have to be handled with caution. You have to keep the rarefaction curve in mind, which leads to an increase of the number of caught species with an increase of the sample effort. This can either reinforces a claim or moderate it. With an increase of temperature, productivity of a water body increases as well, resulting in higher abundances and more diverse species richness (Figure 3.11). The described maximum between 31-33°C indicates the maximum tolerances of some of the local fish species (Beitinger et al., 2000). Regarding the mean shading of the water surface, Nazinga exhibits the highest value (18 %, Figure 3.10). This can In addition have an effect by protecting the water bodies from heating up by the sun. Consequently one should increase riparian vegetation for sun protection and as a consequence heating up of the water. Oxygen saturation between 90 and 150 % show the highest abundances. The gap between 110 and 130 % saturation in Figure 3.12 occurred because these site all were heavily impacted by dam or road obstruction (Stranzl, in prep.).

4.5 Habitat use at species level

In temporal water bodies such as in sub Sahalian Burkina Faso it is difficult to distinguish between habitat preferences and minimum requirements or tolerances. However the results highlight that the Burkinabe fish species do have different habitat uses.

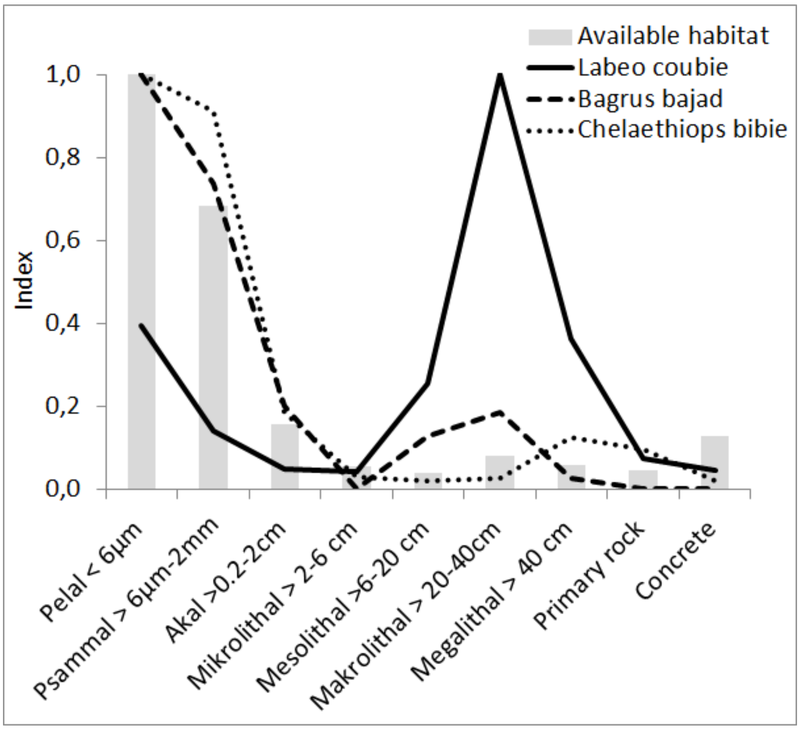


Figure 4.2. Habitat usage curves of substrate size for *Labeo cubie, Bagrus bajad* and *Chelaethiops bibie.*

Figure 4.2 points out the different habit usage curves for three different species. It indicates that *Bagrus bajad* and *Chelaethiops bibie* share the same habitat concerning substrate. However, *Labeo cubie* clearly uses habitats with coarser substrate shares. Looking at the available substrate distribution, it is clear that its potential habitat is more limited compared to the others (Figure 4.2).

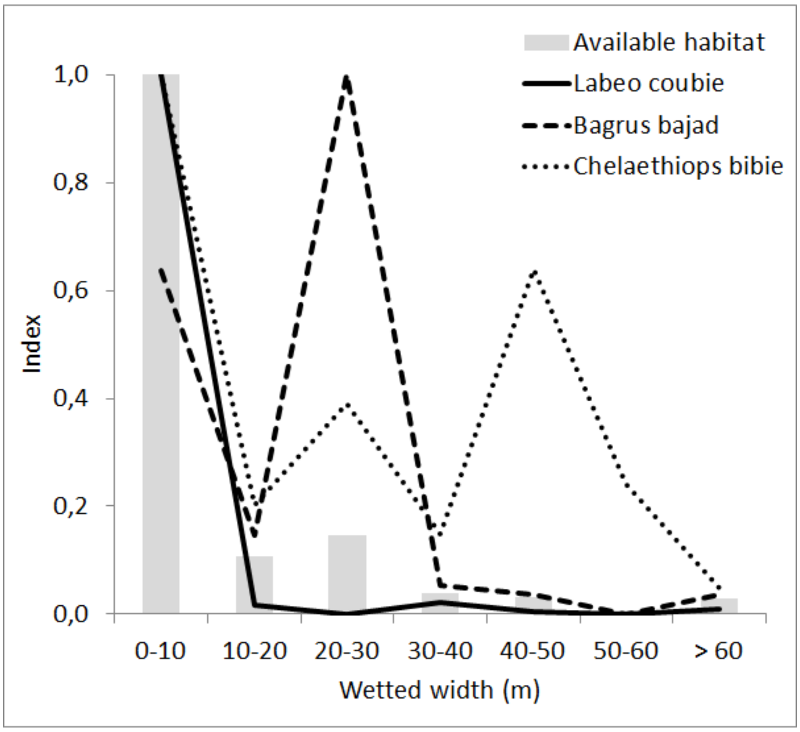


Figure 4.3. Habitat usage curves of wetted width (m) for *Labeo cubie*, *Bagrus bajad* and *Chelaethiops bibie.*

For the habitat use in terms of wetted width you see three different patterns. *Labeo Cubie* nearly only uses water bodies with a wetted width smaller than 10 m. *Bagrus bajad* has its maximum up to 30 m and *Chelaethiops bibie* shows high usages of water width around 50 m (Figure 4.3).

Figure 4.4 shows that water depth usage of *Chelaethiops bibie* and *Labeo Cubie* are nearly the same. *Bagrus bajad* avoids areas with water depth smaller than 0.5 m. Its usage curve is staggered a bit to the deeper areas.

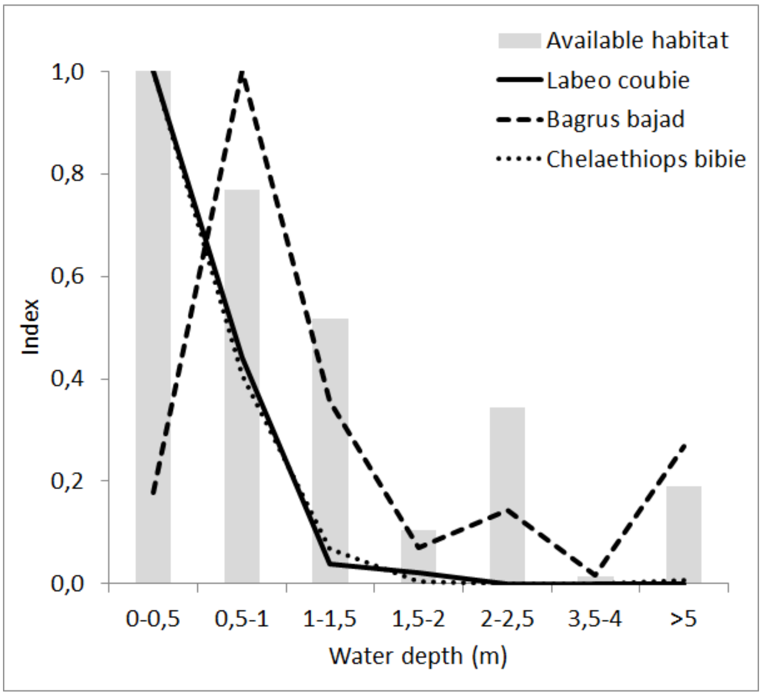


Figure 4.4. Habitat usage curves of water depth (m) for *Labeo cubie, Bagrus bajad* and *Chelaethiops bibie.*

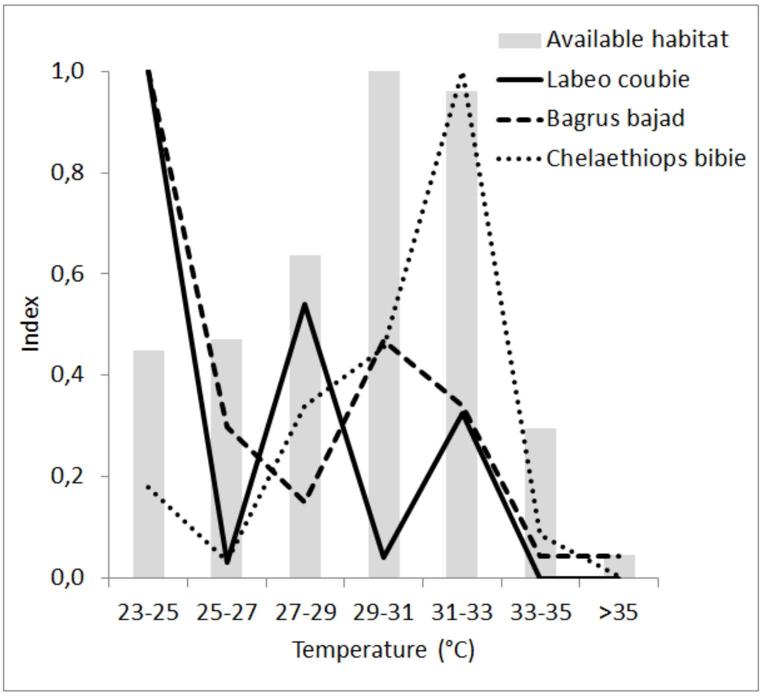


Figure 4.5. Habitat usage curves of Temperature (°C) for *Labeo cubie, Bagrus bajad* and *Chelaethiops bibie.*

Bagrus bajad and *Labeo Cubie* clearly prefer water temperatures < 25°C. However *Chelaethiops bibie* mostly uses water bodies with temperatures between 31 and 32°C (Figure 4.5).

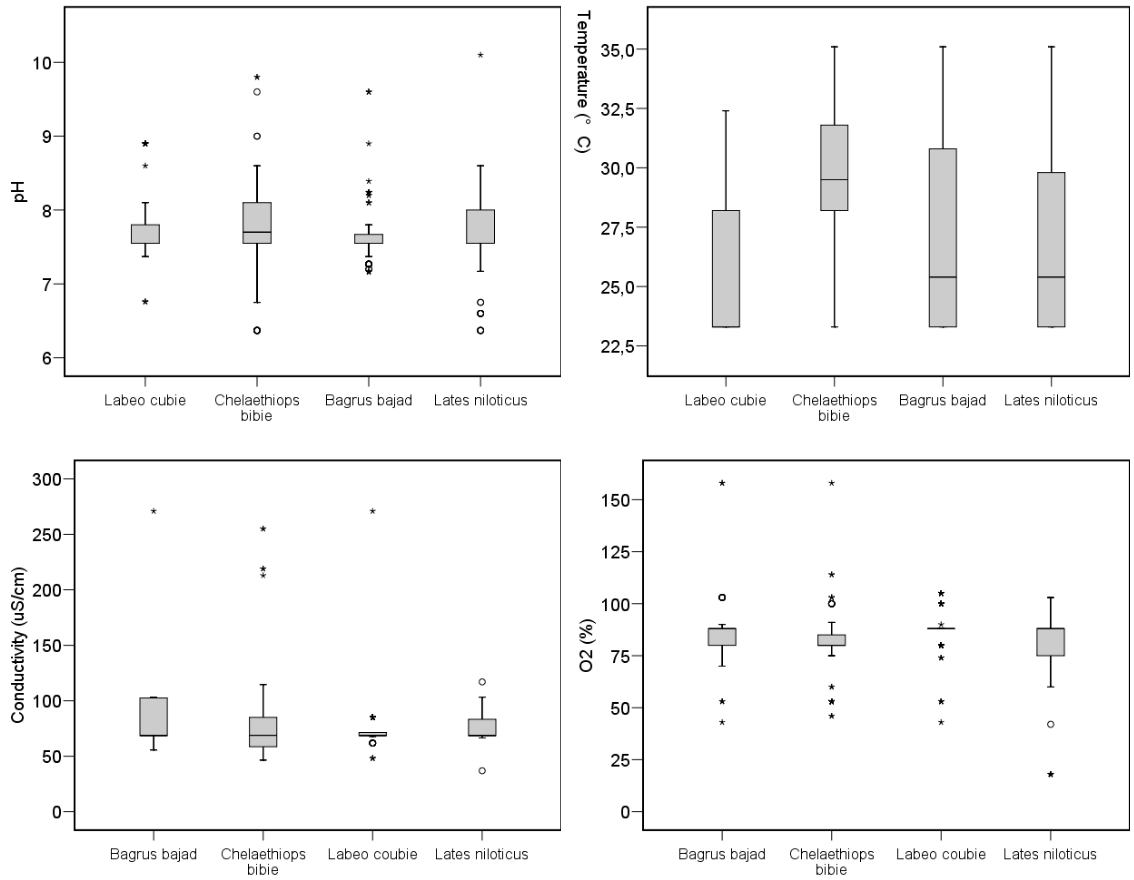


Figure 4.6. Physicochemical parameters for *Labeo cubie*, *Chelaethiops bibie*, *Bagrus bajad* and *Lates niloticus.*

Summarizing the habitat usage curves and physicochemical parameters (Figure 4.6) you can see differences in the habitats of the species (Figure 4.2-4.5). *Chelaethiops bibie* uses shallow, big and warm water bodies with fine sediments and high proportions of Xylal. The high occurrence of Xylal (90 %) is evidence that this structural element is an essential one for his lifecycle. *Bagrus bajad* prefers deeper, cool, midsize water bodies also dominated by fine substrates. *Lates niloticus* shows similar habitat characteristics. *Labeo cubie* in contrast inhabits water bodies which are characterized by coarse substrate and higher flow velocity. It occurs in narrow and shallow streams. For the described habitat of *Labeo cubie* you have to consider, that we only caught young fish (max size 150 mm). In further studies man could prove if these species could be used as indicator species for the assessed habitat conditions.

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6. Appendix

Table 6.1. Potential fish species in Burkina Faso (after Paugy et al. 2004, Ouedraogo 2010, Froese and Pauly 2013, Roman 1966)

Name	Paugy et al.	Ouedraogo	fishbase.org	Roman	Number of sources
Alestes baremoze	X	X	X	X	4
Alestes dentex	X	X	X		3
Amphilius sp.				X	1
Arius gigas	X		X		2
Auchenoglanis occidentalis	X	X		X	3
Bagrus bajad	X	X	X	X	4
Bagrus docmak	X	X	X	X	4
Bagrus filamentosus	X		X	X	3
Barbus ablabes	X	X	X	X	4
Barbus baudoni	X		X	X	3
Barbus bawkuensis	X		X	X	3
Barbus bynni occidentalis	X		X		2
Barbus leonensis	X		X	X	3
Barbus macinensis	X		X	X	3
Barbus macrops	X	X	X		3
Barbus nigeriensis	X		X		2
Barbus parablabes			X		1
Barbus perince			X		1
Barbus pobeguini	X		X	X	3
Barbus punctitaeniatus	X		X	X	3
Barbus stigmatopygus	X		X	X	3
Barbus sublineatus	X		X	X	3
Brienomyrus niger	X	X	X	X	4
Brycinus leuciscus	X		X	X	3
Brycinus luteus	X		X	X	3
Brycinus macrolepidotus	X	X	X	X	4
Brycinus nurse	X	X	X	X	4
Campylomormyrus tamandua	X		X	X	3
Chelaethiops bibie	X	X	X		3
Chelaethiops elongatus				X	1
Chiloglanis occidentalis			X		1
Chiloglanis voltae	X		X	X	3
Chromidotilapia guntheri	X				1
Chrysichthys auratus	X		X	X	3
Chrysichthys nigrodigitatus	X	X		X	3
Chrysichthys walkeri				X	1
Citharinops distichodoides	X		X	X	3
Citharinus citharus	X	X	X	X	4
Citharinus latus	X		X	X	3
Clarias agboyiensis	X				1
Clarias anguillaris	X		X	X	3
Clarias gariepinus	X	X	X		3
Clarias laeviceps	X				1
Clarotes laticeps	X		X	X	3
Clypeobarbus hypsolepis			X	X	2
Cromeria nilotica	X		X		2
Ctenopoma kingsleyae	X	X		X	3
Ctenopoma petherici	X	X			2

Cyphomyrus psittacus	X				1
Distichodus brevipinnis	X		X	X	3
Distichodus engycephalus	X		X	X	3
Distichodus rostratus	X	X	X	X	4
Epiplatys bifasciatus	X		X	X	3
Epiplatys spilargyreius	X		X		2
Fundulosoma thierryi				X	1
Gymnarchus niloticus	X			X	2
Hemichromis bimaculatus	X		X	X	3
Hemichromis fasciatus	X	X	X	X	4
Hemichromis letourneauxi		X			1
Hepsetus odoe				X	1
Heterobranchus bidorsalis	X	X	X	X	4
Heterobranchus isopterus			X		1
Heterobranchus longifilis	X	X	X	X	4
Heterotis niloticus	X	X	X	X	4
Hippopotamyrus paugyi		X			1
Hippopotamyrus pictus	X	X	X	X	4
Hippopotamyrus psittacus			X	X	2
Hydrocynus brevis	X		X	X	3
Hydrocynus forskali	X	X	X	X	4
Hydrocynus vittatus	X	X			2
Hyperopisus bebe	X	X	X	X	4
Kribia nana				X	1
Labeo coubie	X	X	X	X	4
Labeo niloticus		X			1
Labeo parvus			X	X	2
Labeo senegalensis	X	X	X	X	4
Laeviscutella dekimpei			X		1
Lates niloticus	X	X		X	3
Leptocypris niloticus	X		X	X	3
Malapterurus electricus	X	X	X	X	4
Malapterurus minjiriya	X		X		2
Marcusenius abadii	X		X		2
Marcusenius senegalensis	X	X	X	X	4
Mastacembelus nigromarginatus	X			X	2
Micralestes comoensis			X		1
Micralestes elongates	X	X	X	X	4
Micralestes occidentalis	X		X	X	3
Micralestes pabrensis	X		X	X	3
Micropanchax pfaffi	X		X	X	3
Mormyrops anguilloides	X	X		X	3
Mormyrops breviceps	X		X	X	3
Mormyrops curviceps				X	1
Mormyrus hasselquistii	X	X	X	X	4
Mormyrus macrophthalmus	X			X	2
Mormyrus rume	X	X		X	3
Nannaethiops unitaeniatus				X	1
Nannocharax ansorgii	X		X	X	3
Nannocharax fasciatus	X			X	2
Neolebias unifasciatus	X		X	X	3
Nothobranchius thierryi			X		1
Oreochromis macrochir			X		1
Oreochromis niloticus	X	X	X		3
Parachanna obscura	X		X	X	3
Paradistichodus dimidiatus	X		X	X	3

Parailia pellucid	X		X	X	3
Pellonula leonensis	X		X	X	3
Petrocephalus bane			X	X	2
Petrocephalus bovei	X	X	X	X	4
Petrocephalus pallidomaculatus			X		1
Petrocephalus sinus				X	1
Petrocephalus soudanensis	X		X		2
Phractura clauseni	X		X	X	3
Pollimyrus isidori	X	X	X	X	4
Polypterus bichir lapradei	X		X	X	3
Polypterus endlicheri	X	X	X	X	4
Polypterus senegalus senegalus	X	X	X	X	4
Poropanchax normani	X		X	X	3
Pronothobranchius kiyawensis	X		X		2
Protopterus annectens annectens	X	X	X	X	4
Raiamas senegalensis	X		X	X	3
Rhabdalestes septentrionalis	X		X		2
Rhexipanchax schioetzi	X		X		2
Sarotherodon galilaeus	X	X			2
Schilbe intermedius	X	X	X		3
Schilbe micropogon	X		X		2
Schilbe mystus	X	X		X	3
Scriptaphyosemion banforense			X		1
Scriptaphyosemion guignardi	X		X		2
Siluranodon auritus	X	X	X	X	4
Steatocranus irvinei			X	X	2
Synodontis arnoulti			X	X	2
Synodontis clarias	X	X		X	3
Synodontis eupterus				X	1
Synodontis filamentosus	X	X		X	3
Synodontis membranaceus	X	X		X	3
Synodontis nigrita	X			X	2
Synodontis ocellifer	X				1
Synodontis punctifer		X			1
Synodontis schall	X	X	X	X	4
Synodontis sorex	X		X	X	3
Synodontis velifer	X	X	X	X	4
Synodontis vermiculata		X			1
Synodontis violacea	X		X	X	3
Synodontis voltae			X		1
Tetraodon lineatus	X		X	X	3
Tilapia dageti	X		X		2
Tilapia galilaea				X	1
Tilapia zillii	X	X		X	3
Total	115	55	108	104	

Table 6..Potentiele fish families in Burkina Faso

Family	Number of genera	Number of species
ALESTIDAE	5	14
AMPHILIIDAE	2	2
ANABANTIDAE	1	2
APLOCHEILIDAE	4	5
ARIIDAE	1	1
BAGRIDAE	1	3
CENTROPOMIDAE	1	1
CHANNIDAE	1	1
CICHLIDAE	6	11
CITHARINIDAE	2	3
CLARIIDAE	2	7
CLAROTEIDAE	3	5
CLUPEIDAE	2	2
CROMERIIDAE	1	2
CYPRINIDAE	6	23
DISTICHODONTIDAE	5	8
ELEOTRIDAE	1	1
GYMNARCHIDAE	1	1
HEPSETIDAE	1	1
MALAPTERURIDAE	1	2
MASTACEMBELIDAE	1	1
MOCHOKIDAE	2	16
MORMYRIDAE	10	21
NOTHOBRANCHIIDAE	2	2
OSTEOGLOSSIDAE	1	1
POECILIIDAE	3	3
POLYPTERIDAE	1	3
PROTOPTERIDAE	1	1
SCHILBEIDAE	3	5
TETRAODONTIDAE	1	1
30	72	149

Site Protocol .... **Site Name......................** **Date (dd/mm/yy) ....**

Habitat	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Description								
Writer								
GPS-point (N/E)								
GPS-Coordinat								
Run/Throw nr.								
Start time								
End time								
Photo nr.								
Weather								
Fishing method								
Blockage								
Water type								
Fished area (m²)								
Distance bank (m)								
Secchi depth (cm)								
Condcutivity (µS/cm)								
pH								
Temperature (°C)								
O_2 (%)								
O_2 (mg)								
Probe nr.								
Landuse								
Impact								
Shading (%)								
Structure								
Dam								

CATEGORIES	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Weather	sun	cloud	rain	wind				
Fishing method	1 aggregat	2 aggregat	gill net	cast net	longline	Nasse fishing	commercial	
Blockage	net	electric	barrier					
Water type	reservoir	running	con sidearm	dead sidearm	pond	Dissipation	channel	
Landuse	savanna	rice	agriculture	livestock	settlements	roads	forest	protected
	9 cotton	**10** vegetables						
Structure	tree	xylal	rock	waterplants	reed	outwashed bank		
Impact	fishing	sandmining	water abstracti	deforestation	channalisation	invasiv plant	nutrient inp	riprap
Dam	upstream	downstream	between	free flowing				

Figure 6.1. Habitat Assessment sheet for sub sahalian countries

Site Protocol .....   Site Name......................   Date (dd/mm/yy) ....

	1	2	3	4	5	6	7	8
writer								
riverbed width (m)								
riverbed height (m)								
distance to bank 1(m)								
distance to bank 2(m)								
distance to bank 3(m)								
distance to bank 4(m)								
distance to bank 5(m)								
distance to bank 6(m)								
distance to bank 7(m)								
wetted width 1 (m)								
wetted width 2 (m)								
wetted width 3 (m)								
wetted width 4 (m)								
wetted width 5 (m)								
wetted width 6 (m)								
wetted width 7 (m)								
water depth 1 (m)								
water depth 2 (m)								
water depth 3 (m)								
water depth 4 (m)								
water depth 5 (m)								
water depth 6 (m)								
water depth 7 (m)								
velocity 1 (m/s)								
velocity 2 (m/s)								
velocity 3 (m/s)								
velocity 4 (m/s)								
velocity 5 (m/s)								
velocity 6 (m/s)								
velocity 7 (m/s)								
Choriotop in %								
Pelal < 6µm								
Psammal > 6µm-2mm								
Akal >0,2-2cm								
Mikrolithal > 2-6 cm								
Mesolithal >6-20 cm								
Makrolithal > 20-40cm								
Megalithal > 40 cm								

Continue Figure 6.1. Habitat Assessment sheet for sub sahalian countries