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MORPHOMETRIC VARIATION AMONG *Bagrus docmak* (SSEMUTUNDU) OF THE UGANDAN MAJOR WATER BODIES

MWANJA M.T.[1]*, ARUHO C.[1], NAMULAWA V.[1], DDUNGU R.[1], ONDHORO C.C.[1,2] AND BASIITA R.K.[1,2]

[1]National Agricultural Research Organization, National Fisheries Resources Research Institute, Aquaculture Research and Development Center, Kajjansi, P.O. Box 530 Kampala, Uganda
[2]Centre for Sustainable Tropical Fisheries and Aquaculture, College of Marine and Environmental Science, James Cook University, Townsville, 4811 QLD Australia
*Corresponding Author: Email- mmtenywa@hotmail.com

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Abstract- *Bagrus docmak*, locally known as Ssemutundu, is one of the native catfishes of Uganda occurring in lakes Albert, Edward, Kyoga and Victoria; and rivers Kagera and the Victoria Nile. The species is a high value food fish that has been targeted for domestication, a process that requires definition of the different strains/taxa of the species. We investigated the morphological variations based on 22 morphological characters in an attempt to identify the different strains of *B. docmak* and define the species' morphological phylogenetics in Uganda's major water bodies. Morphometric data taken from 372 samples was analysed using multivariate methods in an attempt to establish the morphological phylogenetics relationships within and among the different geographical populations. A scatter diagram based on the two most significant components and a multidimensional scaling plot (MDS) based on Euclidean similarity measure clustered the *B. docmak* from Uganda's major water bodies into two groups. One group exclusively contained the Victoria Nile individuals whereas the second group contained the rest of the samples. These two groups require further studying for they may require different management approaches and may have different potential aquaculture traits. The findings are discussed in such a way as to emphasise revival, domestication, culture and sustainable exploitation of the Ssemutundu fishery in the country.

Keywords- Bagrus docmak, morphometric variation, phylogenetics, Uganda's waters, domestication efforts

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Introduction

According to FAO [1] it is clear that aquaculture is developing, expanding and intensifying in almost all regions of the world including sub-Saharan Africa. However the contribution of Africa to the global aquaculture production is still minimal. As the global population expands, demand for aquatic food products is expected to increase. Globally, production from capture fisheries are leveling off and most of the main fishing areas have reached their maximum potential [2]. Sustaining fish supplies from capture fisheries will, therefore, not be able to meet the growing global demand for aquatic food. Demand for fish is responsible for overexploitation and species loss estimated at more than 50% from the wild [3]. Although aquaculture has not yet reached commercial levels in most Sub Saharan Africa, production levels with the objective of generating income are increasing in Uganda based on three commercial fish species. African catfish (*Clarius gariepinus*), Nile tilapia (*Oreochromis niloticus*) and Mirror carp (*Cyprinus carpio*) as the three most commonly reared species depicting a limited range of cultured commercial fish species [4]. There is need to diversify into the culture of other high value species like *Bagrus docmak* indigenous to Uganda's water system with existing commercial importance to the country as well as with a possible potential globally [5]. *Bagrus docmak* locally known as Ssemutundu, is an indigenous piscivorous fish native to Lakes; Albert, Edward, George and Victoria; and the Rivers; the Nile and Kagera in Uganda [6-7]. Ssemutundu is a highly valued species in Uganda and has a great potential to generate income to farmers and the country from local, regional and international markets like its relative the channel catfish that fetches high prices on the world market [8]. It is a carnivorous fish and hence could also be used in polyculture with *Oreochromis niloticus* as a measure to check the latter's populations in culture systems caused by early and prolific breeding [9-10]. The natural stocks of *B. docmak* in the Lake Victoria region (LVR) waters have declined since the introduction of the Nile perch and concomitant ecological changes with the *B. docmak* currently restricted to refuggia in rocky habitats [11-12].

The species is no longer considered threatened though experiencing heavy fishing pressure in East Africa, IUCN calls for clear understanding of the species threats, sustainable exploitation and conservation efforts for the species [13]. Domestication and culture of *B. docmak* under captivity will provide an alternative source and hence reduce on the fishing pressure on the species in the wild. Therefore the successful culture will not only provide additional choice of currently cultured fish species to farmers in the country, but will as well provide seed base for restocking of natural water bodies to bolster the species' numbers. This is done following a domestication model that promotes mixed types with a combination of commodity and wild-like traits for culture-based and enhanced fisheries [14]. To culture any species from the wild it is prudent that the species is characterized taxonomically, ecologically and geographically as the first step. This enables one to define this species and to determine the performance of the different taxons that are in the wild so as to aid selection of the best suited taxon for culturing [15]. In addition, such studies provide a bench mark for studying feral domestic animals to find out if the morphological changes that occur in multigenerational captive animals persist in the wild, or if they are simply individual responses to the captive environment [16].

The current study aimed at establishing the morphological phylogenetics of the natural stocks of *B. docmak* in its native range in the country in a bid to identify and determine the different stocks, taxa or strains in Uganda's major water bodies for possible use in aquaculture. In this paper, characterization of *B. docmak* populations and subdivisions were based on traditional landmark morphometrics of 20 morphological characteristics. The measured morphological characters were subjected to multivariate analysis a tool highly recommended for determining relationships between populations of a species [16] and for use in stock identification of freshwater fish and investigating taxonomical problems in sympatric populations [17]. The findings in this study will provide information that will be validated by molecular characterization of the species in an attempt to definitely classify the populations of ssemutundu in Ugandan major water bodies. As the identified strains or taxa of *B. docmak* may be different in their qualitative and quantitative traits, they will be subjected to performance trials to aid choice of best performing taxa for use in aquaculture.

Materials and Methods

Study Area

Bagrus docmak samples were taken from Lakes - Albert, Edward and Victoria; and Rivers - Kazinga channel and Victoria Nile in Uganda [Fig-1]. Lakes George and Edward are typical rift valley lakes, found in the western rift on the border of Uganda with Democratic Republic of Congo. The two lakes are connected by Kanzinga, which is about 40 km long and 1 km wide channel [18]. Lake Edward is the smallest of the great lakes of Africa, with a maximum depth of 112m. Its main inflows are the Rivers Nyamugasani, Ishasha, Rutshuru and Rwindi. Its major outflow is the Semliki River, which connects it to Lake Albert [18]. Lake Victoria with an area of 68,800 Km^2 is the largest tropical lake as well as the second largest freshwater lake in the world [19]. There are numerous inflows into Lake Victoria but the principal one is Kagera River, which is about 580 km long, entering the lake from the western shore and comes from the highlands of Rwanda and Burundi [18].The only outlet from Lake Victoria is the Victoria Nile River, which flows through Lake Kyoga and then to Lake Albert, to the north and northwest, respectively with waterfalls - Owen and Murchison on either side of Lake Kyoga that limit big faunal exchange [20]. Lake Albert is one of the Great Lakes of Africa and is located at the northern end of the western branch of the East African rift system. Lake Albert occupies the northernmost rift basin in the western rift valley. The lake is approximately 130 km long and approximately 35 km wide and is an open hydrologic system that receives its major input from the Semliki River to the southwest and the Victoria Nile to the northeast [Fig-1]. It has a maximum water depth of approximately 58 m.

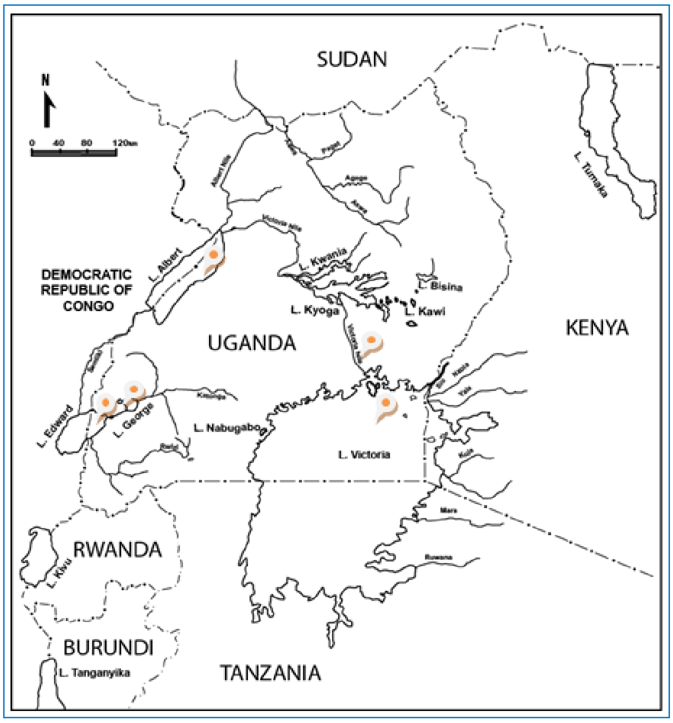

Fig. 1- Map of Uganda showing the major water bodies from which *B. docmak* samples were collected

Sample Collection

Fish samples were purchased at the landing sites from fishers who caught them by using mostly long liners and seine nets. A total of 372 *Bagrus docmak* fish were sampled from lakes Albert, Edward and Victoria; rivers Kazinga channel, and the Victoria Nile from a total of 13 different landing sites. Morphometric and biometric measurements were done for each sampled fish immediately after being landed. Land marks for the morphometric characters measured (truss) using vernier callipers included - snout, ventral junction of operculum, supra orbital, lower pectoral fin insertion, anterior dorsal fin insertion, posterior end of pelvic fin insertion, posterior end of dorsal fin insertion, anterior end anal fin insertion, dorsal caudal fin insertion, ventral caudal fin insertion [Fig-2]. The biometric measurements (non-truss) included total length (TL), standard length (SL), folk length (FL), orbital distance (OBD), pectoral fine length (PFL), dorsal fin length (DFL), pelvic ventral fin length (PVFL), anal fin length (AFL) and caudal fin length (CFL) [Fig-3].

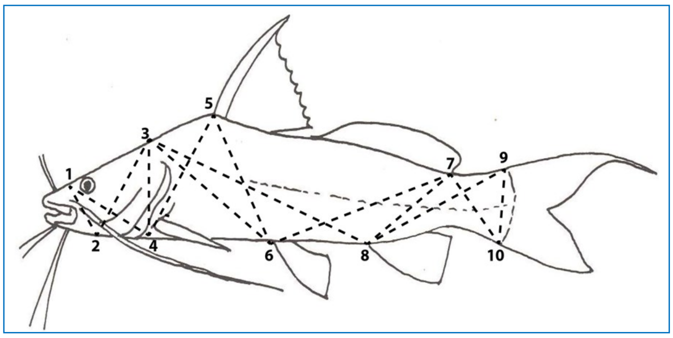

Fig. 2- Showing land marks for measured morphological characters

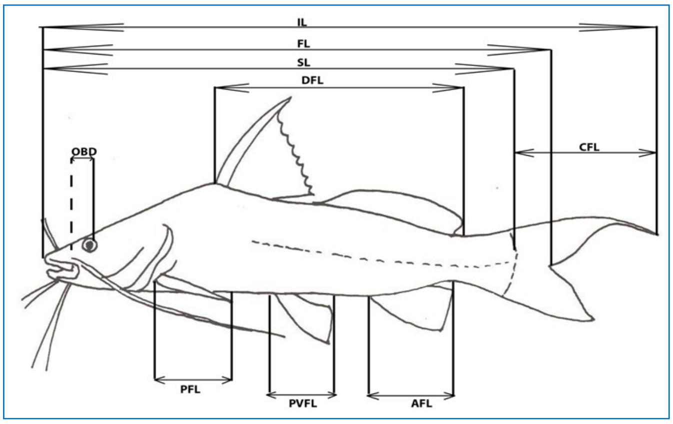

Fig. 3- Showing selected non-truss measurements taken for this study

Data Analysis

Each lake or river population was considered a *priori* as a discrete population. The measured morphological characters were subjected to multivariate analysis, a tool highly recommended for determining relationships between populations of a species and for use in stock identification of freshwater fish and investigating taxonomical problems in sympatric populations [21]. In order to standardize the data, taken, measurements obtained for all variables were log_{10} - transformed before statistical analyses were performed. The outcomes were then subjected to the Principal Component Analysis (PCA) under multivariate data analysis using the PAST software [22]. PCA was used to extract principal components from the considered variables. The most significant component that contributed most to the variance was identified and used in determining the morphological phylogenetic relationships of the *B. docmak* from the Uganda's major water bodies. Phylogenetic relationships were assessed using mixture analysis, multidimensional scaling (MDS) and dendogram construction. Basing on the outcome of the mixture analysis in 'PAST', all data were subjected to K-means clustering to determine non-hierarchical clustering of all the samples into the number of groups specified under the mixture analysis. For all analyses the significance level considered was 0.05.

Results

Univariate data summaries for the 22 variables are given in [Table-1]. Total length (TL) ranged from 14.40 cm to 88.00 cm (mean TL= 48.01 cm) for the 372 samples of *B. docmak* used in the analyses. The largest *B. docmak* was caught off Kasensero landing site offshore of Lake Victoria. There was no size range or form associated with any particular water body. The PCA of the 22 variables showed that the first two principle components (PC) accounted for 87.73% of the total variance. The Eigen scores/values and respective percentage contributions to variation by the 22 resolved components are given in [Table-2]. The 22 variables were resolved into two most significant components with 87.73% of the morphological variation explained along the 2 most significant components - component 1 (69.23%) and component 2 (18.50%) [Fig-4], [Table-2]. Of the 22 variables, AFL, CFL, OBD, body size (H) and PVFL in that order contributed most to variation exhibited by the 2 most significant components [Fig-6], the respective factor loadings are given in [Table-3].

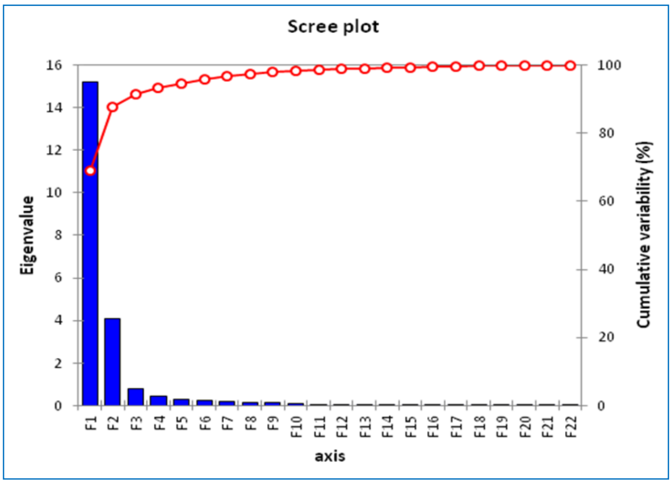

Fig. 4- Eigen values and percentages of inertia

Table 1- Univariate statistics for the 22 morphometric statistics of *Bagrus docmak* sampled from Ugandan major water bodies - lakes Edward, George, Albert and Victoria; and Rivers Kagera and Victoria Nile.

Statistic (cm)	TL	FL	SL	A	B	C	D	E	F	G	H	I	J	K	L	M	OBD	PFL	DFL
No. of observations	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198
Minimum	14.4	5	3.5	2.1	1.7	1.7	2.4	2	2.7	3.7	1.8	2.8	2.8	3.4	1.1	3.1	0.8	1.7	2.1
Maximum	88	76.4	68.9	19.3	15.2	20.1	21.7	19.3	21.6	27.8	19.9	103	27.7	22.9	15.9	31.5	12.2	10.9	19.3
1st Quartile	37.53	29.35	26.6	6.2	4.7	5.25	8.3	6.63	7.4	10.13	5.75	7.23	10.03	8.8	3.23	11.85	2.8	4.5	6.2
Median	47.75	39.7	36.55	8.15	6.4	7.2	10.9	8.95	10	14	8	9.6	13.85	11.5	4.5	16.4	3.7	5.9	8.3
3rd Quartile	56.38	46.98	43.4	9.6	7.78	8.98	13.4	11.2	12.5	17.45	10.3	11.4	16.88	14.4	5.7	20.25	4.5	7.2	11.08
Mean	47.26	38.23	34.92	8.11	6.48	7.26	10.95	9.06	10.19	14.16	8.3	9.92	13.52	11.57	4.75	16.03	3.89	5.96	8.66
Variance (n-1)	171.01	190	164.45	7.3	5.58	7.26	12.22	11.42	12.01	23.13	11.38	52.31	22.13	14.82	3.71	31.11	2.79	3.31	10.17
S.D (n-1)	13.08	13.79	12.82	2.7	2.36	2.69	3.5	3.38	3.47	4.81	3.37	7.23	4.71	3.77	1.93	5.59	1.67	1.82	3.19

TL: Total length, SL: standard length, FL: Fork length, A:BCD; Descriptive statistics (Quantitative data)

Table 2- Eigen scores/values and respective percentage contributions to variation by the 22 resolved components

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22
Eigen value	15.21	4.07	0.81	0.45	0.28	0.25	0.21	0.16	0.12	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.03	0.02	0.02	0.01	0.01	0.01
Variability %	69.23	18.5	3.67	2.03	1.26	1.15	0.93	0.74	0.55	0.28	0.28	0.23	0.2	0.19	0.18	0.16	0.15	0.1	0.08	0.07	0.05	0.03
Cumulative %	69.23	87.73	91.4	93.43	94.69	95.84	96.77	97.51	98.06	98.34	98.62	9885	99.05	99.26	99.46	99.52	99.67	99.77	99.85	99.92	99.97	100

A scatter diagram based on the two most significant components [Fig-5] and an MDS plot based on Euclidean similarity measure [Fig -7] clustered the *B. docmak* of Uganda major water bodies into two groups. Similarly a dendogram to show the phylogenetic relationships of the species brought out two major clades. One group exclusively contained the Victoria Nile individuals whereas the second group contained the rest of the samples.

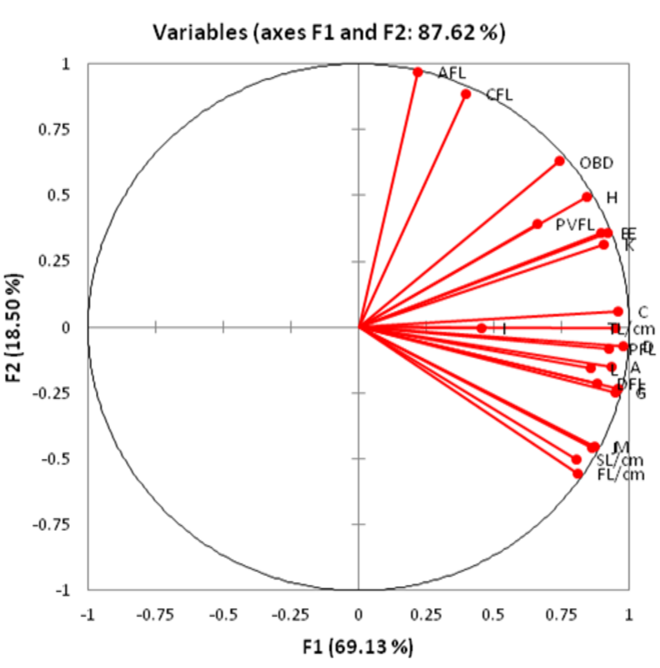

Fig. 6- Contributions of the different variables to the two most signicant components of the morphological variation of *B. docmak* of Ugandan major waters.

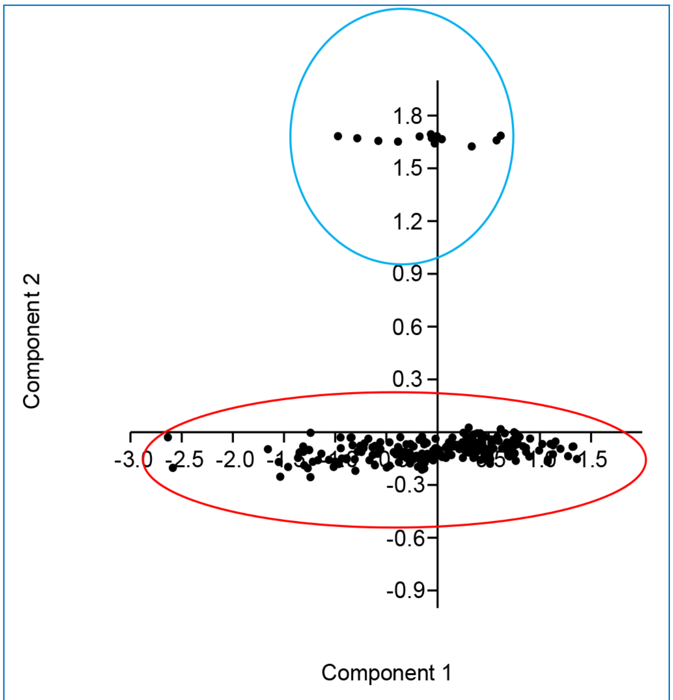

Fig. 5- Plot of Principal component I (component1) and residuals of Principal component II (compnent 2) of 22 morphometric characters of *Bagrus docmak*

Table 3- Factor loadings indicating contributions from each of the 22 variables to the two most significant components; 1 and 2.

	Component 1	Componenet 2
TL/cm	5.948	0.000
FL/cm	4.312	7.581
SL/cm	4.256	6.196
A	5.724	0.546
B	5.271	3.187
C	6.020	0.088
D	6.269	0.119
E	5.547	3.177
F	6.054	1.344
G	5.917	1.483
H	4.670	6.012
I	1.364	0.000
J	4.882	5.166
K	5.420	2.454
L	4.807	0.607
M	4.997	5.028
OBD	3.639	9.734
PFL	5.617	0.154
DFL	5.082	1.099
PVFL	2.851	3.820
AFL	0.312	23.003
CFL	1.043	19.201

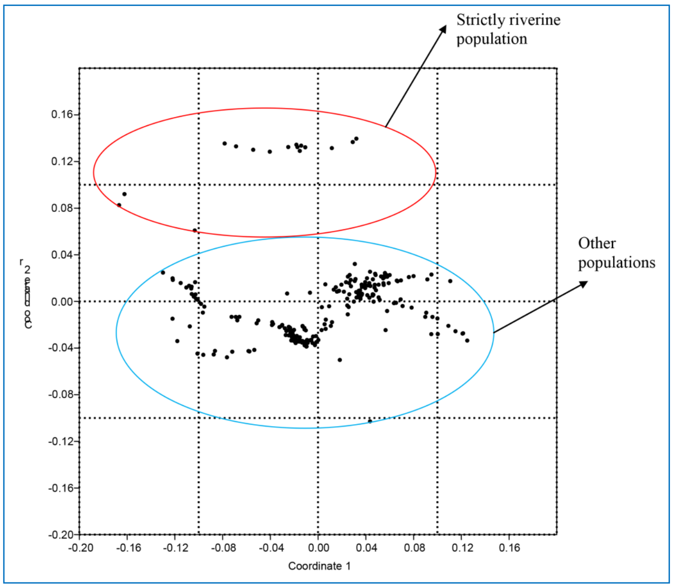

Fig. 7- MDS plot - Euclidean similarity measure 3D of sampled *Bagrus docmak* of Ugandan major water bodies

Discussion

In Uganda, *Bagrus docmak* is found in lakes Victoria, Nabugabo, Kyoga, Albert, Edward and George, and rivers Semliki, Albert Nile and the Victoria Nile [13]. In this study samples were taken from both the riverine and lacustrine environments. The findings showed a tendency of morphological separation between the riverine and lacustrine forms of the fish species. Morphological variation was mostly contributed by the fin lengths - the anal and caudal fin lengths and the inter-orbital distance. The fin lengths are associated with swimming and the OBD strongly associated with the form (sleekness) of the fish [23]. The riverine fish that swim along or against the flow of the river would be expected to be sleeker with longer fin lengths than the fish from the more stable lacustrine environments. [24], found a strong correlation between swimming performance and the environment from the fish is found, with the performance decreasing in the order - riverine, generalists and lacustrine environments. [25], who compared two landlocked lacustrine and two diadromous riverine populations of *Galaxias truttaceus*, suggested that the differences in water movement and food type may in part account for the differences shown and that selective pressures peculiar to the lacustrine environment may be causing the lake populations to diverge from the riverine populations.

It was expected that that rift populations of *B. docmak* would be morphological different from the Lake Victoria region (LVR) waters populations of this species. Populations of this species in the LVR are associated with the shallow morphometry of the water bodies in the LVR - lakes - Victoria and Kyoga as compared to the freshwater abyss of the rift Lake Albert [26].

There is need to study and compare the life history traits of the two populations - lacustrine and riverine populations in order to determine whether they are different as hypothesised by [27] that the riverine populations may have later maturity, higher fecundity and faster growth. This will enable choice of the best broodstock according to the farmers' needs for the proposed domestication of this species.

Conclusions and Way Forward

There appears to be morphological variation between the different geographical populations of *B. docmak* from the different water bodies within Uganda. This initial finding is only indicative and further work to complement the morphological analysis is required. Molecular genetic analysis of these populations when complete will give a much higher resolution of the phylogenetic relationships between the different populations. With the confirmation of the existence of different strains of the species, for the species domestication efforts, the identified strains shall need to be further studied for their respective economically important aquaculture traits performance. The best performing strain will then be targeted for use in aquaculture.

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Conflicts of Interest: None declared.

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