TRANSYLVANIAN REVIEW OF SYSTEMATICAL AND ECOLOGICAL RESEARCH

21.1

The Wetlands Diversity

Editors

Angela Curtean-Bănăduc & Doru Bănăduc

Sibiu – Romania
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"*Lucian Blaga*" University of Sibiu,
Faculty of Sciences,
Department of Ecology and Environment Protection

Sarasota Bay Foundation

International Association for Danube Research

"*Lucian Blaga*" University of Sibiu

Ecotur Sibiu N.G.O.

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IN MEMORIAM

Ernst Heinrich Philipp August Haeckel
(1834 – 1919)

Ernst Heinrich Philipp August Haeckel, the eminent German zoologist and evolutionist who was one of the period's most enthusiastic advocates of Darwinism, was born on 16 February 1834 in Potsdam, and died on 9 August 1919 in Jenna. He projected and proposed original ideas on the evolutionary descent of humans and he asserted that phylogeny is briefly and partially repeated in the process of ontogeny ("ontogeny recapitulates phylogeny").

Haeckel grew up in Merseburg. He studied in Würzburg and in Berlin University, where one of his professors, Johannes Müller, began to take him on expeditions to the North Sea coasts and to kindle his interest in sea organisms.

This contact with marine biology directed Haeckel's interests towards biology, but initially he took a medical degree, to satisfy his family's plans for him, at Berlin in 1857. For a while he practiced medicine; and travelled in Italy, where he painted and even considered art as a path. At Messina he researched Radiolaria one-celled protozoans.

The direction of Haeckel's interest was induced by reading Charles Darwin's On the Origin of Species by Means of Natural Selection. Meanwhile, in 1861 he obtained a dissertation in zoology at Jena University. In 1862 he was appointed associate professor of zoology, and that year, when he published his Radiolaria monograph, he asserted his understanding and acceptance of Darwin's theory of evolution. Since then he began to be a strong supporter of Darwinism, and he started lecturing to wide lay audiences on the theory of descent. For Haeckel, this was only the starting point, with effects and results to be sought further. In 1865 he was appointed full professor in Jena University, where he remained in charge until his retirement in 1909.

Haeckel's best-known published works were: Generelle Morphologie der Organismen (General Morphology of Organisms) and Die Perigenesis der Plastidule (The Generation of Waves in Small Vital Particles).

Haeckel brought debate to substantial and valuable biological questions. His gastraea theory, tracing multicellular animals to a theoretical two-layered ancestor, aroused both analysis and deliberations. His attraction to systematization along evolutionary lines drive to his very important improvements in the knowledge related to some invertebrate taxa such as radiolaria, medusa, siphonophores, and sponges.

Gathering and building collections, Haeckel founded the Phyletic Museum in Jena and also the Ernst Haeckel Haus; the latter contains his books and archives, and it cares for many other memorabilia of his extraordinary life and prestigious professional work.

The centenary of Haeckel reminds us of his lifelong devotion to natural sciences in a heroic stage of the history of the theory of evolution, a beautiful and remarkable life under the signs of art-like science.

The Editors

Transylvanian Review of Systematical and Ecological Research

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Preface

In a global environment in which the climate changes are observed from few decades no more only through scientific studies but also through day by day life experiences of average people which feel and understand allready the presence of the medium and long-term significant change in the “average weather” all over the world, the most comon key words which reflect the general concern are: heating, desertification, rationalisation and surviwing.

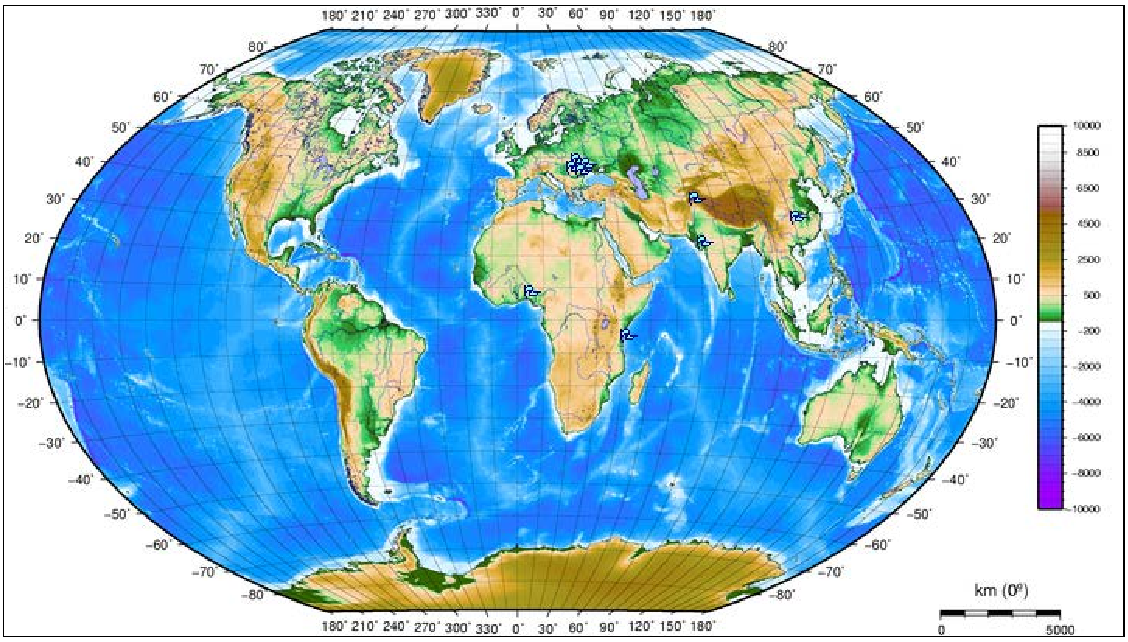
The causes, effects, trends and possibilities of human society to positively intervene to slow down this process or to adapt to it involve a huge variety of aproacess and efforts.

With the fact in mind that these aproaces and efforts shuld be based on genuine scientific understanding, the editors of the *Transylvanian Review of Systematical and Ecological Research* series launch three annual volumes dedicated to the wetlands, volumes resulted mainly as a results of the *Aquatic Biodiversity International Conference*, Sibiu/Romania, 2007-2017.

The therm wetland is used here in the acceptance of the Convention on Wetlands, signed in Ramsar, in 1971, for the conservation and wise use of wetlands and their resources. **Marine/Coastal Wetlands** – Permanent shallow marine waters in most cases less than six metres deep at low tide, includes sea bays and straits; Marine subtidal aquatic beds, includes kelp beds, sea-grass beds, tropical marine meadows; Coral reefs; Rocky marine shores, includes rocky offshore islands, sea cliffs; Sand, shingle or pebble shores, includes sand bars, spits and sandy islets, includes dune systems and humid dune slacks; Estuarine waters, permanent water of estuaries and estuarine systems of deltas; Intertidal mud, sand or salt flats; Intertidal marshes, includes salt marshes, salt meadows, saltings, raised salt marshes, includes tidal brackish and freshwater marshes; Intertidal forested wetlands, includes mangrove swamps, nipah swamps and tidal freshwater swamp forests; Coastal brackish/saline lagoons, brackish to saline lagoons with at least one relatively narrow connection to the sea; Coastal freshwater lagoons, includes freshwater delta lagoons; Karst and other subterranean hydrological systems, marine/coastal. **Inland Wetlands** – Permanent inland deltas; Permanent rivers/streams/creeks, includes waterfalls; Seasonal/intermittent/irregular rivers/streams/creeks; Permanent freshwater lakes (over eight ha), includes large oxbow lakes; Seasonal/intermittent freshwater lakes (over eight ha), includes floodplain lakes; Permanent saline/brackish/alkaline lakes; Seasonal/intermittent saline/brackish/alkaline lakes and flats; Permanent saline/brackish/alkaline marshes/pools; Seasonal/intermittent saline/brackish/alkaline marshes/pools; Permanent freshwater marshes/pools, ponds (below eight ha), marshes and swamps on inorganic soils, with emergent vegetation water-logged for at least most of the growing season; Seasonal/intermittent freshwater marshes/pools on inorganic soils, includes sloughs, potholes, seasonally flooded meadows, sedge marshes; Non-forested peatlands, includes shrub or open bogs, swamps, fens; Alpine wetlands, includes alpine meadows, temporary waters from snowmelt; Tundra wetlands, includes tundra pools, temporary waters from snowmelt; Shrub-dominated wetlands, shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils; Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils; Forested peatlands; peatswamp forests; Freshwater springs, oases; Geothermal wetlands; Karst and other subterranean hydrological systems, inland. **Human-made wetlands –** Aquaculture (e. g., fish/shrimp) ponds; Ponds; includes farm ponds, stock ponds, small tanks; (generally below eight ha); Irrigated land, includes irrigation channels and rice fields; Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture); Salt exploitation sites, salt pans, salines, etc.; Water storage areas, reservoirs/barrages/dams/impoundments (generally over eight ha); Excavations; gravel/brick/clay pits; borrow pits, mining pools; Wastewater treatment areas, sewage farms, settling ponds, oxidation basins, etc.; Canals and drainage channels, ditches; Karst and other subterranean hydrological systems, human-made.

The editors of the *Transylvanian Review of Systematical and Ecological Research* started and continue the annual sub-series (*Wetlands Diversity*) as an international scientific debate platform for the wetlands conservation, and not to take in the last moment, some last heavenly "images" of a perishing world …

This volume included variated original researches from diverse wetlands around the world.



The subject areas (⚑) for the published studies in this volume.

No doubt that this new data will develop knowledge and understanding of the ecological status of the wetlands and will continue to evolve.

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The Editors

Editorial Office:

"Lucian Blaga" University of Sibiu, Faculty of Sciences, Department of Ecology and Environment Protection, Dr. Ion Rațiu Street 5-7, Sibiu, Sibiu County, Romania, RO-550012, Angela Curtean-Bănăduc (ad.banaduc@yahoo.com, angela.banaduc@ulbsibiu.ro)

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DE GRUYTER OPEN

GREEN AND CHAROPHYTE ALGAE IN BIOINDICATION OF WATER QUALITY OF THE SHAH ALAM RIVER (DISTRICT PESHAWAR, PAKISTAN)

Izaz KHURAM *, *Zahir MUHAMMAD* *, *Nadeem AHMAD* *,
Rehman ULLAH * and *Sophia BARINOVA* **

* University of Peshawar, Khyber Pakhtunkhwa, Old Jamrud Road, Pakistan, PK-25120, izazkhuram@gmail.com, zahirbotany@gmail.com, nadeemgul77@gmail.com, rehmanbotany@gmail.com
** University of Haifa, Institute of Evolution, Mount Carmel, Abba Khoushi Avenue 199, Haifa, Israel, IL-3498838, Israel, sophia@evo.haifa.ac.il

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KEYWORDS: green algae, charophytes, bioindication, Shah Alam River.

ABSTRACT

58 species and infraspecies of Chlorophyta and Charophyta algae were observed in 60 samples collected in September 2017 from the Shah Alam River, Pakistan. The algal species richness and environmental variables increased down the river, except for pH. Bioindication revealed low saline, low alkaline, middle streaming, and middle oxygenated water with low to middle organic pollution with Index saprobity S 1.48-1.73, Class 2-3 of Water Quality. The trophic state was eutrophic and meso-eutrophic with increasing eutrophication down the river. River Pollution Indices RPI demonstrated increasing of pollution in the Shah Alam River in comparison with the parallel part of the Kabul River.

ZUSAMMENFASSUNG: Süßwasser Grünalgen und Armleuchteralgen im Shah Alam Fluss (Distrikt Peshawar, Pakistan).

Zwecks Untersuchung der Grünalgen und Charophyta wurden im September 2017 aus dem Shah Alam River in Pakistan 60 Proben gesammelt, wobei insgesamt 58 Arten und infraspezifische Einheiten von Algen aus 60 Proben bestimmt wurden. Der Artenreichtum der Algen und die Werte der Umweltvariablen erhöhten sich – mit Ausnahme des pH-Werts – im unteren Abschnitt des Flusses. Mit Hilfe der Bioindikatoren lässt sich ein geringer Salzgehalt, schwach alkalines Wasser mittlerer Strömungsgeschwindigkeit und mittlerem Sauerstoffgehalt feststellen sowie eine niedrige bis mittlere organische Verschmutzung mit einem Saprobienindex von S 1.48-1.73 und Klasse 2-3 der Wasserqualität. Der trophische Zustand war eutroph und meso-eutroph mit steigenden Werten im unteren Abschnitt des Flusses. Der Wasserverschmutyungsindex RPI zeigte im Vergleich zum parallelen Teil des Kabul Flusses eine zunehmende Verschmutzung des Shah Alam River.

REZUMAT: Alge verzi și Charophyta din râul Shah Alam (Districtul Peshawar, Pakistan).

În vederea studiului algelor verzi și a Charophytelor au fost prelevate din râul Shah Alam, Pakistan, 60 de probe, în septembrie 2017. Au fost identificate 58 de specii și infraspecii de alge Chlorophyta și Charophyta. Bogăția speciilor de alge și variabilele de mediu au crescut cu excepția pH-ului în sectorul din aval al râului. Bioindicatorii relevă un grad mic de salinizare și al alcalinității, o scurgere și oxigenare medie a apei prezentând o poluare organică scăzută până la medie și indicele de saprobitate S 1.48-1.73, clasa 2-3 a calității apei. Starea trofică a apei a fost eutrofă și mezo-eutrofă crescând în sectorul din aval al râului. Indicatorii de poluare a râului (RPI) au arătat o poluare crescândă în râul Shah Alam în comparație cu partea paralelă a râului Kabul.

INTRODUCTION

Freshwater algae are very diverse organisms that occupied all natural environments where the water and light are present. Algae of aquatic habitats have a definite answer to changes in the water properties and, thus, are widely used as bioindicators of water quality and ecosystem status. (Rasiga et al., 1999; Barinova et al., 2006; Bellinger and Sigee, 2010)

It is crucial to assess the water quality in the rivers of Pakistan, which are major water sources for drinking, industry and agriculture in a semi-arid climate zone. The Pakistan rivers represent a part of the Indus River basin. Usually, they flow down from the mountains and later into flat relief valleys in which the settlements and industries are concentrated. The capital of Khyber Pakhtunkhwa is Peshawar, which is enriched with four main rivers: Kabul River, Nagoman River, Shah Alam River, and Bara River. Out of these four rivers, the Shah Alam River, is known for its anthropogenic load because diverse types of industry and agriculture are located on its banks, which directly dumps its waste into the river.

Freshwater algae are widely used in ecological assessment and monitoring of water quality (Stevenson, 2014; Barinova et al., 2006). It is very important to know about algal diversity in inland waters because most of algal species can be used as environmental indicators. Algal flora of the Peshawar District with special emphasis on Shah Alam River is under exploration.

A few scientific articles about its algae had been published (Sarim, 1989a, b, 1991; Sarim and Faridi, 1976; Khan and Faridi, 1977; Anjum and Faridi, 1985; Sarim and Ayaz, 2000; Sarim and Zaman, 2005; Anjum et al., 1980, 1982; Faridi et al., 1981; Sarim et al., 2008, 2011; Hussain et al., 1985, 2009, 2010, 2011, 2012; Khuram et al., 2014). This region of Pakistan is very loaded anthropogenically because it has flat territory in the Kabul River basin between high mountains with high capacity for agricultural production. The territory between the Warsak areas in the upper part of the Peshawar Plain and before the Swat River tributary input represents a region in which the Kabul River has many meanders in its flow with a minimum of three different flows in parallel. This territory is placed in the semi-arid climatic zone. Many birds are concentrated in this area near the riverbanks. Therefore, it is important to assess the water quality in one of these rivers – the Shah Alam River, the most southern one.

The aim of our present work was to reveal an algal species list with species-specific ecological preferences and abundance of algae from the Shah Alam River to assess the water quality dynamics based on bioindication methods.

MATERIAL AND METHODS

The Shah Alam River is almost 82 km long (Fig. 1), originates from Kabul River up to Machni and falls back to Kabul River after Mian Gujar.

Three algae sampling sites, Machni (1), Khazana (2), and Mian Gujar (3), were selected. 60 algal samples, 20 from each site, were collected during autumn (September 2017.

The collected algal samples ware fixed with 4% formalin (Edler and Elbrächter, 2010).

Taxonomic assessment of the algae specimens was carried out in the Department of Botany of University of Peshawar. For identification, the specimens were mounted on the glass slides and examined under a compound microscope. The specimens were identified with standard identification manuals (Collins, 1909; Transeau, 1951; Prescott, 1962; Wehr, 2002; Tiffany and Britton, 1952; Bellinger and Sigee, 2015) and updated with algaebase.org.

Temperature, pH, electrical conductivity, total dissolved solids, salinity, and dissolved oxygen were measured on the sampling site by using a multiparameter water quality meter (HANNA HI 98194).

Species frequency was assessed with a six-score scale (Barinova et al., 2006).

Species ecology data was derived from a database (Barinova et al., 2006) for seven ecological bioindication systems. A total list of revealed algal taxa was correlated with ecological database in the Office Access (Microsoft). Relationships of biological and environmental variables were calculated in Statistica 12.0 program. Diversity indices and comparative floristics were done in the GRAPHS program (Novakovsky, 2004). Algal abundance in each algological sample was calculated as a sum of scores of species in six-scores scale frequency (Barinova et al., 2006). Pearson coefficients were calculated with help of Wessa (2018). River Pollution Indices (RPI) were calculated as integral of each measured variable over the distance between sites (Barinova et al., 2006, 2010).

$$RPId = \sum_{i=1}^{n} (Di + Dj) * 0.5 \ \ l / L \qquad \text{(Eq. 1)}$$

Where Di, Dj – an estimate of environmental variable or the corresponding index value for adjacent stations i and j;
l – the distance between two adjacent stations (km);
L – the total length of the river.
Index of saprobity S was calculated on the base of species ecology (Barinova et al., 2006) as:

$$S = \sum_{i=1}^{n} (s_i \times h_i) \Big/ \sum_{i=1}^{n} (h_i) \qquad \text{(Eq. 2)}$$

Where si is species-specific index saprobity, hi abundance scores of i-species, S is index saprobity of community on the station.

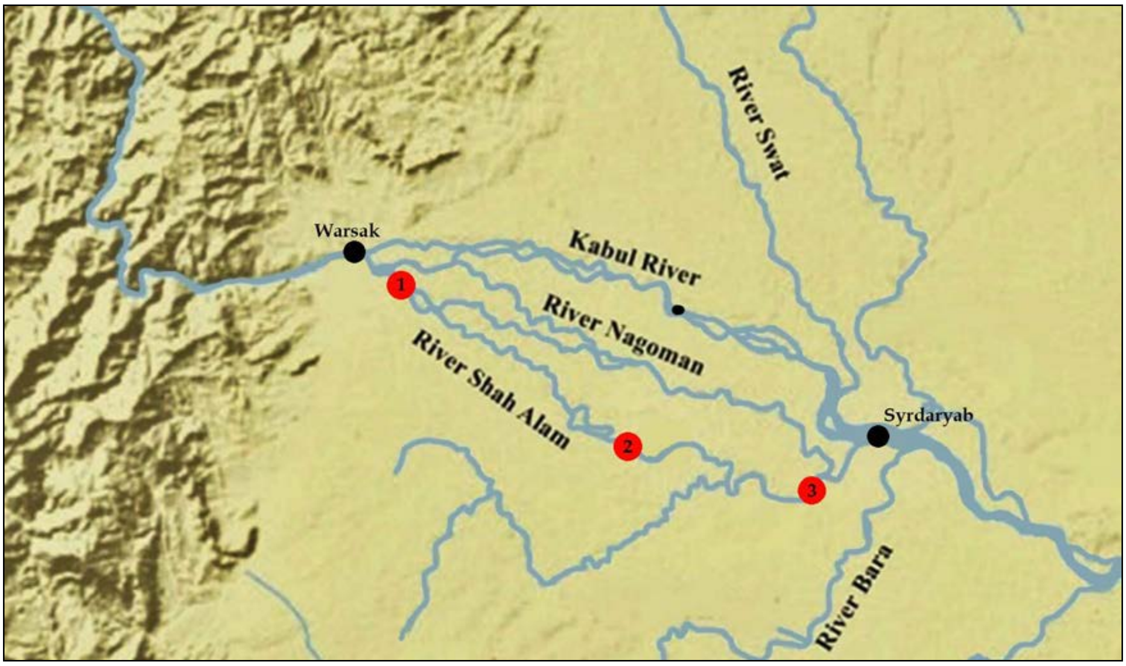

Figure 1: Sampling sites in the Shah Alam River: Machni-1, Khazana-2, and Mian Gujar-3.

RESULTS AND DISCUSSION

Studied sites in the Shah Alam River (Fig. 1; Tab. 1) are placed in almost the same latitude and altitude about 300 m above sea level (a.s.l.). Total length of studied river part is 32.2 km. The water temperature increased significantly from 18°C in Machni site to 22°C in Mian Gujar. In the same order other measured variables increased water conductivity, TDS, dissolved oxygen, and salinity as demonstrated in figure 2. The water pH in the river is changed in the opposite direction (Fig. 2). Therefore, the measured variable that fluctuated was salinity, and only pH was proto-opposite. This led us to assume that some processes in the river have a regular, not chaotic fluctuation.

Table 1: Physicochemical variables of water over sampling sites in Shah Alam River.

Parameter	Unit	Machni	Khazana	Mian Gujar
Number of site		1	2	3
Temperature	°C	18.30	20.44	22.27
pH		9.10	8.48	8.01
Electrical conductivity	µS/cm	417	552	768
Total dissolved solids	mg/l	208	276	384
Salinity	PSU	0.20	0.27	0.38
Dissolved oxygen	mg/l	34.1	47.4	85.2
Latitude		34.17096	34.09239	34.09021
Longitude		71.43341	71.61279	71.73102
Distance	km	0	21.3	10.8

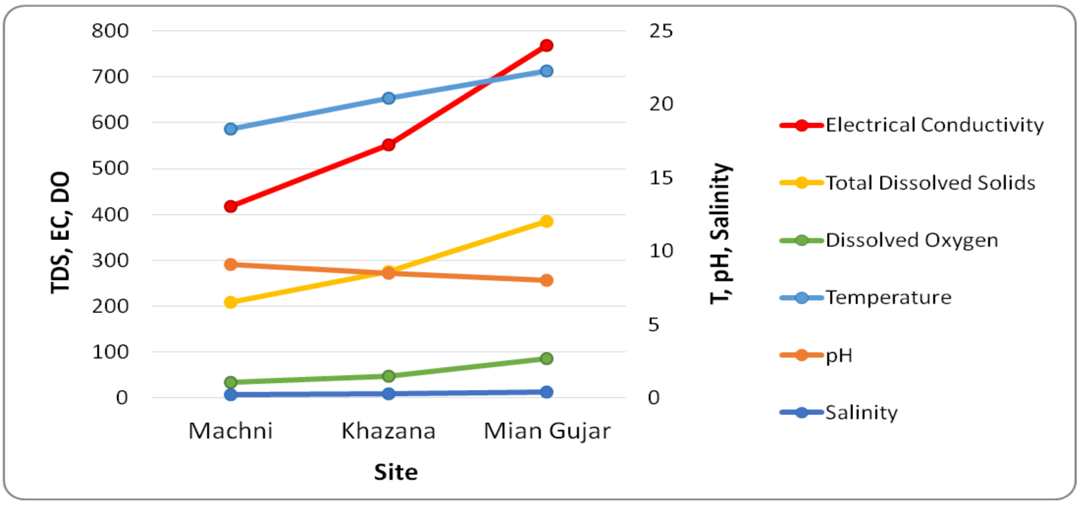

Figure 2: Dynamic of water pH, salinity, algal species richness and index saprobity S over sampling sites in the Shah Alam River; the units as in the upper table 1.

16 genera with 58 species of unicellular and filamentous green and charophyte algae were identified from the collected samples of the Shah Alam River (Tab. 2). The genera are *Chlamydomonas* with three species, *Chlorella* – one sp., *Chloroidium* – one sp., *Cladophora* – four sp., *Closterium* – five sp., *Cosmarium* – seven sp., *Hyalotheca* – one sp., *Microspora* – two sp., *Mougeotia* – four sp., *Mougeotiopsis* – one sp., *Oedogonium* – five sp., *Rhizoclonium* – two sp., *Pseudorhizoclonium* – one sp., *Schizomeris* – one sp., *Spirogyra* – 12 sp., *Temnogyra* – one sp., *Stigeoclonium* – two sp., *Uronema* – one sp. and *Zygnema* – four sp.

Table 2: Species diversity and autecology with a six-score scale frequency (Barinova et al., 2006) in sampling sites of the Shah Alam River; number of sites as in table 1.

Taxa	1	2	3	Hab	Oxy	pH	Sal	Sap	S	Tro
Chlorophyta										
Chlamydomonas angulosa Dill O.	0	2	3	P	st	–	–	o-a	1.80	–
Chlamydomonas globosa Snow J. W.	0	3	0	P, S	–	–	–	o-a	1.90	–
*Chlamydomonas sphagnicol*a (Fritsch F. E.) Fritsch F. E. and Takeda H.	2	0	2	–	–	–	–	o	1.20	–
Chlorella vulgaris Beyerinck	0	0	3	P-B, pb,S	–	–	hl	a	3.10	–
Chloroidium ellipsoideum (Gerneck) Darienko, Gustavs, Mudimu, Menendez, Schumann, Karsten, Friedl and Proschold	0	2	2	–	–	–	–	–	–	–
Cladophora fracta (Müller and Vahl O. F.) Kützing	5	5	4	P-B	st-str	–	–	b	2.30	–
Cladophora glomerata var. *glomerata* (Linnaeus) Kützing	5	5	5	P-B	st-str	alf	i	o-a	1.90	–
Cladophora glomerata var. *crassior* (Agardh C.) Hoek	5	3	0	–	–	–	–	–	–	–
Cladophora rivularis (Linnaeus) Hoek	0	4	3	–	–	–	–	–	–	–
Microspora amoena (Kützing) Rabenhorst	0	0	4	B	–	–	–	x-b	0.80	–
Oedogonium autumnale Wittrock ex Hirn	0	0	2	–	–	–	–	–	–	–
Oedogonium crassum Wittrock ex Hirn	2	3	1	–	–	–	–	–	–	–
Oedogonium intermedium Wittrock ex Hirn	0	3	0	–	–	–	–	–	–	–
Oedogonium minus Wittrock ex Hirn	0	4	2	–	–	–	–	–	–	–
Oedogonium multisporum Wood H. C. ex Hirn	2	0	0	–	–	–	–	–	–	–
Pseudorhizoclonium africanum (Kützing) Boedeker	1	0	3	–	–	–	–	–	–	–
Rhizoclonium crassipellitum West and West G. S.	1	0	3	–	–	–	–	–	–	–
Rhizoclonium fontanum Kützing	0	3	2	–	–	–	–	–	–	–
Schizomeris leibleinii Kützing	0	2	0	–	–	–	–	b-a	2.4	–
Stigeoclonium fasciculare var. *glomeratum* (Hazen) Islam A. K.	2	4	5	–	–	–	–	–	–	–
Stigeoclonium lubricum (Dillwyn) Kützing	2	3	3	–	–	–	–	b-a	2.5	–
Uronema elongatum Hodgetts	1	0	0	–	–	–	–	–	–	–

Table 2 (continued): Species diversity and autecology with a six-score scale frequency (Barinova et al., 2006) in sampling sites of the Shah Alam River; number of sites as in table 1.

Taxa	1	2	3	Hab	Oxy	pH	Sal	Sap	S	Tro
Charophyta										
Closterium acerosum Ehrenberg ex Ralfs	0	0	2	P-B	st-str	ind	i	a-o	2.60	e
Closterium lanceolatum Kützing ex Ralfs	1	4	2	B	st	ind	–	–	–	e
Closterium leibleinii Kützing ex Ralfs	0	2	2	P-B	st-str	ind	–	a-o	2.60	e
Closterium littorale Gay F.	0	3	0	P-B	–	ind	–	b-a	2.40	e
Closterium parvulum Nägeli	0	0	1	P-B	–	ind	i	b	2.00	m
Cosmarium botrytis Meneghini ex Ralfs	3	1	0	P-B	st-str	ind	i	o-a	1.90	m
Cosmarium granatum Brébisson ex Ralfs	0	5	0	B	st-str	ind	i	o	1.20	m
Cosmarium nitidulum De Notaris	2	0	0	–	–	acf	–	–	–	m
Cosmarium quadrifarium Lundell P.	0	2	1	–	–	acf	–	–	–	o
Cosmarium reniforme (Ralfs) Archer W.	0	0	1	P-B	st-str	ind	hb	o	1.00	me
Cosmarium subcrenatum Hantzsch	5	1	3	B, aer	aer	acf	–	o	1.10	m
Cosmarium subimpressulum Borge	0	2	0	–	–	acf	–	–	–	m
Hyalotheca mucosa Ralfs	0	0	2	P-B	–	acf	hb	–	–	o-m
Microspora stagnorum (Kützing) Lagerheim	0	2	3	B	st	–	–	b-o	1.60	–
Mougeotia capucina Agardh C.	0	0	2	B	–	–	–	o	1.00	–
Mougeotia genuflexa (Roth) Agardh C.	4	3	3	B	–	–	–	o-x	1.00	–
Mougeotia punctata (Wittrock) De Toni	2	3	3	B	–	–	–	o	1.00	–
Mougeotia robusta (De Bary) Wittrock	0	0	3	B	–	–	–	o	1.00	–
Mougeotiopsis calospora Palla	3	0	5	–	–	–	–	x-b	0.90	–
Spirogyra communis (Hassall) Kützing	3	5	4	B	st	–	–	b	2.0	–
Spirogyra crassa (Kützing) Kützing	3	2	0	B	–	–	–	o-b	1.5	–
Spirogyra daedalea f. *daedaloides* (Czurda) Poljansky V.	5	4	4	–	–	–	–	–	–	–
Spirogyra groenlandica Rosenvinge	4	0	3	–	–	–	–	–	–	–
Spirogyra pratensis Transeau	3	0	4	–	–	–	–	–	–	–
Spirogyra scrobiculata (Stockmayer) Czurda	2	5	2	–	–	–	–	–	–	–

Table 2 (continued): Species diversity and autecology with a six-score scale frequency (Barinova et al., 2006) in sampling sites of the Shah Alam River; number of sites as in table 1.

Taxa	1	2	3	Hab	Oxy	pH	Sal	Sap	S	Tro
Charophyta										
Spirogyra setiformis (Roth) Martens ex Meneghini	0	1	4	–	–	–	–	–	–	–
Spirogyra spreeiana Rabenhorst	5	0	0	–	–	–	–	–	–	–
Spirogyra tenuissima (Hassall) Kützing	3	3	2	B	–	–	–	o	1.1	–
Spirogyra tetrapla Transeau	0	2	1	–	–	–	–	–	–	–
Spirogyra varians (Hassall) Kützing	0	4	3	P-B	–	–	oh	b	2.1	–
Spirogyra weberi var. *grevilleana* (Hassal) Kirchner O.	0	2	3	–	–	–	–	–	–	–
Temnogyra punctiformis (Transeau) Yamagishi	0	2	4	–	–	–	–	–	–	–
Zygnema conspicuum (Hassall) Transeau	4	0	2	B	–	–	–	o	1.0	–
Zygnema cyanosporum Cleve	0	3	0	B	–	–	–	o	1.0	–
Zygnema pectinatum (Vaucher) Agardh C.	2	2	0	B	st-str	–	oh	o	1.0	–
Zygnema sterile Transeau	0	1	5	B	–	–	–	o	1.0	–
Total number of indicators	28	38	43	29	13	14	10	31	31	13

Note – table 2: Substrate preferences. (Habitat): P – planktonic, P-B – plankto-benthic, B – benthic, Ep – epiphyte, S – soil. Temperature preferences (Temp): cool – cool-water, temp – temperate, eterm – eurythermic, warm – warm-water. Oxygenation and streaming (Reo): st – standing water, str – streaming water, st-str – low streaming water, ae – aerophiles. Halobity degree according Hustedt (1938-1939) (Hal): hb – oligohalobes-halophobes, i – oligohalobes-indifferent, mh – mesohalobes, hl – halophiles. Acidity (pH) degree according Hustedt (1957): alb-alkalibiontes, alf – alkaliphiles, ind – indifferent, acf – acidophiles, neu – neutrophiles as a part of indifferents. Species-specific Index of Saprobity (S). Self-purification zone preferences (Sap): x – xenosaprob, x-o – xeno-oligosaprob, o-x – oligo-xenosaprob, x-b – xeno-beta-mesosaprob, o – oligosaprob, o-b – oligo-beta-msosaprob, b-o – beta-oligosaprob, o-a – oligo-alpha-mesosaprob, b – beta-mesosaprob, b-a – beta-alpha-mesosaprob, p-a – poly-alpha-mesosaprob, b-a – beta-alpha-mesosaprob, a – alpha-mesosaprob, a-o – alpha-oligosaprob. Saprobity degree according Watanabeet al. (1986) (D): sx – saproxen, es – eurosaprob, sp – saprophil. Nitrogen uptake metabolism (Aut-Het) (Van Dam et al., 1994): ats – nitrogen-autotrophic taxa, tolerating very small concentrations of organically bound nitrogen, ate – nitrogen-autotrophic taxa, tolerating elevated concentrations of organically bound nitrogen, hne – facultative nitrogen-heterotrophic taxa, needing periodically elevated concentrations of organically bound nitrogen, hce – obligatory nitrogen-heterotrophic taxa, needing continuously elevated concentrations of organically bound nitrogen. Trophic state (Tro) (Van Dam et al., 1994): ot – oligotraphentic, o-m – oligo-mesotraphentic, m – mesotraphentic, me – meso-eutraphentic, e – eutraphentic, o-e – oligo- to eutraphentic (hypereutraphentic). Class of water quality according EU scale.

Table 2 reveals that species richness as well as total abundance scores are increasing down the river from Machni to Mian Gujar. Charophyta prevails in species number and abundance (as sum of scores) significantly in each studied site (Tab. 3) in the same direction. But the proportion of species and abundance in each site for green and charophyte algae was the same – Charophyta 60%, and Chlorophyta 40% (Fig. 3).

Community structure changed down the river. In the upper Machni and Khazana sites the Charophyte species of *Spirogyra* and *Cosmarium* dominated. The algal community changed to domination of *Mougeotiopsis* and *Zygnema* also from Charophyta in lower Mian Gujar site. Green filamentous algae *Cladophora* were rich in all studied sites of the river.

Statistically calculated diversity indices were used for assessment of structural changes in algal communities over the studied sites in the Shah Alam River (Tabs. 4 and 5). Species richness was determined through Margalef index. Pielou's evenness index was used for species evenness. Species dominance was measured by using Simpson's index.

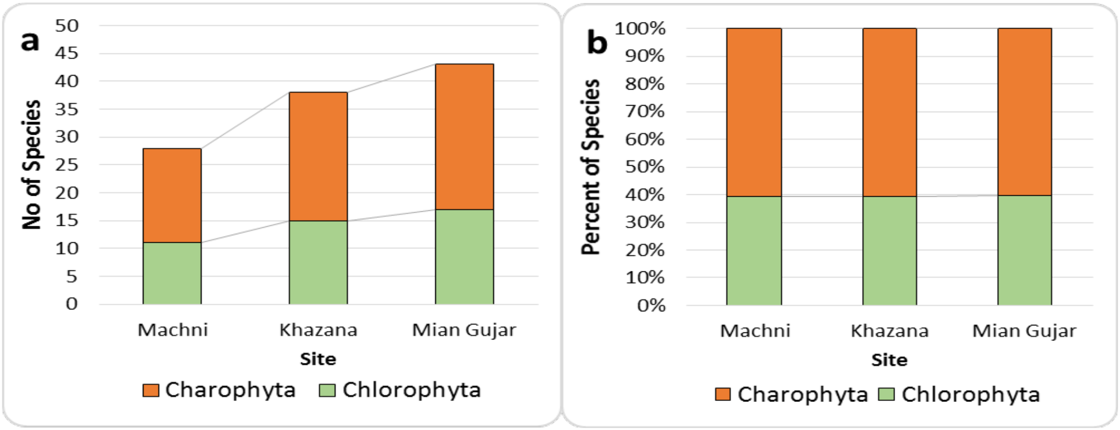

Figure 3: Distribution of Chlorophyta and Charophyta species richness over the sampling sites of the Shah Alam River. Species number (a), species percent (b).

Table 3: Distribution of species number, abundance, Chlorophyta and Charophyta species and genera over the Shah Alam River sampling sites.

Division	Species	Genera	Machni	Khazana	Mian Gujar
Chlorophyta	23	9	11	15	17
Charophyta	35	7	17	23	26
Total number of species	–	–	28	38	43
Total abundance scores	–	–	82	110	121

Table 4: Statistics of algal diversity of Shah Alam River over sampling sites.

No.	Statistics	Studied sites		
		Machni	Khazana	Mian Gujar
1.	Total number of taxa	58	58	58
2.	Number of taxa as sp. richness	28	38	43
3.	Mean	0.48	0.65	0.74
4.	Standard error	0.06	0.06	0.05
5.	Variance	0.25	0.22	0.19
6.	Standard deviation	0.50	0.47	0.44

Table 5: Ecological diversity indices of algal communities of the Shah Alam River over sampling sites.

No.	Indices	Studied sites		
		Machni	Khazana	Mian Gujar
1.	Margalef index	8.10	10.17	11.17
2.	Species Evenness	0.95	0.94	0.94
3.	Species Dominance	0.03	0.02	0.02
4.	Combined Ecological Diversity as Shannon index	3.33	3.63	3.76
5.	Index Saprobity S	1.48	1.73	1.57

We observed that community structure regularly changed in statistics variables. Species richness, mean, and Shannon index increased whereas species variance, standard deviation, evenness and dominance decreased down the river. Table 5 also included results of index saprobity S calculation that show fluctuation over the studied sites from Class 2 of Water Quality in upper Machni site to Class 3 in sites Khazana and Mian Gujar. Therefore, we observed that organic pollution in the Shah Alam River was not so large and major sources of pollution can be found in the middle part of the river where Index saprobity S = 1.73 was maxim. As illustrated in table 1 and figure 2, water variables changed regularly. We calculated Pearson coefficients for all measured environmental variables, algal species richness, and Index saprobity S. Only two coefficients show significant correlation. Water pH and salinity were strongly negatively correlated (– 0.98, $p < 0.05$), and also water pH and species richness (– 0.99, $p < 0.03$) were correlated negatively.

We assume that water pH was influenced not only by environmental parameters in the river but also impacted species composition in algal community.

Our calculation show increasing organic pollution in the Shah Alam River in comparison of the parallel flow part of the Kabul River (Barinova et al., 2016) where saprobity varied between 1.55 and 1.59 reflect Class 3 of Water Quality.

We analysed bioindicator species representation in each studied site as well as distribution of specific groups over river communities and between them. Table 2 and figure 4 shows that benthic species strongly prevail in all studied sites, but number of plankto-benthic and planktonic inhabitants was rich in the lower sites. Increasing ecological group indicators of low oxygenated waters reflects the slowing of the river flow and the decrease of dissolved oxygen in the water down the river.

Sufficient decreasing in water pH is reflected in alkaliphilic species and increasing of indicators of low alkaline waters (Fig. 4) down the river. Salinity indicators were diverse in the lower Mian Gujar site only. This means low saline waters over the whole river. Indication of organic pollution dynamic in studied sites with help of saprobity groups (Tab. 2) that combined in the Water Quality classes show increasing of Class 3 and Class 4 indicators down the river (Fig. 4) that can be assessed as increase of organic pollution.

Assessment of trophic state dynamic over the river sampling sites show (Fig. 4) increasing of eutrophic and meso-eutrophic indicators from Machni to Mian Gujar. Therefore, in the Shah Alam River, not only organic pollution increase was detected but also trophic state down the river flow.

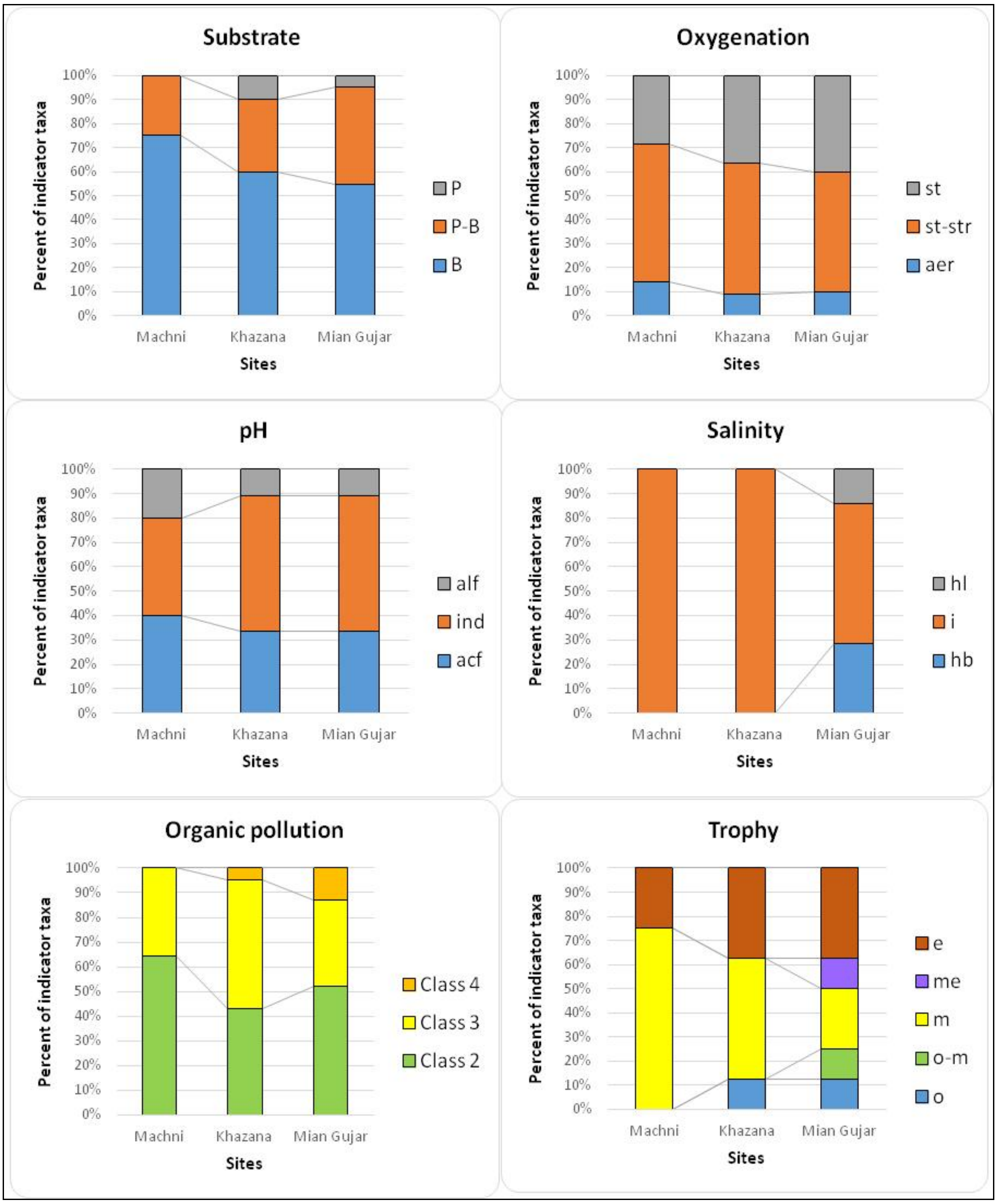

Figure 4: Distribution of indicator species in the ecological groups over the sampling sites of the Shah Alam River.
Classes of Water Quality in the Organic pollution plot are in EU colour code.
Abbreviations of ecological group as in table 2.

We compared community structure in studied sites with help of comparative floristic program GRAPHS. The dendrite in figure 5 shows that Mian Gujar community is the richest including two other site communities to more than 50% of species. It reflects high capacity of revealed algal flora to develop even under pollution stress in the Shah Alam River and community in Mian Gujar that can be marked as floristic core of the river algal diversity.

Dendrogram of community similarity (Fig. 6) revealed more similarity between two lower sites community than uppermost Machni site. This can point to changing environment properties in the studied river after Machni site.

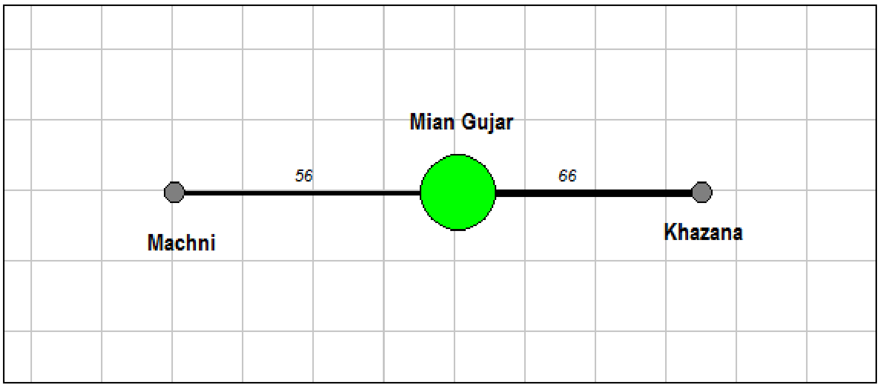

Figure 5: Dendrite of species richness overlapping in sampling sites communities of the Shah Alam River.

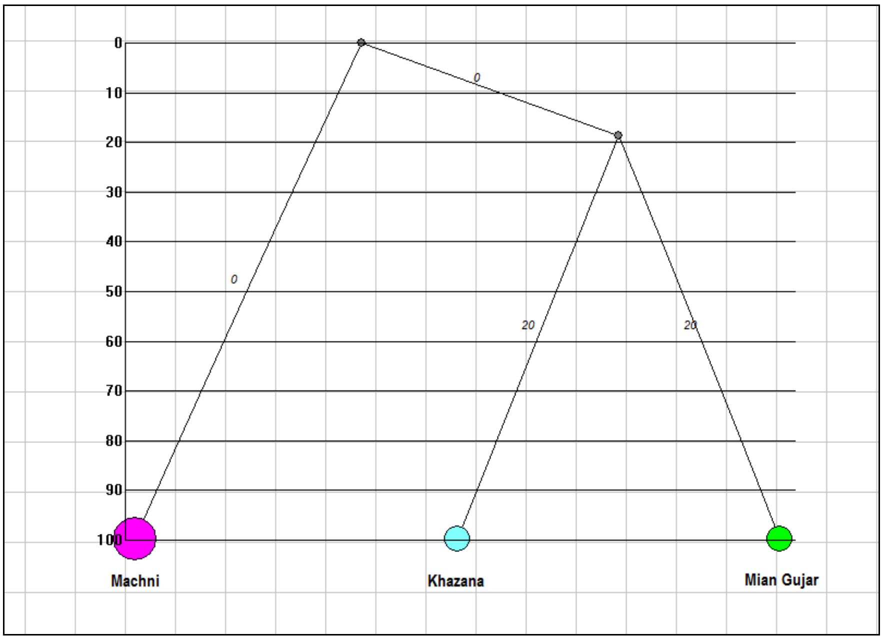

Figure 6: Dendrogram of species richness similarity for sampling sites communities of the Shah Alam River.

Figure 7 presents surface plots that have been generated statistically for revealing relationships of algal diversity and environmental variables in the Shah Alam River. Plots in figures 7a and 7b represent influences of water quality variables to species richness and show that the richest community can be developed in low TDS and low pH of water and preferred more saline water with low oxygenation. At the same time, the green algae that contain no more than 40% of species in each site survived better with the increasing water temperature and salinity, and decreasing of conductivity and dissolved oxygen (Figs. 7c and 7d). The charophytes, that prevail in community of each site, preferred lower TDS, pH and oxygen but increased with salinity increasing in the Shah Alam River (Figs. 7e and 7f).

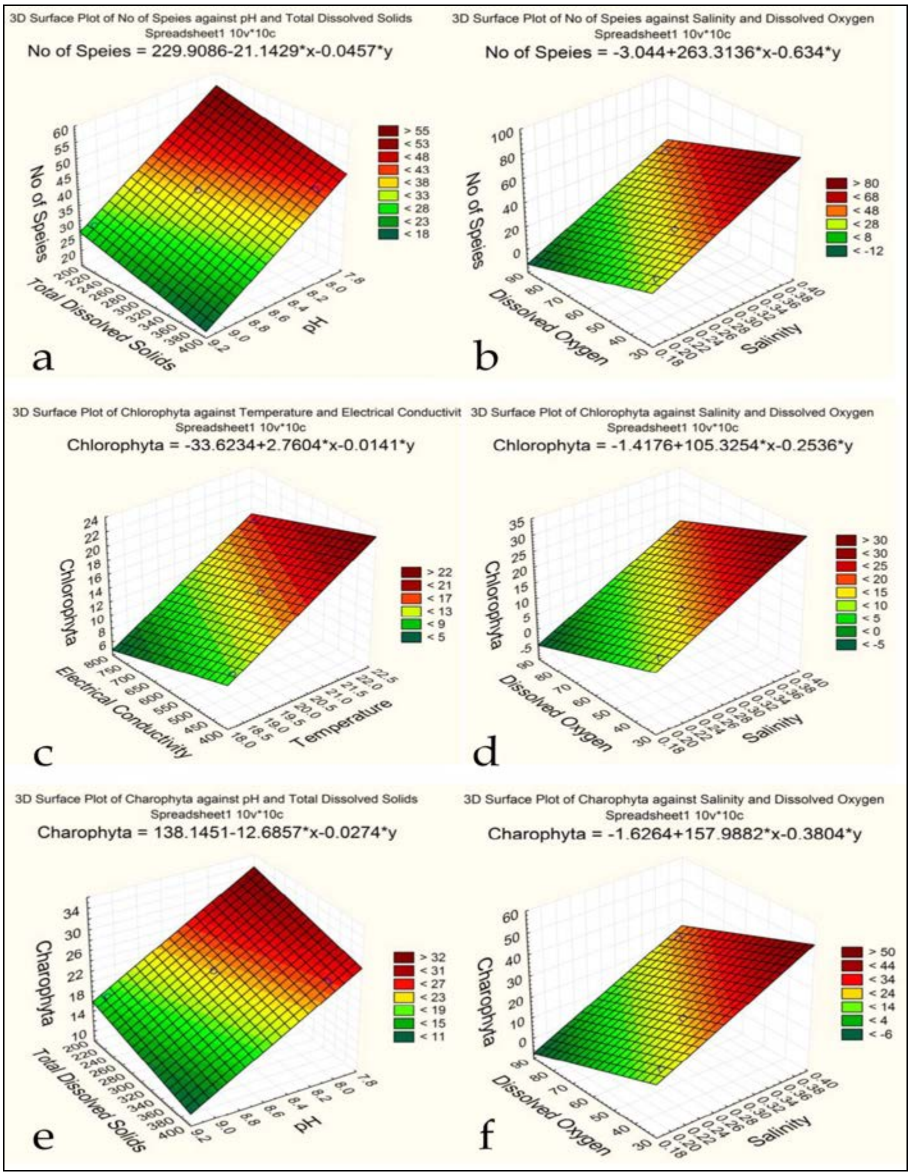

Figure 7: Statistical surface plots of species richness and environmental variables in the Shah Alam River.

The integral indices RPI (River Pollution Index) were calculated for the Shah Alam River (Tab. 6) as has been described previously (Khuram et al., 2017). We observed that the integral RPI for the Shah Alam River is similar to variables in the middle site Khazana. RPI index has been calculated earlier for the Kabul River main stream (Khuram et al., 2017) that flow in parallel with the Shah Alam River from Warsak to Syrdaryab sites. We compared the data about Kabul and Shah Alam rivers and calculated RPI for parallel stream Shah Alam including upper site Warsak in the Kabul River and site Syrdaryab that placed below the Mian Gujar site in the Shah Alam River. Total length of the river between Warsak and Sardaryab is 51.5 km. Total length of the river channel (across the studied sites of the Shah Alam River) between Warsak and Sardaryab is 51.5 km. The distance between Warsak and Machni is 10.15 km, while the distance from Machni to Khazana is 21.32 km. The distance from Khazana to Mian Gujar is 10.83 km, and between Mian Gujar and Sardaryab is 9.2. Second column in table 6 represents RPI calculation for the Shah Alam River including sites in the Kabul River. Comparisons show that environmental integral RPI and RPI for the Charophyta species richness were slightly lower in the Kabul River part including sites before and after the Shah Alam River than in studied river itself. Only total species richness RPI and RPI of Chlorophyta species number were greater in part with Kabul sites than in the Shah Alam River itself. Therefore, the calculation of RPI shows not only increasing water pollution in the Shah Alam River more than in the parallel Kabul River, but also a decreasing of total species richness, and a decrease in Chlorophyta in particular. RPI let us choose the Kazansa site as it reflects mean parameters of algal community and environment as reference for the whole Shah Alam River.

Table 6: River Pollution Indices (RPI) for variables of the Shah Alam River itself on the base of table 1 (first column) and with upper and lower stations of the parallel part of the Kabul River on the base of data according Khuram et al., 2017 (second column).

Variable	RPI Machni-Khazana-Mian Gujar	RPI Warsak-Machni-Khazana-Mian Gujar-Syrdaryab
Temperature	20.0	19.8
pH	8.6	8.4
EC	543.6	498.9
TDS	271.6	247.3
Salinity	0.3	0.29
Dissolved oxygen	49.4	42.9
Number of species	35.5	44.2
Chlorophyta species	14.0	26.4
Charophyta species	21.5	17.8
Abundance, sum of scores	102.6	–
Chlorophyta, sum of scores	40.2	–
Charophyta, sum of scores	62.4	–

CONCLUSIONS

The study of the diversity of algae in the Shah Alam River is still far from complete. Nevertheless, it revealed 58 algal taxa of species and subspecies levels which helped us characterize the changes in algal community under river pollution conditions.

We revealed that charophytes prevail in each of the three studied sites and contain 60% of community. Species richness, abundance as sum of scores, and community structure complexity increased down the river, whereas statistically calculated dominance decreased. Algal species-indicators of environment quality were revealed for seven ecological variables and demonstrated prevailing of benthic algae, but plankto-benthic and planktonic inhabitants enriched the community down the river. Diversity analysis showed that algal community in the Shah Alam River contained the green and charophytic algae. Community dominants changed from Cladophora-Spirogyra-Cosmarium at the upper site to Cladophora-Mougeotiopsis-Zygnema species down the river.

Bioindication method revealed that algal community in the river prefer low saline, low alkaline, middle streaming, and middle oxygenated water with low to middle organic pollution. The trophic state of the river waters was defined as eutrophic and meso-eutrophic and demonstrated that in the Shah Alam River not only organic pollution increased but also trophic state down the river. Major water variables that regulated the total species richness were TDS, oxygen and pH as negative, and salinity (as a part of organic pollution) as positive for species richness increasing. Whereas salinity stimulated the development of both green and charophyte algae, while the water temperature was stimulating for greens. The richest community in the lower site of Mian Gujar can be chosen as the floristic core of algal flora of the Shah Alam River. The statistical comparison revealed that environmental impact to the river algal community starts after Machni site, in Khazana site with increasing water pollution which then self-purifies in the Mian Gujar site.

River Pollution Indices (RPI) demonstrated increasing pollution in the Shah Alam River in comparison with the parallel part of the Kabul River main stream and led us to choose the Khazana site as reference for whole Shah Alam River for future monitoring.

Therefore, these results can confirm the effectiveness of bioindication methods for water quality assessment in the Kabul River basin as well as its effectiveness for future use including the water monitoring in Pakistan.

ACKNOWLEDGEMENTS

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HABITAT PREFERENCE OF PHAEOPHYCEAE SPECIES: *IYENGARIA STELLATA* (BØRGESEN) BØRGESEN (1939) IN GUJARAT COAST (INDIA)

Dimpal SANGHVI *, *Nandini Ray CHAUDHURY* ** and *Bhanukumar JAIN* **

* Mafatlal Gagalal Science Institute, Department of Botany, Navarangpura, Ahmedabad, Gujarat, India, IN-300009, dimpalsanghvi@gmail.com

** Space Applications Centre, Indian Space Research Organisation, Jodhpur Tekra, Ambavadi Vistar, Ahmedabad, Gujarat, India, IN-380015, nandinirc@sac.isro.gov.in, bkjain_mgsc@yahoo.com

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KEYWORDS: Macroalgae, variation, growth, habitat, shore platform, reef flat.

ABSTRACT

Many species of phaeophyta are found at Dwarka and at the Bet-Shankhodhar coast, Gujarat, India. For the study of *Iyengaria stellata*, the shore platform and reef flat were divided into three sections: Dwarka in i) North, ii) Centre and iii) South sections and Bet-Shankhodhar in i) West, ii) Centre and iii) East sections. *I. stellata* was monitored based on systematic random sampling for two years (April, 2013 to February, 2015). In the months of December and February, *I. stellata* was recorded with high frequencies of reef, flat zones and shore platforms. When compared to shore platform, the frequency of *I. stallata* was highest in coral reef and flat zones. This study supports that reef flat is very suitable for growth of *I. stellata*. *I. stellata*'s growth cycle corresponds with local winter season.

ZUSAMMENFASSUNG: Habitat Präferenzen der Braunalgen-Phaeophyceae-Art *Iyengaria stellata* (Børgesen) Børgesen (1939) an der Gujarat Küste (Indien).

An der Dwarka und der Bet-Shankhodhar Küste, Gujarat, Indien wurden zahlreiche Braunalgenarten festgestellt. Für die Untersuchungen betreffend die Braunalge *Iyengaria stellata*, wurde die Küstenplattform und die Riff Flächen in drei Abschnitte eingeteilt: Dwarka in einen i) nördlichen, ii) zentralen und iii) einen südlichen und Bet-Shankhodhar in i) einen westlichen, ii) einen zentralen und iii) einen östlichen Abschnitt. *I. stellata* wurde mit Hilfe systematischer Stichproben verteilt über zwei Jahre – von April 2013 bis February 2015 – untersucht. Die Art wurde jeweils mit hoher Frequenz während der Monate Dezember und Februar in den Bereichen der Riffniederungen und dem Küstensockel festgestellt. Die höchste Frequenz von *I. stellata* wurde im Vergleich zum Küstensockel in den Flächen der Korallenriffe festgestellt. Die Untersuchung unterstützt die Annahme, dass die Flächen des Riffs für die Entwicklung von *I. stellata* sehr geeignet sind. Der Wachstumszyklus dieser Art entspricht der lokalen Winterzeit.

REZUMAT: Preferințele de habitat a speciei de algă brună *Iyengaria stellata* (Børgesen) Børgesen (1939), Phaeophyceae, pe coasta Gujarat (India).

În sectoarele de coastă Dwarka și Bet-Shankhodhar din zona costieră Gujarat, India, au fost găsite numeroase specii de alge brune. Pentru studiul speciei *Iyengaria stellata*, platforma costieră și câmpul recifelor a fost divizat în trei secțiuni: Dwarka într-o secțiune i) nordică, ii) centrală și iii) sudică și Bet-Shankhodhar într-o secțiune i) vestică, ii) centrală și iii) estică. *I. stellata* a fost studiată cu ajutorul unor probe de sondaj sistematic pe o perioadă de doi ani (din aprilie 2013 până în februarie 2015). Specia *I. stellata* a fost găsită cu frecvență mare în luna decembrie și februarie în zona câmpului recifelor, și a platformei costiere. Frecvența cea mai mare a speciei a fost găsită în câmpul recifului coralier față de cea a platformei costiere. Acest studiu confirmă că întinderea recifelor este foarte favorabilă pentru dezvoltarea speciei *I. stellata*, ciclul ei de creștere corespunzând sezonului local de iarnă.

INTRODUCTION

Algae are relatively simple photosynthetic plants with unicellular reproductive structures; they range from unicellular organisms to non-vascular filamentous or thalloid plants (Thahira, 2011).

Seaweeds (macroalgae) are large algae that grow in the marine environment and lack true stems, roots and leaves; they commonly grow on coral reefs, in rocky landscape or at significant depth if sunlight can penetrate through the water above. Most of the seaweeds can be seen thriving in underwater beds floating along the sea surface attached to rocks. (Thahira, 2011)

Seaweeds are biologically and ecologically important in the marine ecosystems. They make a substantial contribution to marine primary production and provide habitat for near shore benthic communities. Seaweeds are key space occupiers of rocky shore and interact with other organisms; hence, they play a key role in overall coastal biodiversity (Satheesh and Wesley, 2012). Seaweeds are well known and have been used since ancient times as food, fodder, fertilizer and also a source of medicinal drugs; today seaweeds are the raw material for industrial production of agar, algin and carrageenan (Manivannan et al., 2009).

Chlorophyta, Phaeophyta and Rhodophyta are major groups of seaweeds. These groups are recognized according to their pigments that absorb light of a particular wavelength which in turn, gives them their characteristic colour of green, brown and red. Out of these three, brown algae (Phaeophyta) are multi-cellular and are found in a variety of different physical forms including crusts and filaments. They contain green pigment such as chlorophyll, brown pigment like fucoxanthin, and gold pigment. (Thahira, 2011)

Numerous species of phaeophyta are found at Dwarka and Bet-Shankhodhar coast in Gujarat, India. *Iyengaria stellata* has looked very different compared to other species of phaeophyta. It has a dark brown, multi-cellular and semi-stellate, spongy and hollow thallus with hollow projections. *Iyengaria stellata* possess pronounced antidepressant and an anxiolytic property (Bushra et al., 2014). Chronic administration of *Iyengaria stellata* yields stimulant effects on hematopoietic system which is very beneficial (Bushra et al., 2014). It has been found to have less density and growth on Dwarka coast, in the shore platform area, and high density and growth in Bet-Shankhodhar coast, in the reef flat area.

The present study concentrates on spatial and seasonal variations of seaweed of *Iyengaria stellata* (Børgesen) Børgesen, brown alga on Dwarka and Bet-Shankhodhar (or Bet-Dwarka) coast, Gujarat, India.

It was carried out with the following principal objectives: to study the spatial variation of *I. stellata* in Dwarka and Bet-Shankhodhar; to study the temporal variation of *I. stellata* in Dwarka and Bet-Shankhodhar; to record the stages of growth of *I. stellata* with respect to the sampling seasons.

MATERIALS AND METHODS

Study area

For the seaweeds' growth, the geographical, geological, topographical and physical nature of the shore is very important. The rocky and coral reef coasts provide a good platform and stable coastal environments compared to that of soft sediment coasts such as beaches and spits. Shore platform and coral reef represent a case environment where the majority of seaweeds grow with a firm substratum attachment.

The Gujarat coast of India represents the north-western most part of the peninsular India. This coastline occurs within the geographical limits of 20°00'-24°45'N and 68°00'-78°30'E. It is 1,650 km long with 164,200 km^2 continental shelf (Jha et al., 2009). It extends in the form of four major coastal ecologic components: i) Kori creek ii) Gulf of Kachchh iii) Saurashtra coast from Okha to Porbandar and iv) Gulf of Khambhat.

The substratum is rocky in many parts, which provides suitable environment for macroalgae growth (Chakraborty and Bhattacharya, 2012).

The Saurashtra coast, which runs for an approximate length of 985 km, is characterized by rocky, sandy and muddy intertidal zones, harbouring rich and varied flora and fauna (Gohil and Kundu, 2012). The Gulf of Kachchh (GoK) is the largest coastal habitat in the Gujarat coastal area and contains 42 islands (Jha et al., 2009). It has an approximate length of 1,000 km and is delimited in the north by the Kachchh region and in the south by the Saurashtra region. The Marine National Park and Marine Sanctuary are situated along the southern shore of the Gulf from Okha and extends eastwards to the vicinity of Khijadia. The islands are fringed with corals, mangroves, mudflats, sandflats, coastal salt marsh, sand and rocky beaches which support great diversity of flora and fauna. (Jha et al., 2009; *, http://www.annauniv.edu/iom/iomour/EIA's%20gujarat.htm)

The present study was carried out on the shore platform of Dwarka, located on the Suarashtra coast and the coral reef adjacent to Bet-Shankhodhar Island, located on the Kachchh Gulf, to study *Iyengaria stellata* (Fig. 1). This is about five km north of the mainland of Okhamandal and to the east of Okha port (Fig. 2). Bet-Shankhodhar Island is also known as Bet-Dwarka. The eastern part of the island is comprised of sand-hills and bushes and is known as Hanumandandi point. On this island, 28 hectares' areas were covered by the coral reefs. (Satyanarayana Ramakrishna, 2009)

Geographical location and total area of study sites are given in table 1.

Table 1: Details of area of the study sites Dwarka and Bet-Shankhodhar.

Sr. no.	Sites	Geographical location		Total study area		
		Latitude	Longitude	Length (m)	Maximum width (m)	Surface area (m^2)
1	Dwarka	22˚14'22"N to 22˚14'38"N	68˚57'15"E to 68˚57'25"E	572.28	143.8	82,293.86
2	Bet-Shankhodhar	22˚28'14"N to 22˚28'56"N	68˚06'17"E to 68˚09'76"E	1606.45	338.5	543,783.33

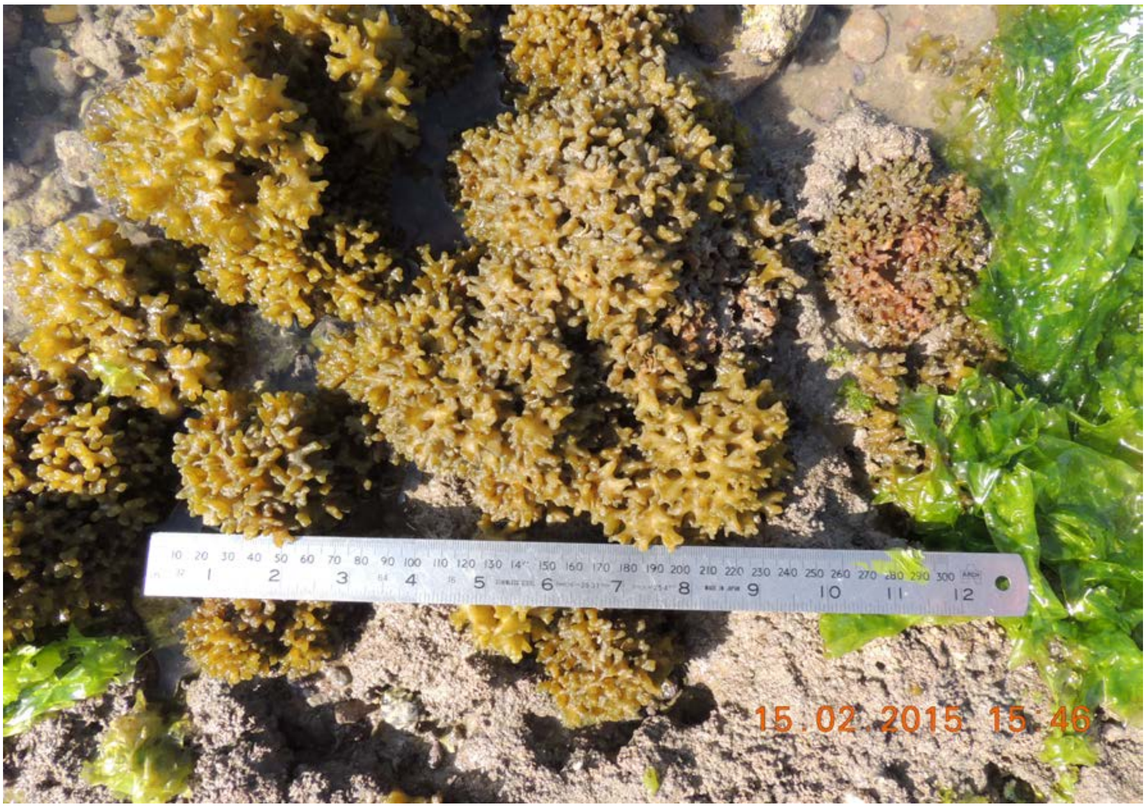

Figure 1: *Iyengaria stellata*.

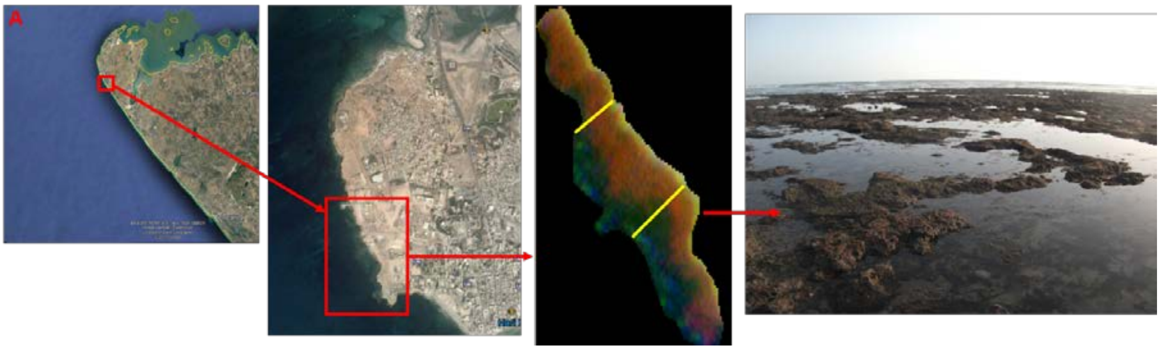

Figure 2a: Shore Platform, Dwarka.

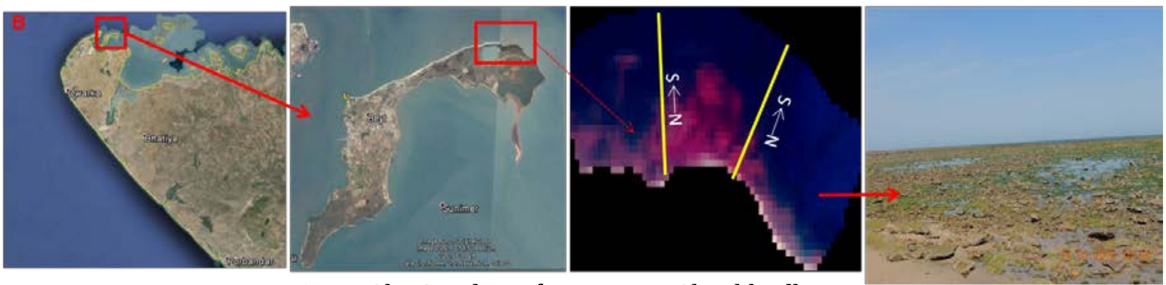

Figure 2b: Coral Reef Zone, Bet-Shankhodhar.

Field data collection

For the study of *I. stellata*, the shore platform of Dwarka was divided into three sections (in North-South direction): i) Northern, ii) Central, and iii) Southern; Bet-Shankhodhar was also divided into three sections (in East-West direction): i) Western ii) Central, and iii) Eastern for convenience of field sampling. Field sampling of seaweeds was done from April, 2013 to February, 2015 (April, June, October, and December, 2013; December, 2014, and February, 2015). Field survey and/or sampling were performed during the low tides. For qualitative and quantitative assessment, the GPS (Spheroid and Datum: WGS 84) tagged line transect.

Maximum and minimum transect length survey and maximum depth of the subtidal zone sampled for macroalgae are given in table 2 for Dwarka and Bet-Shankhodhar. Length of transect lines depended on the tidal exposure of the shore platform during the field surveys.

Table 1: Information about transect length and depth of subtidal zone of Dwarka and Bet-Shakhodhar.

Sr. no.	Study site	Maximum transect length (m)	Minimum transect length (m)	Maximum depth of the subtidal zone
1	Dwarka Coast	143.8	24	0.5
2	Bet-Shankhodhar Coast	338.5	52	1

For quantitative assessment of the *I. stellata* in the given area, line transects was laid perpendicular to the coast from land to sea with the help of a long rope (50 m) (Dhargalkar and Kavlekar, 2004). A sampling point along the rope is marked depending on the gradient and exposure of intertidal and subtidal areas. In Saurashtra coast, the tidal amplitude is very high as compared to other parts of the western coast and the entire east coast of India (Jha et al., 2009). Growth of seaweeds in intertidal and shallow subtidal regions can be easily observed in this area as the spring tides expose the intertidal area up to a maximum length of one km (Jha et al., 2009). Each of the three sections at Dwarka and Bet-Shankhodhar were represented by one transect line and quadrates of one m^2 were positioned on the transect lines. Wherever the algae growth, density and diversity were high (Tab. 3). GPS tagged photos of quadrates were taken for further analysis. Seaweeds present within the quadrates were sampled. All specimens were identified and the specific numbers of individuals were registered for quantitative assessment of frequency.

Table 2: Total transects lines and quadrates on study sites.

Sr. no.	Study sites	Total transect Lines	Total quadrates
1	Dwarka Coast	18	111
2	Bet-Shankhodhar Coast	13	83

Field data analysis

For the study of *I. stellata*, collected seaweeds samples from the field were taken to the laboratory for preparation of herbarium sheets and specimen identification. Morphological criteria were analysed for taxa identification. To understand their spatial variation, quadrate data was analysed and were graphically represented as cross profile on shore platform and coral reef with embedded bar charts showing frequency of different months. Frequency of *I. stellata* encountered at the transect intercepts is represented as bar charts. X-axis of the bar chart represents in which months and sections *I. stellata* present while Y-axis shows their respective frequencies (in percentage) (Figs. 2 and 3).

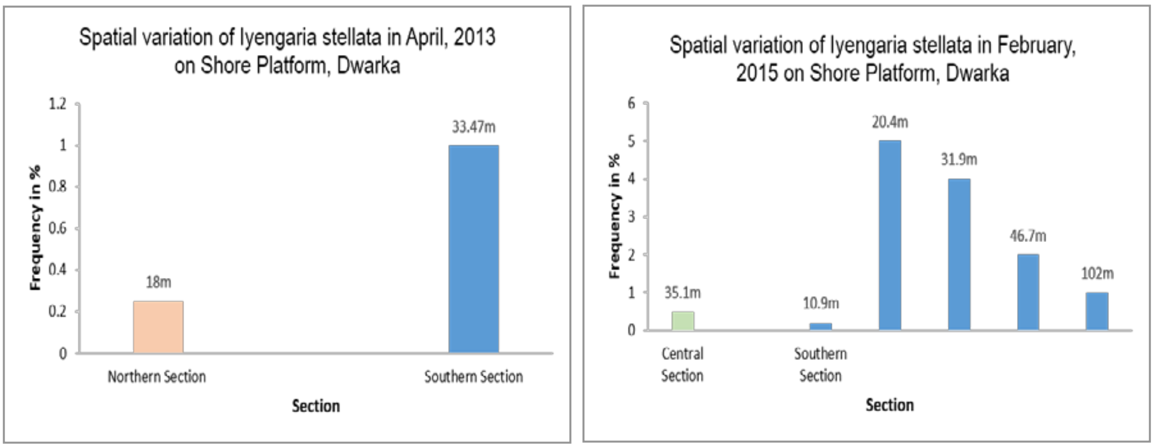

Figure 2: Spatial variation of *I. stellata* on Shore Platform, Dwarka.

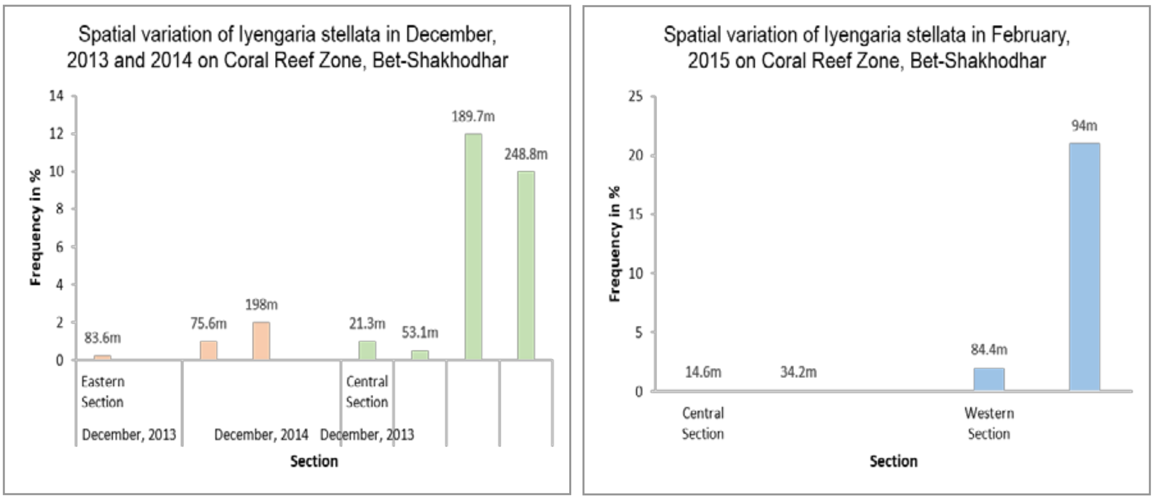

Figure 3: Spatial variation of *I. stellata* on Coral Reef Zone, Bet-Shankhodhar.

RESULTS AND DISCUSSION

Shore platform and coral reef zones

From the field data, it emerged that the shore platform and coral reef flat can be divided into three zones (in North-South direction and East-West direction respectively) based on areas the groups of seaweed were observed. The shore platform and reef flat can be divided into: i) cliff base part, ii) an intertidal mixed zone, and iii) a subtidal zone from the land to the sea. In shore platform, it was found that phaeophyta in rock pools (these pools were found in less numbers in the northern section) dominate the cliff base zone. The cliff base is followed by a mixed intertidal area, where there is a transition from phaeophyta (dominant in the intertidal zone) to chlorophyta (dominant in the subtidal zone). The subtidal zone dominated by chlorophyta, is found at the seafront.

In the case of coral reef flat, it was found that phaeophyta dominates in land front and chlorophyta and rhodophyta is dominated in subtidal zone. The intertidal zone is again a mixed zone (followed phaeophyta to chlorophyta and rhodophyta).

Spatial variation of *I. stellata*

As discussed the shore platform and coral reef flats were divided into three sections for the convenience of field sampling: the results are reported here section wise.

Shore platform: Dwarka

Northern section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February, 2015) of field survey are represented in table 4 and figure 2. During April, 2013 profile *I. stellata* was recorded at 18 m with 25% frequency. In other months *I. stellata* was not detected in northern section.

Central section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February, 2015) of field survey are represented in table 4 and figure 2. During February, 2015 profile *I. stellata* was observed at 35.1 m with 0.5% frequency. In other months *I. stellata* was not detected in the central section.

Southern section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February, 2015) of field survey are represented in table 4 and figure 2. During April, 2013 profile *I. stellata* was found at 33.47 m with 1% frequency. In February profile *I. stellata* was recorded at 10.9 m (0.2%), 20.4 m (5%), 31.9 m (4%), 46.7 m (2%), 102 m (1%). In February profile, frequency was increased at 10.9 m to 20.4 m and at 31.9 m to 102 m, frequency got decreased. In other months *I. stellata* was not detected in the southern section. *I. stellata* was found highest in the southern section.

Coral reef zone: Bet-Shankhodhar

Western section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February 2015) of field survey are showed in table 4 and figure 3. During February profile *I. stellata* was observed at 84.4 m (2%) and 94 m (21%) with increased frequency. In the months April and June, *I. stellata* was not recorded; data was not available for October and December months. In western section *I. stellata* was recorded with highest frequency.

Central section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February, 2015) of field survey are represented in table 4 and figure 3. During December, 2013 profile *I. stellata* was found at 21.3 m and 53.1 m with less frequency and at 189.7 m and 248.8 m, it was recorded with high frequency. In February, *I. stellata* was recorded at 14.6 m and 34.2 m (0.1%) with same frequency. Data was not seen in December, 2014 and in other months, *I. stellata* was not present.

Eastern section

Transect and quadrate data sampled for *I. stellata* during two years (April, 2013 to February, 2015) of field survey are represented in table 4 and figure 3. In December, 2013 profile *I. stellata* was recorded at 83.6 m with 0.25% frequency and in December, 2014 *I. stellata* was recorded at 75.6 m and 198 m with 1% and 2% frequency respectively. In April, June and October, *I. stellata* was absent and in February, data was not available.

Table 4: Frequency of *I. stellata* based on line transects and quadrate survey on the shore platform, Dwarka and coral reef zone, Bet-Shankhodhar.

Study sites	Month	Sections	Frequency (%)	Quadrate Distance on transects (m)
Dwarka	April, 2013	Northern section	0.25	18
		Southern section	1	33.47
	February, 2015	Central section	0.5	35.1
		Southern section	0.2	10.9
			5	20.4
			4	31.9
			2	46.7
			1	102
Bet-Shankhodhar	December, 2013	Eastern section	0.25	83.6
	December, 2014		–	–
			1	75.6
			2	198
	December, 2013	Central section	1	21.3
			0.5	53.1
			12	189.7
			10	248.8
	February, 2015	Central section	0.1	14.6
			0.1	34.2
		Western section	2	84.4
			21	94

Temporal variation of *I. stellata*

Temporal variation of *I. stellata* in the three sections of shore platform, Dwarka are presented in table 4 and figure 4. In the northern section, a total of twenty-nine quadrates were studied in the six sampling months, while in the central section thirty-eight quadrates were studied and for the southern section forty-four were studied. In the northern and central sections *I. stellata* was found highest in April and was highest in the southern section in February. On shore platform *I. stellata* was highly recorded in the February, while during in June to November it was absent.

Temporal variation of *I. stellata* in section three of coral reef zone, Bet-Shankhodhar is presented in table 4 and also in figure 4. In eastern section, total thirty-one quadrates were studied in the six sampling months, while in central section thirty-four quadrates were studied and for western section eighteen were studied. In central section *I. stellata* was found with highest values in December and in western section in February. *I. stellata* was absent from June to October. So, we found that *I. stellata* grows during January to February.

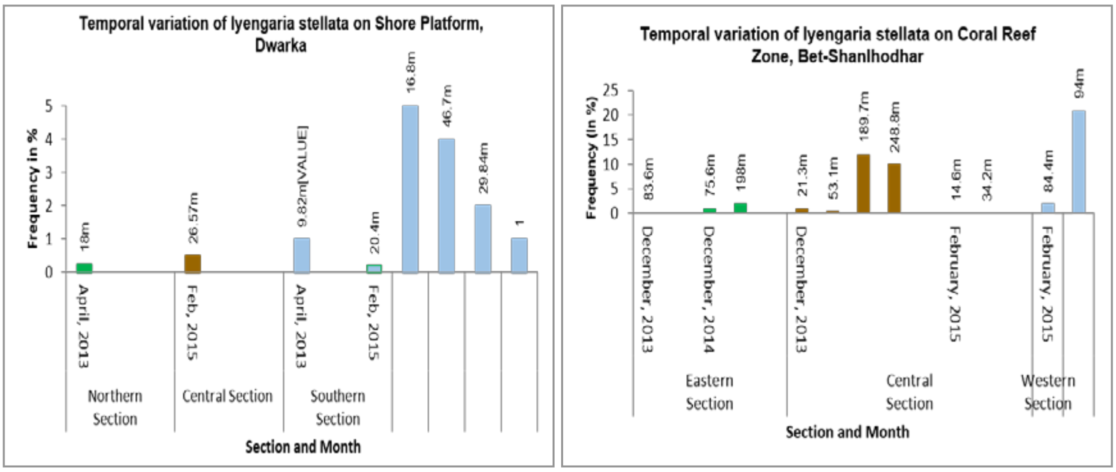

Figure 4: Temporal variation of *I. stellata* on Shor platform, Dwarka and coral reef zone, Bet-Shankhodhar.

Stage of growth of *I. stellata*

On the shore platform of Dwarka and reef flat zone of Bet-Shankhodhar, the occurrence of *I. stellata* was noted during six sampling months. Out of these six months, *I. stellata* was only found between December to April. The highest frequency was recorded in February and *I. stellata* decreased in April.

The present study shows the presence of *I. stellata* from December to April and growth in full phase in February on the shore platform. On reef flat zone *I. stellata* was present in November-March period growing in full phase in January and February. Density of *I. stellata* was higher in reef flat of Bet-Shankhodhar as compared to shore platform of Dwarka.

Numerous researchers have studied the distribution of marine macroalgae on seasons in India. They researched seasonal variation of macroalgae in the east and west coasts but not the *I. stellata* growth cycle. Usmanghani et al. (1987) has worked on the sterols of a brown seaweed *I. stellata* from Pakistan. They were studied for sterol composition of *I. stellata*; they found two sterols (ergosterol and cholesterol) for the first time from brown seaweed. Bushra et al. (2014) has studied an evaluation of nephrotoxic potential of *I. stellata*. The species was very effective on renal function. They gave one dose every thirty days of *I. stellate* to rabbits and the level of urea and creatinine measured showed an increased level of urea after continued administration of *I. stellate*. *I. stellata* has nephroprotective effect.

Kesava Roa and Singbal (1995) have worked on the seasonal variation in halides and their ratio were estimated in three marine brown algae, namely *Cystoseira indica* (Thivy and Doshi) Mairh, *Sargassum tenerrimum* Agardh J. G. and *Sargassum johnstonii* Setchell and Gardner from Porbandar and Okha coasts (NW coast of India). Halides were found higher in early stages of growth in this study. This study showed Br: F (Bromine: Fluoride) ratio was higher in the reproductive stage indicating that algae tend to accumulate Br compared to F during this stage than at early and senescent stages, though Br level in ambient medium is not a limiting factors. Bhanderi and Trivedi (1975) have worked on the seaweed resources of Hanumandandi Reef and Vumani Reef near Okha Port, Gujarat. This study computed quantities of seaweeds peak periods of the growth and projected twice proper for harvesting of each economic seaweed. In this study, edible seaweeds, the two species of genus Ulva, i.e. *Ulva lactuca* Linnaeus and *Ulva fasciata* Delile, were available in maximum quantity in different months on Hanumandandi reef, while on Vumani reef. Only *U. fasciata* was available throughout the season and the maximum availability was 9.077 tons in February, 1974. The peak period of growth was observed during October, 1973 and February, 1974 on Vumani Reef while it was only observed in March, 1974 on Hanumandandi reef. Agarophytes and iodine-yielding algae were less on both the reefs as compared to the edible seaweeds. Maximum availability of agarophytes was estimated in January, 1974 on Hanumandandi reef. On Vumani reef, different agarophytes species showed peak growth in different months. Iodine-yielding plants were observed maximum on both reefs in December, 1993.

This study reports seasonal, temporal and growth stages of *I. stellata* on the basis of systematic field inventory. This kind of study, when done on routine annual basis, can bring out the variability on spatial and temporal/seasonal province for the study area. Additionally, same species have been spotted and identify on paga and pirotan.

CONCLUSIONS

This study shows the frequency of *I. stellata* is high on reef flat zone as compared to shore platform. Reef flat zone is very suitable for growth of *I. stellata*. Its growth cycle is in the winter. This study is to help further studies about *I. stellate*, because it is an important species for extraction of two type of sterols used for pharmaceutic/medicinal purposes.

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FACTORS THAT DETERMINE THE ADOPTION OF SCIENTIFIC INDICATORS IN COMMUNITY-BASED MONITORING OF MANGROVE ECOSYSTEMS IN TANZANIA

*Daniel SABAI **

* University of Dar es Salaam, Faculty of Humanities and Social Sciences, College of Education, Geography and Economics Department, P. O. Box 2329, Dar es Salaam, dosabai@yahoo.co.uk

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KEYWORDS: mangroves, monitoring, indicators, learning, knowledge.

ABSTRACT

This article reveals factors that need to be considered by facilitating institutions and organisations prior to adoption of scientific indicators in community-based monitoring of mangrove ecosystems; as a necessary route towards achieving effective participation and meaningful experiential learning processes. It employs an Experiential Learning Intervention Workshop (ELIW) as a key methodological tool and a useful space for analysing conditions that are necessary for adoption of scientific frameworks in the Tanzanian coastal area. ELIW also offers an opportunity for local people to share knowledge and decide the kind of input required for monitoring mangroves and fisheries.

RÉSUMÉ: Facteurs déterminant l'adoption des indicateurs scientifiques dans la surveillance communautaire des écosystèmes des mangroves de Tanzanie.

Cet article montre les facteurs à prendre en compte par les institutions et les organisations faciliter avant l'adoption des indicateurs scientifiques dans l'adoption communautaire des écosystèmes des mangroves, un parcours nécessaire pour l'obtention d'une participation efficace et des processus d'apprentissage d'expériences utiles. Il utilise un Atelier d'Intervention pour l'Apprentissage d'Experiences (ELIW) en tant qu'instrument méthodologique clé et d'espace utile pour l'analyse des conditions nécessaires à l'adoption des cadres scientifiques pour la zone côtière tanzanienne. ELIW offre aussi l'opportunités aux habitant locaux de partager leurs connaissances et à décider quelles sont les ajouts nécessaire pour la surveillance des mangroves et la pêche.

REZUMAT: Factori determinanți în adoptarea indicatorilor științifici în monitorizarea comunitară a ecosistemelor de mangrove din Tanzania.

Lucrarea de față indică factorii ce trebuie să fie luați în considerare de instituțiile și organizațiile facilitatoare înainte de adoptarea indicatorilor științifici pentru monitorizarea comunitară a ecosistemelor de mangrove, parcurs necesar pentru o participare eficientă și pentru obținerea unor procese de învățare din experiență care să aibă sens. Lucrarea a folosit rezultatele Atelierului de Intervenție pentru Învățare prin Experiență Practică (ELIW) folosit ca instrument metodologic cheie și spațiu util de analiză a condițiilor necesare pentru adoptarea cadrelor de lucru științifice în zona de coastă a Tanzaniei. ELIW oferă și posibilitatea localnicilor de a-și pune în comun cunoștințele și a decide ce fel de informații sunt necesare pentru monitorizarea mangrovelor și zonelor de pescuit.

INTRODUCTION

Mangroves are salt-tolerant plant species that grow in intertidal coastlines in sub-tropics and tropics, serving as habitats for biological diversity and nurseries for fish resources (Tomlison, 1994; IUCN, 2006; Aluri, 2013). They play significant ecological roles, including carbon sequestration, pollutants filtration, hydrological cycle, coastal protection against soil erosion, flood control, and expansion of coastal land by trapping sediments and binding them together as part of the coastal landmass (Mazda et al., 2002; Aziz and Hashim, 2011; Lee et al., 2014). Mangroves also serve as a source of income for coastal people and a space for social functions and practices (UNEP, 2014).

In the last 25 years, there were observed intentional actions of coastal countries, principally low income states, to engage local communities in participatory monitoring of coastal and marine resources such as mangroves, fisheries, coral reefs, seagrass and coastal land on social, economic, and ecological grounds. (NICEMS, 2003; Wagner, 2005)

Community-based mangrove ecosystem monitoring has been successfully conducted in other countries, including India and Sri Lanka (Datta et al., 2010; IUCN, 2011) and in the Philippines (Daupan, 2016). Top, post-2004 Indian Ocean tsunami mangrove rehabilitation efforts in Thailand clearly demonstrated multi-generation community involvement together with strong "social capital" building on existing mangrove dependency like fishing (Paphavasit et al., 2008) and will typically underachieve or fail if real local participation is lacking (Soegiarto, 2008). The International Union for Conservation of Nature (2008) reports very successful multi-sector, post 2004 tsunami community participation (women, students, children, scientists and international volunteers) in a Maldives coastal rehabilitation project featuring mangroves.

Efforts have also been made to provide an overview of key processes and directives on the right approaches and procedures that may help communities to improve mangrove management initiatives and encourage active participation (Schmitt and Duke, 2015). A call has also been made to encourage various countries to decentralize mangrove management initiatives as a necessary element of sustainability (Datta et al., 2012).

Some of the key drivers that justify community involvement in the management of the coastal resources include such ecological systems contain a wide range of productive habitats necessary for subsistence and sustenance of poor communities who rely on them for survival (UNCED, 1992; NICEMS, 2003). There is no doubt that such initiatives are carried out in countries that are parties to the Rio de Janeiro-Earth Summit of 1992, which among other reasons, work to comply with the obligations of chapter 17 of the Agenda 21; which require member states to prioritize integrated coastal management initiatives in their own countries (UNCED, 1992).

Community-based mangrove monitoring initiatives were introduced in several countries in the mid and late 1990s, including those that are located near the Indian Ocean such as Madagascar, Mauritius, Seychelles, Somali Republic, Union of Comoros, Kenya and the United Republic of Tanzania (RECOMAP, 2009). In Tanzania, such initiatives were started in five coastal regions, namely Dar es Salaam, Coast, Lindi, Mtwara, and Tanga. Specifically, the following programs were operational in the specified coastal regions. These include; Tanga Coastal Zone Conservation and Development Programme (TCZCDP), Rufiji Environment Management Project (REMP), National Mangrove Management Project (NMMP), Rural Integrated Project Support (RIPS), Mafia Island Marine Park (the first Marine Park in Tanzania) established under the Marine Parks and Reserve ACT.29 of 1994, Kinondoni Integrated Coastal Area Management Programme (KICAMP) and Saadani Mkwaja Game Reserve (TCMP, 1998; TCZCDP, 2005).

The emphasis on participatory monitoring of coastal and marine resources in Tanzania did not aim at reducing incidences of unsustainable practices through mechanistic approaches. The focus was to expose coastal communities to processes and practices that would enable them to learn and share knowledge as they continue to take part in participatory programs (NEECS, 2005-2009). This could help them to see things differently and adopt positive attitudes towards the sustainability of mangroves and other coastal and marine resources.

Lotz-Sisitka (2012) argues that community-based natural resource management creates a space for learning and encourages knowledge sharing, experimentation, reflective practice, problem solving, effective monitoring and informed planning; leading to behavioural change and trust. Leys and Vanclay (2010) view such forms of learning as an approach that can strengthen communities' capacity to collectively manage ecosystems sustainably.

While learning through direct involvement in practice is necessary (Kuper et al., 2009), much relies on the methods and the indicators employed by development experts and scientists in participatory natural resource management initiatives, such as monitoring of mangroves resources and fisheries. In East Africa, (particularly Tanzania where Integrated Coastal Management Programmes were initiated in early, mid to late 1990s under internal and external funding) specific monitoring plans were developed by scientific institutions to guide community-based monitoring practices (KICAMP, 2005). The said monitoring plans contained scientific indicators and attributes adopted from the Survey Manual for Tropical Marine Resources (English et al., 1994, 1997), which are similar to those put forward by the Science and Technical Working Group (STWG) of Tanzania Coastal Management Partnership (KICAMP, 2005).

After few years of implementing community-based monitoring plans, the local participants (coastal communities) still struggled to understand and apply the scientific framework of indicators (KICAMP, 2005). This fact was affirmed, when one of the studies carried out by Julius (2005) along the eastern Coast of Tanzania indicated that there was no effective monitoring of coastal and marine resources. This implied that learning through participatory monitoring practices did not yield positive results as previously envisaged. Campbell (2000) affirms that problems emerge when facilitating firms and organisations prioritize natural scientific norms and approaches in community-based initiatives.

Proceedings from the scientific forum on Integrated Coastal Management issues in Tanzania indicate that scientific knowledge was being presented in a manner that was too complicated that tended to limit understanding and access to information for management purposes (TCMP, 1998).

This journal article does not suggest that the adoption and application of scientific indicators and methodologies in the local context constrain the learning process. It rather raises a concern whether or not conditions that necessitate development or adoption of scientific knowledge are properly addressed by experts and scientists prior to involving or engaging target communities in the participatory monitoring of coastal and marine resources, particularly the mangroves and fisheries that use them as key habitats. The article seeks to communicate a special message to different actors who are involved in coastal-based monitoring practices; that effective learning in community-based initiatives may not occur by simply adopting models, plans, and frameworks from other contexts, but by addressing key conditions that are necessary for stimulating and mobilising the learning process. These are presented here as key findings and described further using theoretical insights.

This research produce information on the elements that require to be considered by coastal practitioners before adopting scientific indicators from other geographical areas and put them into use in their own coastal specidic contexts. Prduced knowledge stems from experienced coastal communities in Mkinga District, who reveal the difficulties they have experienced as an effect of adopting the attributes and indicators from different contexts. The study complements the captured knowledge with existing literature sources to help the facilitators of participatory coastal monitoring practices in the Eastern Coast of Tanzania and other actors from similar contexts to use the generated knowledge as a guide for community-based monitoring of coastal resources (particularly mangroves and mangrove-based fisheries). The study also suggests a new methodological tool called "The Experiential Learning Intervention Workshop (ELIW)" for facilitating participatory analysis of the adopted framework of scientific indicators and attributes. This tool was developed in 2013 by the author of this journal article in a PhD research process which was carried out in the Eastern Coast of Tanzania (Sabai, 2014) and can serve as a useful method for analysis and learning. Moreover, it offers a space for coastal communities to generate and use existing traditional ecological knowledge in improving the adopted frameworks. Procedures for its application are covered under the material and methods section.

MATERIAL AND METHODS

This research was carried out in the mangrove ecosystem area restoration context in the eastern coast of Tanzania. It intended to analyse challenges that emerge as a result of adopting scientific indicators in the study area (Mkinga District), which in one way or another, can enable or constrain the learning process where participatory monitoring of coastal and marine resources is carried out. The study also sought to examine the possibility of employing existing local knowledge as an input for complementing adopted scientific framework of indicators and a response to the challenges raised by research participants (coastal communities). Embarking on this kind of study was also a response to the advice given by some scientists that local input is required when developing participatory monitoring indicators in order to accurately measure what is locally important (Fraser et al., 2005).

Research strategy This was a case study strategy which according to Yin (2003), allows the investigator to retain holistic and meaningful characteristics of real-life events that occur in the mangrove ecosystem. Opting for this strategy also implied choosing to have a deeper understanding of phenomena under study (depth) than how wide they are (breadth). Case study research yields either descriptive or explanatory knowledge (Babbie, 2001, 2007). This strategy, therefore, allowed selected fishers, mangrove restorers and local elders who have experienced real-life mangrove and fishery events to share their knowledge under the facilitation of the researcher, in the presence of invited marine scientists.

Sampling The sampling process was guided by Vershuren and Doorewaard (1999) who recommend the use of a strategic sample to allow in-depth analysis of the phenomenon under study. Selection of research participants was based on their previous involvement in mangrove and fishery practices in the study area. Using this criterion, the study selected fishers who had participated in fishing activities for at least 15 years, mangrove restorers with at least 10 years record and local elders who had witnessed trends, threats, changes and conditions of fisheries and mangrove resources for at least 20 years. Using previous contacts, the researcher formed a team of five experienced mangrove restorers and fishers (three females and two males) to assist in the process of selecting potential workshop participants. The team suggested a total of 26 participants whom they believed to have met the specified sampling criteria.

Data generation and analysis

The inquiry process was carried out through the Experiential Learning Intervention Workshop (ELIW) as a key methodological tool and a useful space for analysing conditions that are necessary for adoption of proposed monitoring approaches or scientific frameworks in a specified case study. The ELIW was completed in four sessions, across two workshop days. This allowed mangrove restorers, mangrove-based fishers, local elders and marine scientists to mirror the scientific framework of indicators and specifically analyse challenges that are associated with the adoption and application of the same.

Procedures adopted in the ELIW as a methodological tool

The Experiential Learning Intervention Workshop (ELIW) enabled workshop-participants to verify data from individual responses, analyse the same, and create a learning space throughout the workshop sessions. The method may be applied in a community of researchers, academicians, teachers, students, fishers, mangrove restorers, and in any other context where generation of data is possible. It is a useful methodological tool that may potentially attract and enhance learning through guided interactions (Sabai, 2014).

The main tool for guiding the ELIW was the framework of scientific indicators which was developed in Australia (English et al., 1994, 1997) by a team of marine scientists (Tab. 1). As stated in the introduction section, the attributes and indicators of this framework were adopted in Tanzania and applied in various coastal sites (inclusive in the study area). The workshop participants were therefore facilitated to analyse the usefulness of this particular framework after several years of its adoption.

The intervention workshop was divided into four main sessions. The first session focused on analysing the level of familiarity and comprehension of attributes that constitute the framework of scientific indicators for monitoring mangrove species and mangrove-based fisheries respectively (Tab. 1).

Table 1: The scientific framework of indicators developed outside East Africa and adopted by Tanzania in the 1990s for its coastal management initiative (KICAMP, 2005; English et al., 1994; Hill et al., 2005).

Scientific attributes/indicators for monitoring mangroves	Scientific attributes/indicators for monitoring mangrove-based fisheries
Community structure and biomass	Population size
Primary productivity	Population structure
Leaf litter production	Breeding success
Soil characteristics	Weight and length of fish by species
Area coverage	Type of gear used to catch the fish
Species composition and diversity	Distance to fishing ground
Dynamics (change)	Type of vessel used and size
	Means of vessel propulsion
	Number of crew
	Incidental catches of endangered species

The second session focused on identifying and associating scientific monitoring methods and techniques to the attributes or indicators identified during the first session. The third session aimed at examining the capacity of the participants to apply the framework. This session focused on capturing challenges that users of the framework experienced in the process of applying the scientific framework of indicators in the field and recording the same in special sheets.

The first two sessions were introduced to pave the way for the participants to recall various monitoring moments they had gone through and recognize different challenges that either enabled or constrained them from acquiring knowledge as they took part in the practice. The fourth and last session aimed at analysing the relevance of the indicators to the local context, identify emerging errors, correct observed errors, add local input to improve the framework and produce a user friendly framework (which is contextually relevant and cultural friendly), test the new framework, and provide feedback of the testing exercise. (Figs. 2-4)

RESULTS

Level of familiarity and comprehension

This section presents the results on the level of familiarity and comprehension experienced among the workshop participants (Fig. 1). The results suggest that 65% of the participants did not understand the components of the framework due to a couple of reasons; including language difficulties experienced, too many components in the framework of indicators, lack of formal knowledge, illiteracy, and unknown reasons. 25% of the participants partially understood the components and only 10% of the participants understood the components (their little formal knowledge coupled with opportunities for attending different training workshops helped them to understand).

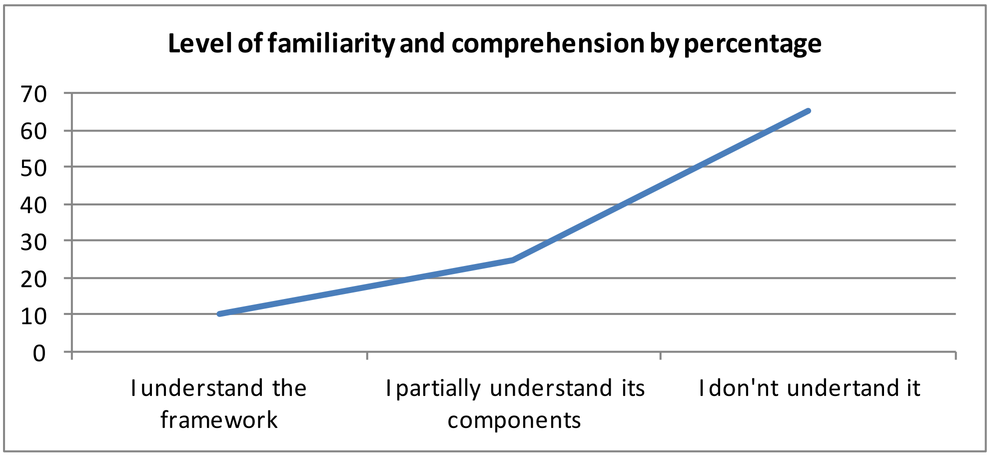

Figure 1: Level familiarity and comprehension
of the framework of indicators
for mangroves and mangrove-based fisheries.

Ability to apply the scientific framework of indicators

50% of the ELIW-participants reported that they were unable to apply the indicators while 40% were able to apply them partially. Reasons for the failure included the level of reification and contextual challenges.

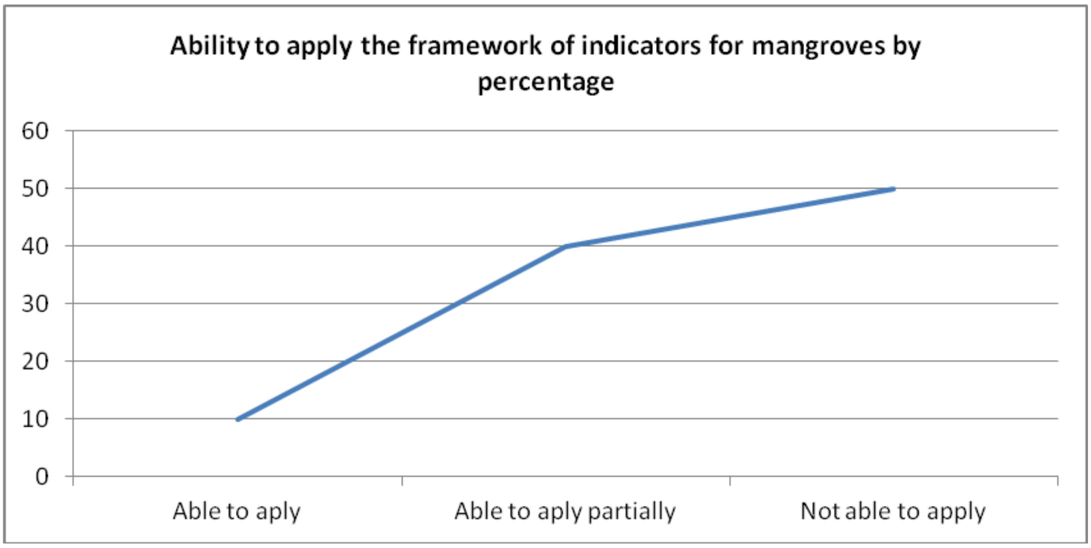

Figure 2: Applying the framework of scientific indicators for monitoring mangroves.

Ability to apply the scientific framework of indicators for monitoring mangrove-based fisheries

45% of the Experiential Learning Intervention Workshop (ELIW) participants reported that they were able to apply the indicators while 40% were unable to use certain attributes in the list. This suggests that the framework for monitoring mangrove-based fisheries was somehow clearer to users than the one adopted for monitoring mangroves. It also suggests that when developing or adopting frameworks, it is necessary to ensure that used components are tuned to reflect the context within which it will be applied.

In spite of promising results in the application of mangrove-based fisheries indicators and attributes, the percentage of those who reported they are able is not significant. Captured reasons are more or less similar to those raised by mangrove restorers. The results, therefore, raise the need for facilitating institutions, organisations and other key players to undertake needs assessment in potential project or programme areas, to uncover necessary conditions that need to be met before the implementation of any development programmes in the coastal area.

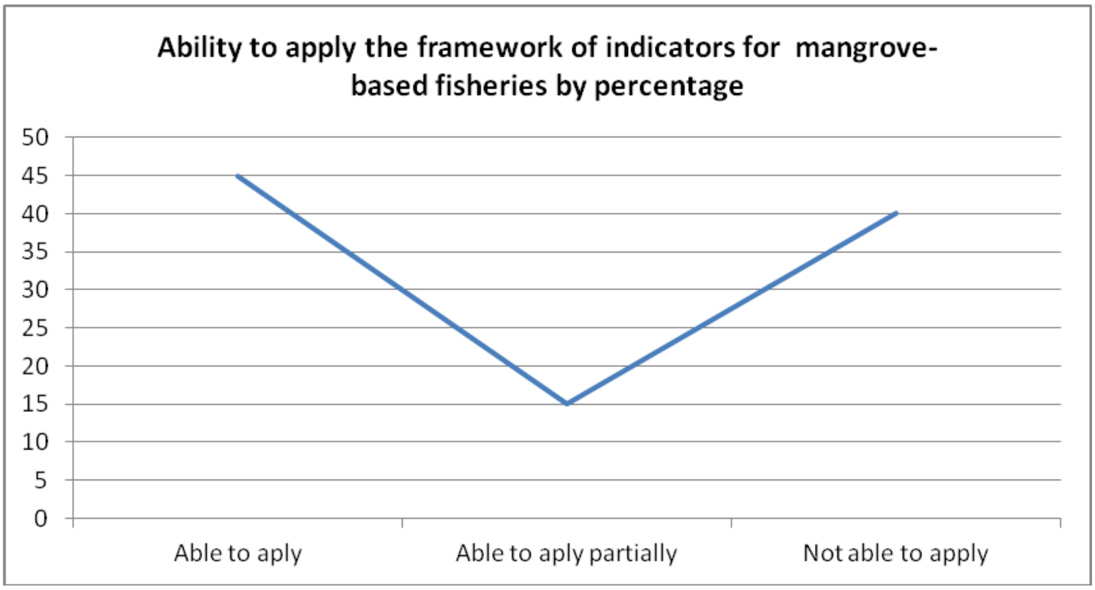

Figure 3: Applying the framework of scientific indicators for fisheries.

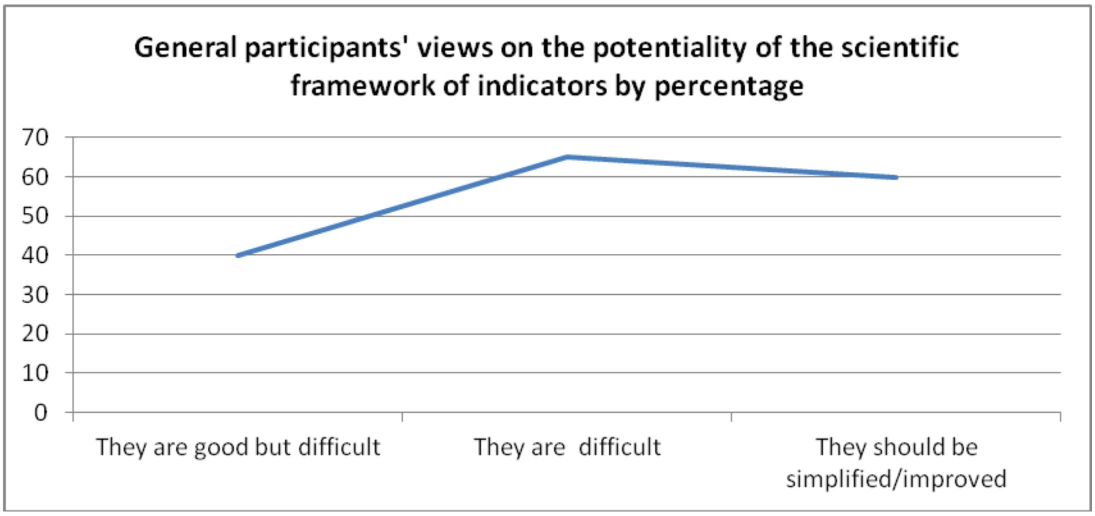

Figure 4: General perceptions of the ELIW participants.

The adoption of the scientific framework of indicators poses a number of challenges that need to be addressed prior to adoption of new frameworks (Fig. 4).

DISCUSSION

Challenges raised from the Experiential Learning Intervention Workshop suggest a list of conditions that determine or necessitate the adaption of scientific knowledge in a mangrove monitoring scenario. These included the level of education that the participating group has, level of participation opted for, contextual realities on the ground, consideration of the potential input that target communities have, and the level of structures opted for. All these determinants are discussed here after.

Level of education

One of the conditions that require attention is, for example, the capacity of the target communities to adapt and apply scientific methodologies. This appears to be necessary since literacy levels, especially in the developing countries, vary across regions. In one of the studies carried out in the eastern coast of Tanzania by a team of marine scientists, a random sample of 145 individuals was taken for purposes of analysing their socio-economic status, including the level of education. The results indicated that the level of education among target communities was very low. About one-third of the population (31%) had no formal education at all, 26% had reached only up to standard IV, 3% had completed standard VII, and only 2% had received post-primary education. The study also revealed that women had generally lower literacy and educational levels than men (Wagner et al., 2001).

In another coastal monitoring context, an assessment was carried out in the same area by one of the capacity building programmes through a two-day participatory workshop to establish the capacity of coastal communities and local government staff to understand and apply the adapted monitoring plan. It was observed that the latter were more conversant with the indicators and methodologies used in the plan than the former (KICAMP, 2005). The difference was ascribed to the varying levels of formal education between the two. The level of practical experience amongst the two groups could not be taken as a confounding factor since both participants were exposed to the plan at the same time and had no prior knowledge of it. This suggests that there is a close link between literacy and numeracy skills and the capacity to adapt and apply scientific indicators and methodologies. In other words, understanding is a prerequisite for taking part effectively in the practice. Reed et al. (2010) argued that for learning to occur in a community of practice (as it is the case with the participatory coastal monitoring initiatives), involved individuals must demonstrate a change in “understanding”, and be able to share their knowledge with other participants to the level that will attract more involvement and wider participation of other community members in the same practice.

Level of participation

The second condition that comes out so strongly in the community-based monitoring is deciding the level of participation that is required for community involvement. This involves taking part in choosing educational tools that are suitable in the learners’ context. It depicts a doctor-patient scenario where involvement and willingness of the patient in the prescription process is necessary. Some facilitators tend to assume that target communities (learners) may only be involved at particular levels of the initiatives, whereas others do not involve them at all (Songorwa, 1999). Campbell and Vainio-Mattila (2003) insist that target communities should influence the conception, design, and implementation of the introduced initiatives. Influencing the conception and the design implies taking part in deciding the structure, approach, and materials that suit their need and situations that address the actual reality in a coastal and marine setting.

There are two options that are normally preferred by facilitators when laying down strategies for participatory learning initiatives at the local level. The first option is to use adapted tools such as models, framework of indicators, plans, and any other interventional methods or techniques (KICAMP, 2005). This approach is common and mostly favoured as discussed earlier in the introduction part. The second option sets opportunities for target communities to create their own monitoring tools depending on conditions that prevail in their context and thereafter apply them. The latter option seems to carry on board the real meaning of participation or participatory approaches and is probably least favoured. Choosing either of the two needs to be decided and agreed by involved individuals and social groups in every community-based scenario. Comprehension of the said tools emerge to be an important factor, since as discussed earlier, learning can hardly occur without understanding (Reed et al., 2010). Campbell and Vainio-Mattila (2003) argue that communities are not passive bystanders in the on-going or introduced initiatives but have to be actively engaged in the negotiations that determine what those initiatives will look like.

Contextual realities on ground

It is observed that long-term change in the initiatives that local communities are involved in may only be realised or experienced if an emphasis will be laid on situated knowledge. Campbell and Vainio-Mattila (2003) defines this as "a process whereby access to the information, and control over knowledge use shifts from experts and scientists to the people whose lives are being affected". Situating knowledge in a particular learning context requires consideration of various elements. Indicator development for the monitoring of mangroves as a practice that stimulates learning should thus be rooted in contextual realities. Arguing in favour of prioritizing contextual information, Glahn et al. (2007) states that actors depend on indicators in order to organise, orientate and navigate through complex environment by utilising contextual information. Contextual information has been proven as important to support the learning processes. It stimulates the learners' engagement in and commitment to collaborating processes; it helps to raise awareness of and stimulates reflection about acquired competences; it supports thoughtful behaviour in navigation and learning paths. Glahn et al. (2007) not only insists on developing indicators that are relevant to the context within which they will be applied, but also brings into view the fact that the processes which lead to development of indicators are closely linked to learning. In other words, it implies that involving local actors, such as coastal communities, in such processes or practices create opportunities for them to learn from each other and, therefore, understand better both the context and the indicators they have developed. This may also suggest that imposing or causing actors to adapt indicators from other contexts deprives them of opportunities for learning and compels them to apply tools that are not their own creation.

According to ITAD (1997), the measures that the indicators suggest must be contextually appropriate, clear and acceptable to target communities to avoid misrepresentation of information, over-reporting or underreporting of events. The indicators should also be cost-effective, relevant to the context, and easy to apply or use. Scheltinga et al. (2004) also emphasized the need to avoid complexity by also avoiding technical abstractions and embarking on simple processes that can be easily be measured, analysed, and interpreted by involved communities. Rydin et al. (2003) noted a wave of change in indicator development, from a technical process which involves experts (at global level) to a participatory process which focuses on understanding the local context within which the indicators are being developed as a process that focuses on the relationship between lay people and experts. They argue that if indicator development is no longer a technical issue, then it should not be left to experts, but rather to people who are directly affected by the situation. Indicator development should thus be centred on the learner's situation or context and not on static approaches, which according to Glahn et al. (2007) follow a fixed set of rules in the process of collecting, aggregating, and indicating information to learners.

As indicated earlier, comprehension is a key element in the learning process without which learning of whatever kind can hardly be attained or attracts a wider level (Reed et al., 2010). Reed et al. (2006) identified two key criteria for indicators: ability of users (learners) to apply them and their relevance at local level, as discussed earlier. For users of the indicators to meet the first criterion (ability to apply them), they must first comprehend them. The level of comprehension amongst them will depend on the level reification and abstraction that underpin their involvement in the initiatives they are undertaking. If, for example, the development of the said indicators pursued a formal natural science route, common people who have never had access to participate in formal learning can hardly understand them. However, if the abstractions favour the local context and the learners or users are part of the process that led to development of such indicators, they are likely not only to understand the indicators but interact and share new knowledge with other local actors.

It is also recommended to learn from target communities whether or not there are cultural aspects that need to be addressed or considered in the monitoring plans prior to adapting any frameworks or tools. This is an important aspect, since culture in most societies is closely linked or related to moral values. (Medin and Atran, 2008)

When it is regarded as a moral duty, it may create a binding situation which compels a defined community to abide by what is believed to be morally acceptable. In this manner, culture may either serve as an enabler or constraining factor. For example, if mangrove forest sites are regarded or designated by a particular local community as being sacred, visiting such areas may be restricted to specified individuals and opportunities for other member of the community including the facilitators to undertake conservation or management activities may be limited. Development of monitoring indicators should thus consider what may be acceptable in a particular culture and what may not. This can be reached by consulting target social groups and encouraging processes that will allow them to take part at all levels of the monitoring plan, as well as through the implementation process.

The level of structures opted for

The kind of structures preferred by facilitators may well affect the process of developing community-based monitoring programmes and ultimately enable or constrain the learning process. Reed et al. (2006) presented two paradigms that determine the development of indicators in the local context as being the top-down and bottom-up. The process that leads to development of indicators under the top-down paradigm tend to exclude contextual aspects and do not encourage consultation of local communities as does the bottom-up approach. Indicators that result from the latter provide a more contextualised understanding of local issues and guarantee sustainability, ownership and accountability of participating learners. Fraser et al. (2005) remind development experts (facilitators) to ensure that the process of choosing indicators should consider their relevance to local situations.

Consideration of local input

There is evidence that local communities that are involved in participatory monitoring of coastal and marine resources are hardly asked to share experiences and situated knowledge for purposes of informing the conception and implementation of planned initiatives. Campbell and Vainio-Mattila (2003) present two cases where marine scientists continued to rely heavily on western scientific criteria in determining conservation practices. Fraser et al. (2005) insist on the fact that local input is required when developing community-based monitoring indicators in order to accurately measure what is locally important. Commenting on the need to consider local knowledge in the monitoring process, Berkes (2012) states that as people with a detailed understanding of the environment and accumulation of observations over generations (e.g. indigenous groups) have a special place in community-based monitoring. He further argues that it is becoming clear that many indigenous groups have developed their own traditional monitoring systems based on their own ways of knowing.

Most traditional monitoring methods used by indigenous people are rapid, low-cost, and easily comprehensible by harvesters themselves as they hunt, fish, and gather the forest products. Berkes (2008) observes that insights of indigenous wisdom offer great potential for broadening epistemological access, given the difficulties and limitations of accessing and using scientific knowledge in addressing complex ecological challenges. Such difficulties emerge when scientific institutions favour the language of description and methodologies that are too difficult for non-specialists at the community level to follow, leading to limited epistemological access between scientific institutions and local communities (Reed et al., 2006). Reid et al. (2006) advised that ways have to be explored in which scientific (western) and traditional knowledge can be used together, and conditions necessary for such integration need to be better understood.

CONCLUSIONS

The article raises the need for actors at institutional and organizational levels to examine contextual realities in the coastal settings prior to adoption of scientific frameworks or approaches. Knowledge of the level of formal education that the target group has, realization of the minimum level of participation that is required, consideration of the structures that govern coastal monitoring practices at the local level, and incorporation of existing traditional ecological knowledge (as local input) may potentially attract smooth adoption process and generate a sense of ownership, belonging, active participation and active experiential learning processes.

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FLASH-FLOODS INFLUENCE MACROINVERTEBRATE COMMUNITIES DISTRIBUTION IN LOTIC ECOSYSTEMS

Octavian PACIOGLU *, *Alina SATMARI* **, *Milca PETROVICI* *, *Mălina PÎRVU* *, *Mirela CÎMPEAN* ***, *Karina Paula BATTES* ***, *Sandra Florina LELE* *, *Angela CURTEAN-BĂNĂDUC* **** and *Lucian PÂRVULESCU* *[C.A.]

* West University of Timişoara, Faculty of Chemistry, Biology, Geography, Pestalozzi Street 16A, Timişoara, Romania, RO-300115, octavian.pacioglu@e-uvt.ro, milca.petrovici@e-uvt.ro, malina.pirvu@e-uvt.ro, sandra.lele@e-uvt.ro, lucian.parvulescu@e-uvt.ro (corresponding author)

** West University of Timişoara, Faculty of Chemistry, Biology, Geography, Department of Geography, Pârvan Boulevard 4, Timişoara, Romania, RO-300223, alina.satmari@e-uvt.ro

*** Babeş-Bolyai University, Faculty of Biology and Geology, Republicii Street 44, Cluj-Napoca, Romania, RO-400006, mirela.cimpean@ubbcluj.ro, karina.battes@ubbcluj.ro

**** "Lucian Blaga" University of Sibiu, Faculty of Sciences, Applied Ecology Research Center, Dr. Ion Raţiu Street 5-7, RO-550012 Sibiu, Romania, angela.banaduc@ulbsibiu.ro, ad.banaduc@yahoo.com

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ABSTRACT

Stream dwelling invertebrate populations are facing an ample array of stressors including the habitat imbalance caused by important floods. In this research we used a novel way to estimate the impact of floods upon the substrate, by utilising a remote variable named "flash-flood potential" (FFP), which accounts for the site slope and the average slope of the upstream catchment. The results showed that certain groups are sensitive to the influence of the FFP whereas other are not. We propose this remote variable as a surrogate for assessing stress imposed by floods and sediment scouring for lotic macroinvertebrates.

RÉSUMÉ: Influencia de inundaciones repentinas en la distribución de comunidades de macroinvertebrados en ecosistemas lóticos.

Las poblaciones de macroinvertebrados fluviales enfrentan una gran variedad de amenazas, que incluyen la inestabilidad del hábitat a causa de fuertes inundaciones. En este estudio se utilizó un enfoque novedoso para estimar el impacto de las inundaciones en el sustrato, que consiste en el uso de una variable remota llamada "potencial de inundación rápida" (FFP), la cual da cuenta de la pendiente del sitio y la pendiente promedio de la cuenca de captación. Los resultados mostraron que ciertos grupos son sensibles a la influencia del FFP, y otros no. Se propone el FFP como variable sinóptica para evaluar el estrés impuesto en las poblaciones de invertebrados lóticos por parte de las inundaciones y la erosión de sedimentos.

REZUMAT: Viiturile influențează distribuția cumunităților de macronevertebrate în ecosistemele lotice.

Populațiile macronevertebratelor lotice sunt supuse unei palete foarte largi de factori de stres, inclusiv instabilitatea substratului cauzată de inundații severe. În acest studiu a fost utilizată o abordare nouă pentru estimarea impactului inundațiilor asupra substratului, prin folosirea unei variabile numite "potențialul de inundație" (FFP), care ia în calcul panta râului dar și a pantei medii a bazinului hidrografic situat în amonte de stația de prelevare. Rezultatele au arătat faptul că anumite grupe taxonomice sunt sensibile la influenta acestei variabile în timp ce alte grupe nu au fost afectate. Propunem folosirea acestei variabile ca un surogat pentru evaluarea stresului indus de inundații asupra macrozoobentosului lotic.

INTRODUCTION

Natural and/or anthropogenic significant events influence continuously the aquatic biota presence or absence, distribution and zoogeography, and ecological status (Resh et al., 1988; Bailey et al., 1998; Staicu et al., 1998; Lake et al., 2000; Anastasiu et al., 2017; Marić et al., 2017).

Infrequent, severe flood events have a direct negative impact upon most freshwater invertebrates, especially when associated with debris flow (Palmer et al., 1996; Relyea et al., 2012) and lack of suitable shelters and refuges (Culp and Davies, 1983; Townsend and Hildrew, 1994). However, floods induce different responses in different taxa. The larvae of freshwater insects are usually more affected compared to other type of invertebrates, although communities can be re-established afterwards through aerial colonisations (Tronstad et al., 2007). On the other hand, invertebrates with a complete aquatic life cycle (non-insects) need a longer period to re-colonise streams after major flood events (Wallace, 1990).

Besides dislodging invertebrates from substrate, another major stress imposed by high flows is the quantity of fine sediments carried downstream (Jones et al., 2012). Following the aftermath of mid-high-power floods, the invertebrate communities are hampered by space availability in both benthic and hyporheic habitats (Dole-Olivier, 2011). As such, different types of macroinvertebrates prefer various types of substrates: oligochaetes (Armitage, 1995) and chironomids (Dudgeon, 1994) are generally associated with fine sediment deposition, whereas other groups of invertebrates cannot withstand intrusion of small particles because of the detrimental effect on dissolved oxygen intake and hence, respiration (Eriksen, 1966; Lemly, 1982). At the other end of the spectrum, erosional, coarser deposits are usually inhabited by a higher frequency of mayfly, stonefly and caddisfly larvae due to a higher availability of dissolved oxygen in substrate (Nebeker, 1972; Wiley and Kohler, 1980; Williams et al., 1987), whereas amphipods and ceratopogonids tend to inhabit fissured and depositional zones (Pennak, 1989; Merritt and Cummins, 1996; Weigel et al., 2003; Kley et al., 2009).

To overcome the knowledge gap induced by the combination of several detrimental events associated with floods, a new variable, named "flash-flood potential" (FFP) was proposed to estimate the impact of irregular high flows upon substrate availability and hence of the invertebrate community stability in streams (Pârvulescu et al., 2016). The FFP accounts for the site slope and the average slope of upstream basins and proved to be a good indicator for assessing the spatial distribution of different size-classes of crayfish in rivers (Pârvulescu et al., 2016). This study goal was to test how this variable predicts the occurrence of various groups of macroinvertebrates inhabiting lotic systems covering a wide variety of catchments slopes within Romania. The taxonomic resolution used was undertaken at a very coarse level (order, class or higher) for two reasons. First, previous studies investigating the effects of floods and substrate availability in shaping invertebrate community structure in streams recognised that major differences within various groups of aquatic invertebrates take place at coarse taxonomic levels (e.g. usually order for insects or even higher for other groups like oligochaetes and nematodes), and that lower taxonomic resolution requires supplementary efforts that does not always bring any significant improvements to the observed patterns (Warwick, 1988; Bowman and Bailey, 1997). Second, such an approach would allow ecologists and local stakeholders, less trained in taxonomy, to assess the impact of detrimental abiotic events on river ecosystems, like floods and sediment scouring potential (Statzner and Beche, 2010). Identification to lower taxonomic levels can be time consuming and therefore expensive and often does not clarify community responses to stressors (Bonada et al., 2006).

MATERIAL AND METHODS

The dataset employed in this study was obtained by field investigation of 408 rivers sites selected in Romania during the summer season (July-August) between 2009 and 2015 (Fig. 1).

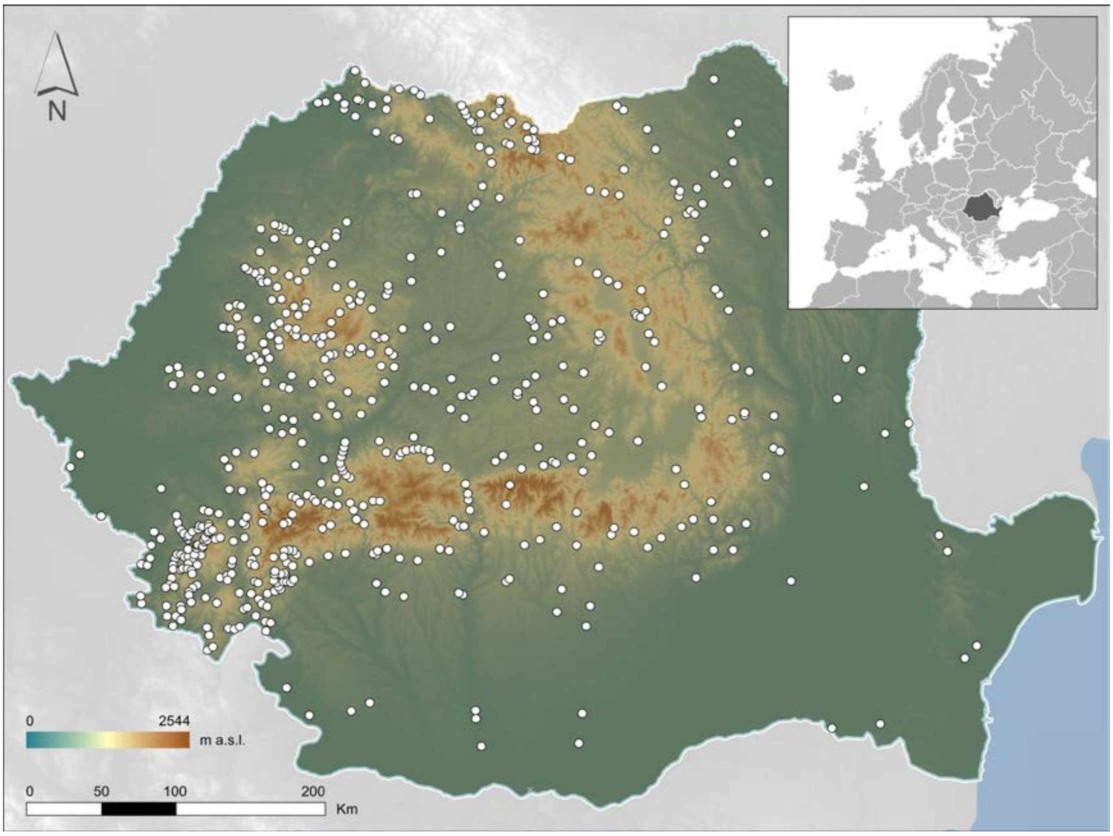

Figure 1: Map showing the sampling points within hydrographical basins in Romania.

The geographical position of each site was recorded with a Garmin GPS receiver (Garmin Ltd., Lenexa, Kansas, United States).

The invertebrates were sampled by employing kick net sampling standard protocol using a standard one mm mesh pond (hand) net (Storey et al., 1991).

Following sampling, the content was transferred in sealed plastic recipients, preserved with 4% formalin solution and further identified in the laboratory to coarse taxonomic resolution (order or higher).

FFP was calculated as the product of two land-surface variables, namely slope gradient (G) and catchment slope (CS). Both variables were derived from a 90 m SRTM DEM (http://srtm.csi.cgiar.org). G was computed in a standard 3 X 3 neighbourhood. This variable estimates local declivity, thus accounting for the potential water velocity at a given site. CS was computed as follows: for each cell, G was calculated and then accumulated downslope (for the entire area that drains towards a cell, not only for the river beds itself). Then, the value of accumulated slope for each cell was divided by the catchment area of that cell (http://www.saga-gis.org/en/index.html). CS estimates the average gradient of a surface that drains towards a given site, thus accounting for the potential of flash-floods and their associated disturbing effects as a consequence of heavy rain falls. Therefore, FFP estimates, the potential for disturbance in streams, by taking into account the potential drainage velocity both upstream and at the site. For further details, we refer readers to Pârvulescu et al. (2016).

Statistical analysis

The values employed in statistical analyses were the relative frequencies of each taxonomic group and logarithmic values of FFP. It was considered a limiting response model (Lancaster and Belyea, 2006), using log-linear regression to describe the rate of change with respect to FFP near the upper boundary of the conditional distribution of invertebrate's frequencies. Therefore, we focused on modelling the distribution of the response at the 90th percentile ($\tau = 0 \bullet 9$). Each taxonomic group was tested using quantile regression, followed by the goodness of fit with the observed pattern with the aid of the Wald test (Tab. 1). We have focused on log-linear models because of monotonic response expected for invertebrates to FFP variation (Pârvulescu et al., 2016). All tests were undertaken in XLSTAT version 2010 package.

Classification and regression trees (C and RT) were employed in this study, aiming for the identification of potential response and to predict an optimum value of frequency occurrence of different groups of invertebrates for different classes of FFP. Despite the difficulty in the interpretation of large trees, there are obvious advantages provided by different responses: the invariance to transformation of variables, simplicity of models and ease in managing missing values (De'ath and Fabricius, 2007). In our case, the predictive variable was the FFP (Tab. 2). Other advantages of this method are the simple graphical representation which is an upside down branching tree with nodes based on the value of one or more explanatory variables (Moldovan et al., 2013). The parent node is split into child nodes and they become, in turn, parent nodes unless they are terminal nodes (De'ath, 2002). In this study, C and RT's were used to build predictive models for the presence and optimum frequencies of invertebrates at different classes of FFP. The Chi-squared Automatic Interaction Detector (CHAID) technique (Kass, 1980) was used to construct trees where each node represents a split that yields optimum prediction for the targeted invertebrate species (Tab. 2). This way, the optimal frequencies for several classes of FFP are estimated for each taxonomic group (De'ath, 2002). Therefore, CHAID builds trees with more than two branches attached to a single node, based on an algorithm which in turn is based on chi-square tests. The decision trees were developed within XLSTAT Version 2010 package and interpreted at 5% significance level. For more detailed information about the usefulness and criteria of this method see Pacioglu et al. (2016).

RESULTS

The FFP values used in this survey varied widely (between 0-8, Fig. 2), covering a large range of river morphologies and topographic slopes, ranging from steep mountain valleys to lowland rivers with very small slopes, and hence reduced FFP values (Fig. 1).

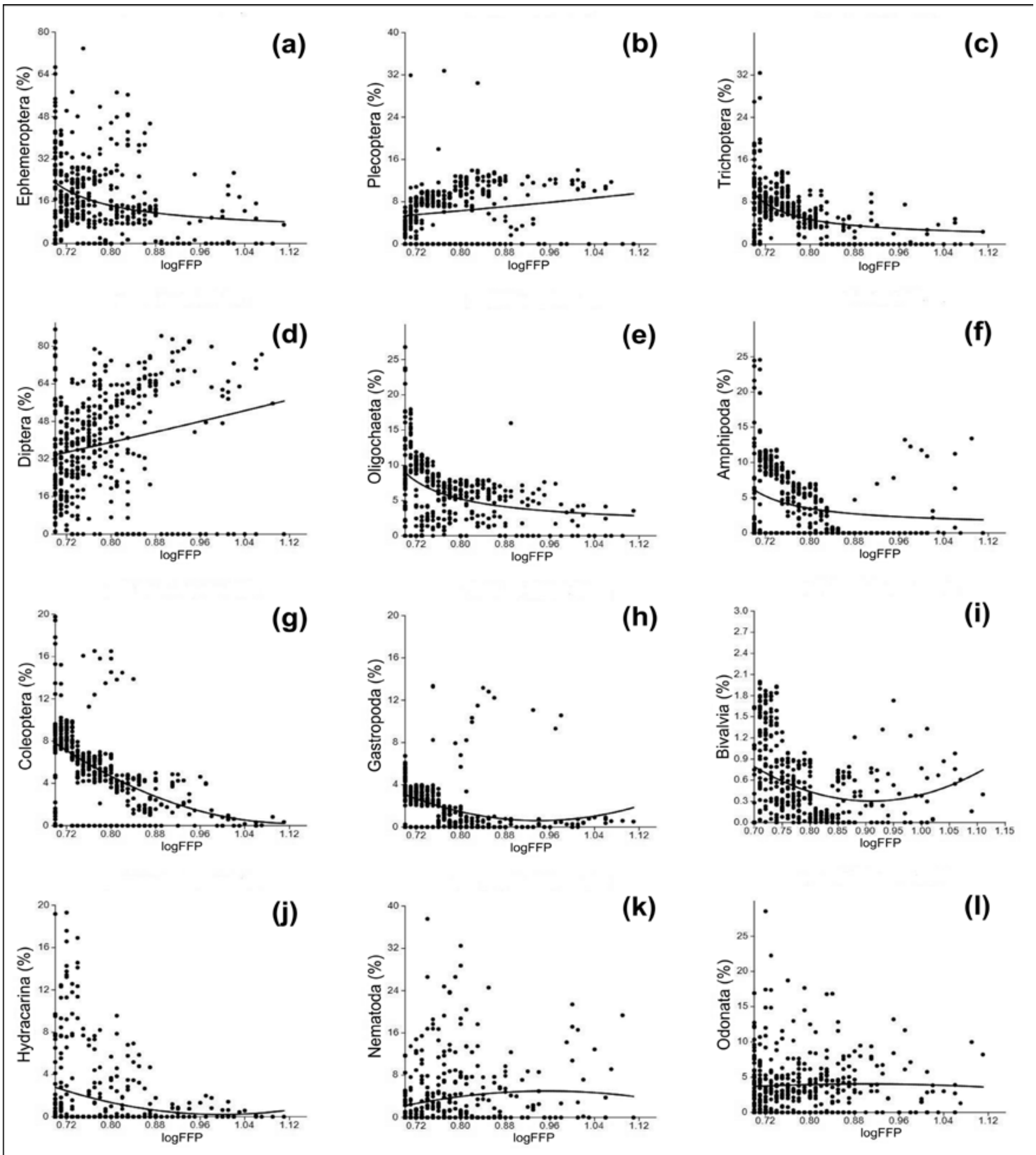

Figure 2: Scatterplots of the frequency versus flash flood potential (FFP) and plots of the 90th percentile quantile regression functions for (a) Ephemeroptera (b) Plecoptera (c) Trichoptera (d) Diptera, (e) Oligochaeta, (f) Amphipoda, (g) Coleoptera, (h) Gastropoda, (i) Bivalvia, (j) Hydracarina, (k) Nematoda, and (l) Odonata.

The invertebrate fauna was classified into very coarse taxonomic groups (usually order) to support the testing hypotheses. Groups with a mean frequency across all sites below 5% were excluded from analysis (e.g. aquatic isopods, flatworms, and water bugs). For most invertebrate groups, the quantile regression models showed that FFP is an important factor influencing their frequency in samples (Tab. 1). The coefficients for the 90th percentile regression functions can also be found in table 1. The main groups of tested macroinvertebrates responded differently to FFP variation (Fig. 2). Whilst the general trend of most groups was a decrease of their frequencies in samples directly with FFP values, there were a few exceptions, which either showed no direct response (e.g. Diptera and Odonata larvae; Tab. 1, Figs. 2d and 2l) or a slight increase of their frequency with FFP (e.g. stoneflies; Fig. 2b).

The explanatory variable in the C and RT analysis was the FFP. The full result of this analysis is summarised in table 2 as a list that yields the highest probability to obtain an optimum frequency for different groups of macroinvertebrates, using kick sampling method, for different classes of FFP. The variation of FFP was divided in classes as a direct consequence of node splits in regression trees by the CHAID technique (Tab. 2). According to results from table 2 and the general trend of nonlinear regressions (Fig. 2), the mayflies and caddisflies larvae, water beetles, oligochaetes, aquatic snails, mussels, and water mites decreased their frequency in samples with increasing FFP values. However, the general decline of various groups directly with FFP values, although nonlinear, encountered a slight increase at mid-level classes of FFP for stoneflies, amphipods and nematodes (Tab. 2). The FFP classes where these groups registered an increase of their frequencies varied widely, from within a narrow range of (4.8-5.6) for stoneflies, up to (3.6-5.6) for amphipods and (1.9-5.1) for nematodes (Tab. 2). Other groups, like Diptera and Odonata larvae, were apparently unaffected by FFP variation (Tab. 2, Fig. 2). The tendency for the former group was a slight increase in frequency with FFP values, whereas the latter provided an inconsistent variation with floods risk (Tab. 2).

DISCUSSION

The application of C and RT's analysis allowed us to estimate the optimum values for occurrence of different groups of invertebrates to different classes of FFP. Previously, this analysis was successfully employed to assess the water quality of aquatic habitats pollution with metals, eutrophication and impact of land use by using invertebrates as bioindicators (Moldovan et al., 2013; Pacioglu et al., 2016). However, in our study, the response of river invertebrates to FFP variation was not that acute as when they are faced with stressors like metal pollution, fluctuations in water pH, eutrophication and colmation (Jones et al., 2012; Pacioglu et al., 2012; Moldovan et al., 2013).

Table 1: Coefficients of the quantile regression models for the 90th percentile (equations in linearized form) for invertebrate groups, along with significance level of Wald test.

Group	Intercept	St. error	FFP	St. error FFP	P value Wald test
Ephemeroptera	39.12	0.02	– 3.35	0.015	< 0.001
Plecoptera	9.03	0.19	1.74	0.1	0.03
Trichoptera	12.49	0.013	– 1.72	0.073	< 0.001
Diptera	57.28	1.28	6.16	0.69	0.79
Oligochaeta	12.86	0.05	– 1.77	0.03	0.04
Amphipoda	11.18	0.19	– 1.29	0.1	0.007
Coleoptera	9.8	0.11	– 1.44	0.06	0.005
Gastropoda	4.23	0.11	– 0.5	0.06	0.008
Bivalvia	1.16	0.002	– 0.14	0.001	0.003
Hydracarina	8.38	0.06	– 1.27	0.033	0.025
Nematoda	10.44	0.13	1.22	0.07	0.006
Odonata	8.77	0.02	– 0.07	0.012	0.86

Table 2: Optimum values of macroinvertebrate frequencies occurrence for different classes of FFP; the FFP classes were established as a direct consequence of node splits in regression trees by the CHAID technique.

Group	(0-1.96)	(1.96-3.63)	(3.63-4.8)	(4.8-5.1)	(5.1-5.6)	(5.6-8)
Ephemeroptera	18.5	5.43	5.43	5.43	5.43	1.27
Plecoptera	6.05	6.05	6.05	11.99	11.99	6.91
Trichoptera	7.07	1.35	0.74	0.48	0.48	1.6
Diptera	35.74	48.34	48.34	48.34	48.34	48.34
Oligochaeta	6.88	4.42	3.45	2.27	2.27	1.58
Amphipoda	4.86	2.56	5.87	5.44	5.44	3.37
Coleoptera	6.24	2.56	2.07	0.26	0.82	0.26
Gastropoda	2.22	0.91	0.91	0.91	0.6	0.6
Bivalvia	0.59	0.41	0.41	0.41	0.41	0.41
Hydracarina	2.03	0.66	0.63	0.62	0.64	0.64
Nematoda	3.3	17.18	17.18	17.18	17.18	17.18
Odonata	–	–	–	–	–	–

Groups like mayflies, caddisflies, aquatic snails, mussels, oligochaetes, water mites, and water beetles decreased their frequency directly with the FFP. Although these groups (as many others) are capable of re-establishing viable population through aerial colonisation (e.g. insects and their associated water mite species), upstream migration or from the underneath hyporheic zone (Wallace, 1990; Dole-Olivier, 2011), it seems that the availability of coarse sediments usually associated with high FFP values (Pârvulescu et al., 2016) is not enough to overcome the steepness of slopes and the associated risks for washout during rainy seasons. The implementation of this index within the Romanian territory showed a high correlation not only with the steepness of slopes, but equally with water velocity (Pârvulescu et al., 2016). Although certain groups of mayflies (e.g. the heptageniids) and caddisflies (e.g. some rhyacophilids and hydropsychids) are generally associated with well oxygenated, high water flows (Armitage, 1995; Pîrvu and Pacioglu, 2012), their frequency, because of their large size, makes them less frequent in rivers with steep slopes as opposed to other groups of invertebrates. The molluscs are not great swimmers, nor equipped with special morphological adaptations like certain insect larvae to withstand the pressure induced by high flows (Kappes and Hasse, 2012). The sensitive nature of mussels makes them vulnerable to natural disasters, but their recovery is assured by the parasitic nature of their larvae on highly mobile fish (Vaughn, 2012).

Water beetles dwelling in rivers are usually associated with low-flow environments (Extence et al., 1999), characterised by small FFP values. The only notable exception (riffle-beetles), associated with high-flows and steep slopes (Extence et al., 1999), are still very vulnerable to spates (Elliott, 2008) and this could be another reason for their low frequency at high FFP values. The oligochaetes are known to have an affinity for fine sediments, either in benthic or hyporheic zone (Jones et al., 2012), therefore the use of interstitial milieu as refuge during floods (Dole-Olivier, 2011) may not be the most straightforward explanation for the observed pattern, but rather their preference for fine organic matter trapped in fine deposited sediments (Pacioglu et al., 2012) and hence their preference for lower FFP values. The water mites comprise a wide range of species, some of which are well adapted to high water speed and can prove very good swimmers (Di Sabatino et al., 2010). However, their preference for low FFP values may be a caveat associated with the sampling design. Because of their small size, the water mites usually belong to meiofauna (63-500 µm length; Rundle, 1990); therefore the probability of being trapped with the usual mesh size of hand nets used in this survey (one mm) was greatly reduced, underestimating their real abundance in river habitats.

Three other groups, the amphipods, nematodes and stoneflies registered their highest percentage in samples at intermediary levels of FFP. Although the macroinvertebrate communities are considered to be highly sensitive to environmental changes (Pârvulescu and Hamchevici, 2010; Milner et al., 2013), it has been equally shown that high species abundance was associated with moderate/intermediate disturbances (Reice et al., 1990). Connell (1978) suggested that at an intermediate level of disturbance there will be sufficient time for colonisation by a wide variety of species, and that some of them can obtain the highest densities in such environmental conditions. The amphipods (due their high borrowing capacity), nematodes, and stoneflies (due their slender body shape) usually dwell in the hyporheic zone (Danielopol, 1989). Therefore, one possible explanation for their distribution is that at moderate levels of FFP, the interstitial habitats may prove a suitable refuge against high flows, as opposed to the aforementioned groups of invertebrates.

Other groups of organisms (Diptera and Odonata larvae) must be used cautiously in the attempt to describe the influence of FFP on their distribution, because they represent either extremely abundant taxa (Diptera) or their samples are infrequent (Odonata). The Diptera larvae (dominated by chironomids) are extremely abundant in streams and rivers worldwide and therefore their use as indicators of potential for wash out is unsuitable. The Odonata comprise families with a wide variety of flow and type of sediment preferences (Extence et al., 1999) and their usual big size compared to other invertebrates could be another reason for their rarity and consistent low percentage in samples, precluding any inference over the effect of FFP. The same lack of response was noticed for other important groups, like aquatic isopods, flatworms, and leeches, which because of low frequencies in samples (< 5%) prevented any meaningful response to FFP variation, according to both C and RT analyses and nonlinear regressions (data not shown).

The coarse taxonomic level undertaken in this study consists with the patterns observed in other studies, which discovered that data aggregated to phylum-level were at least as well correlated with environmental stressors as those based on species identifications (Bowman and Bailey, 1997). Another important cost factor related to the level of taxonomic resolution needed in lotic invertebrate surveys resides in the low number of trained specialists in aquatic invertebrate taxonomy available in laboratories (Bonada et al., 2006). So far, different levels of taxonomy have been used in lotic invertebrate bio-monitoring (family, genus, and species), a fact that has been widely discussed in the context of costs and achieved accuracy and precision of the information associated with these taxonomic levels (Lenat and Resh, 2001; Schmidt-Kloiber and Nijboer, 2004). Therefore, in this context, the FFP can prove a useful method for environmentalists less trained in the cumbersome taxonomy of different groups of freshwater invertebrates, requiring only general skills for differentiating general groups of invertebrates in samples taken with a hand net. Another important benefit of this method is that it does not need costly travel costs generally related to routine monitoring programs (the FFP can be calculated solely based on the GPS coordinates of the site) and it is applicable to any scale, a major detail in current ecologic researches with a principal focus on general patterns occurring at large geographic gradients.

CONCLUSIONS

We conclude that the C and RT method can be used to assess the response of invertebrates from rivers to FFP. It is relatively easy to use (De'ath and Fabricius, 2007; Moldovan et al., 2013) and can therefore indicate optimum frequencies of specific groups of organisms that are sensitive to a given class of FFP and that can mirror the synergic combination of stressors, like potential for dislodging and indirectly of sediment structure and potential for refuge against high flows. This study was conducted on 408 sites, therefore covering a wide range of FFP values within the Romanian national territory.

Preliminary test of this variable can therefore prove to be a reliable basis for further research in describing the potential that it has in combinations with other stressors affecting freshwater life in streams and rivers.

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THE DISAPPEARANCE OF MALE SECONDARY SEXUAL CHARACTERISTICS IN THE TYPICAL CAVE SPECIES IN *TRIPLOPHYSA*

Jun LIANG * and *Jiang ZHOU* ** [C.A.]

* Guizhou Normal University, School of Life Sciences, Guiyang, Guizhou, P. R. C., P. O. Box, CN-550001, 1597556942@qq.com
** Guizhou Normal University, School of Life Sciences, Guiyang, Guizhou, P. R. C., P. O. Box, CN-550001, zhoujiang@ioz.ac.cn

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ABSTRACT
It was suggested that the darkness environment would influence the fishes' morphology, not only the barbells, snout, but also the male secondary sexual features. This paper reported that the three typical cave dwelling fish species of *Triplophysa* did not show these sexual morphological traits, such as *Triplophysa lewangensis, Triplophysa nasobartula* and *Triplophysa zhenfengensis* collected in Guizhou Province, meanwhile, there were not the description on the traits about the 11 typical cave dwelling species of this genus in Guangxi Province.

RESUMÉ: La disparition des caractères sexuels secondaires masculins dans l'espèce typique des cavernes du genre *Tryplophysa*.
Il a été suggéré que l'environnement de l'obscurité influencerait la morphologie des poissons, non seulement les barbillons, le museau, mais aussi les caractéristiques sexuelles secondaires masculines. Cet article rapporte que les trois espèces de poissons troglodytes typiques de *Triplophysa* tels que *Triplophysa lewangensis*, *Triplophysa nasobartula* et *Triplophysa zhenfengensis*récoltés dans la province de Guizhou, n'ont pas présenté ces caractères morphologiques sexuels, qu même temps n'ayant pas de description sur les traits caractéristiques des 11 espèces vraies troglodytes de ce genre de la province de Guangxi.

REZUMAT: Dispariția caracterelor sexuale secundare masculine la speciile troglobionte tipice din genul Tryplophysa.
S-a sugerat că mediul lipsit de lumină ar influența morfologia peștilor, nu numai la nivelul mustăților, rostrului, dar și caracteristicile sexuale secundare masculine. Articolul a concluzionat că cele trei specii de pești din genul *Triplophysa*, tipice pentru mediul cavernicol, nu au prezentat aceste trăsături morfologice sexuale, precum *Triplophysa lewangensis, Triplophysa nasobartula* și *Triplophysa zhenfengensis* colectate în provincia Guizhou, în timp ce nu există o descriere a trăsăturilor celor 11 specii troglobionte tipice din acest gen care sunt întâlnite în Provincia Guangxi.

INTRODUCTION

Rendahl (1933) established *Triplophysa hutjertjuensis* as a model species, and Bănărescu and Nalbant (1975) classified *Triplophysa* into two genera: *Hedinichthy* and *Triplophysa*. Zhu Songquan (1989) combined them in one genus, *Triplophysa*, based on the structural characteristics of the position of the male secondary sexual features of *Triplophysa* and the shape of the small spines. *Triplophysa* is the larger genus in *Nemacheilidae*. Till now 197 species have been described (Eschmeyer et al., 2017), of which more than 100 species have been distributed in China (Zhang Chunguang et al., 2015). In addition, there are 29 species of typical caves species in *Triplophysa* in China *Triplophysa* (Tab. 1), eight species in Yunnan, six species in Guizhou, 13 species in Guangxi, and one species in Chongqing and one species in Hunan.

There are not only surface species, but also 29 species that live in caves. However, the characteristics of male secondary sexual characteristics have not been found in the description of these cave species. Therefore, the species of Guizhou Province's caves (Fig. 1), such as *Triplophysa lewangensis*, *Triplophysa zhenfengensis*, and *Triplophysa nasobartula*, were inspected to determine if the male secondary sexual characteristics were present.

The surface species' adult males have the secondary sexual characteristics mainly on the sides of the head and the pectoral fins (Zhu Songquan, 1989; Hou Feixia, 2010). The phenotype could be divided into: 1. The upper and lower parts of the infraorbital line are thickened with spines (e.g. *T. minxianensis*). 2. No spines in the upper and lower parts of the infraorbital line, only thickened (e.g. *T. daqiaoensis* (Fig. 2-P1). 3. Only the upper part thickened, and no spike (e.g. *T. stenura* (Fig. 3-P2). 4. Only the upper part thickened and has spines (e.g. *T. stoliczkae*) (Fig. 4-P3) have changes in pectoral fins (Hou Feixia et al., 2010). Sexual characteristics are divided into: 1. The pectoral fin masks are thickened with pads with spiny spines (e.g. *T. daqiaoensis*. (Fig. 5-P11) 2. Thick padded pectoral fins on back, no spikes (e.g. *T. markehenensis*) (Fig. 5-P12). 3. The pad on the back of the pectoral fin is not obvious, and there are no spines (e.g. *T. markehenensis* (Fig. 5-P13). (Hou F. X. et al., 2010)

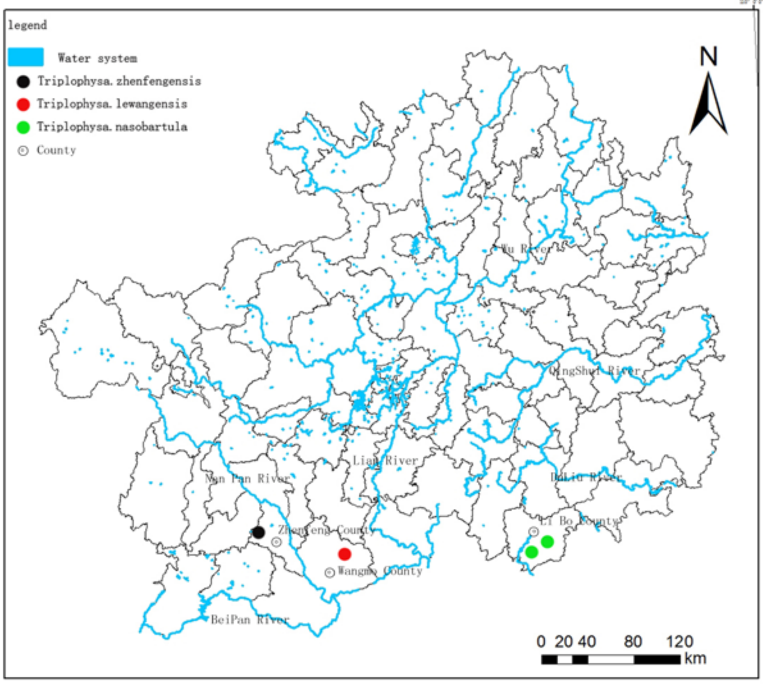

Figure 1: Studied areas.

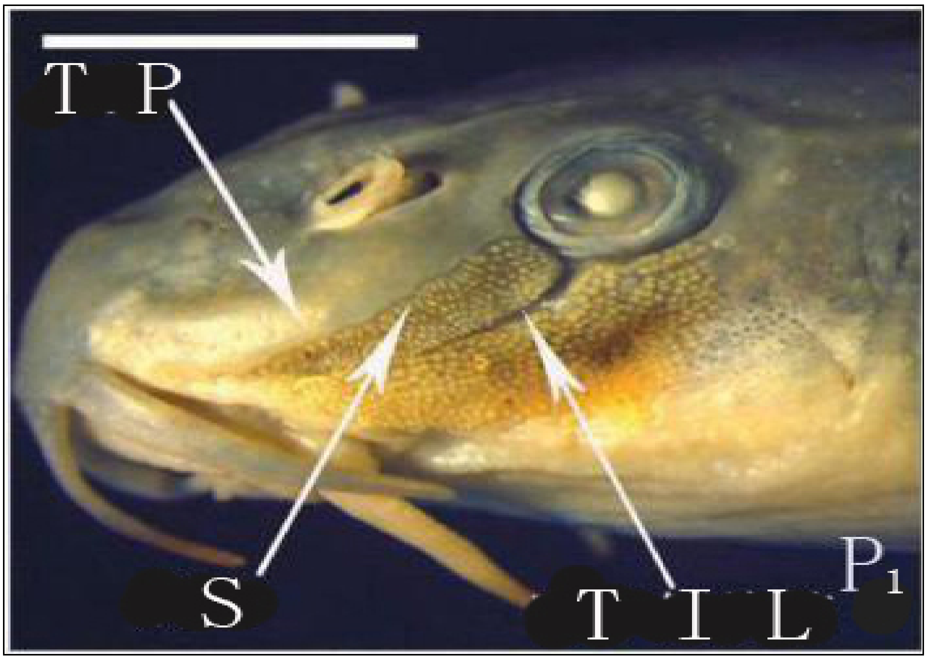

Figure 2: *Triplophysa daqiaoensis*; Lateral view of head of *Triplophysa* males, showing the secondary sexual characters; T P = Thickended pad; S = Spines; T I L = The infraorbital line; Scalebars = five mm (photo Hou F. X. et al., 2010).

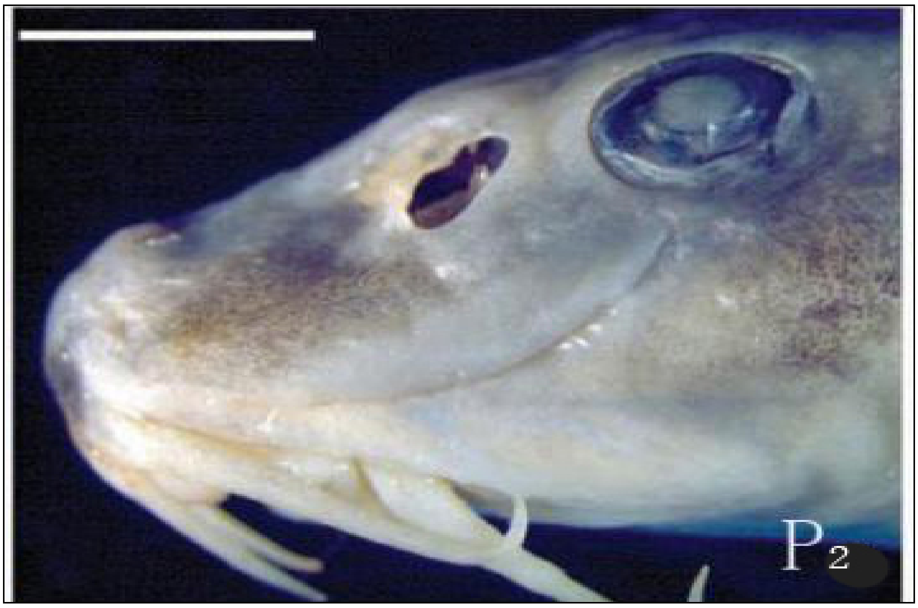

Figure 3: *Triplophysa stenura*; Lateral view of head of *Triplophysa* males, showing the secondary sexual characters; T P = Thickended pad; T I L = The infraorbital line; Scalebars = five mm (photo Hou F. X. et al., 2010).

Figure 4: *Triplophysa stoliczkae*; Lateral view of head of *Triplophysa* males, showing the secondary sexual characters; T P = Thickended pad; S = Spines; T I L = The infraorbital line; Scalebars = five mm (photo Hou F. X. et al., 2010).

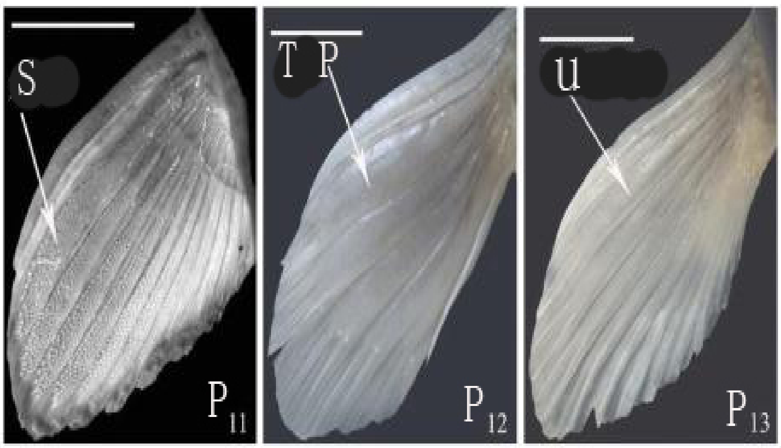

Figure 5: Dorsal view of pectoral fin of *Triplophysa* males, showing secondary sexual characters; S = Spines; T P = Thickened pad; U = Unobvious; P 11 *Triplophysa daqiaoensis*; P 12-P 13 *Triplophysa markehenensis*; Scalebars = five mm (photo Feixia et al., 2010).

Table 1: The species distribution of the typical genus *Triplophysa* in China.

Species	Geographical distribution
Triplophysa aluensis (Li W. X. and Zhu Z. G., 2000)	Alu ancient cave, Luxi County, Yunnan Province
Triplophysa gejiuensis (Chu X. L., et al., 1979)	Gejiu City, Yunnan Province, China
Triplophysa qiubeiensis (Li W. X., et al., 2008)	Nijiao Village, Qiubei County, Yunnan Province
Triplophysa shilinensis (Chen Y. R., et al., 1992)	Boyi Village near Shilin in Lunan County, Yunnan Province
Triplophysa xiangshuingensis (Li W. X., 2004)	Shilin County, Yunnan Province
Triplophysa yunnanensis (Yang, 1990)	Yiliang County, Yunnan Province
Triplophysa tianxingensis (Yang H. F., et al., 2016)	Qiubei County, Yunnan Province
Triplophysa xichouensis (Liu S. W., et al., 2017)	Xichou County, Yunnan Province
Triplophysa nasobartula (Wang D., and Li D., 2001)	Wengang Township and Dongtang Township, Libo County, Guizhou Province
Triplophysa zhenfengensis (Wang D., and Li D., 2001)	Longchang Town, Zhenfeng County, Guizhou Province
Triplophysa longliensis (Ren Q., et al., 2012)	Longli County, Guizhou Province
Triplophysa jiarongensis (Lin Y., et al., 2012)	Libo County, Guizhou Province
Triplophysa longibarbatula (Chen Y. R., et al., 1998)	Libo County, Guizhou Province
Triplophysa lewangensis (unpublished)	Lewang Town, Wangmo County, Guizhou Province
Triplophysa nandanensis (Lan J. H., et al., 1995, 2013)	Mayang Village, Six Village Town, Nandan County, Guangxi Province
Triplophysa tianeensis (Chen X. Y., et al., 2004)	Number eight hole, Bala Township, Tiane County, Guangxi Province
Triplophysa lingyunensis (Liao J. W., et al., 1997)	Sha hole, Mawang Village, Sicheng Town, Lingyun County, Guangxi Province
Triplophysa huapingensis (Zheng L. P., 2012)	Huaping Village, Leye County, Guangxi Province
Triplophysa longipectoralis (Zheng L. P., 2009)	Xunle Township, Huanjiang County, Guangxi Province
Triplophysa macrocephala (Yang J., et al., 2012)	Bawei Township, Nandan County, Guangxi Province

Table 1 (continued): The species distribution of the typical genus *Triplophysa* in China.

Trjplophysa lihuensis (Wu T. J., et al., 2012)	Lihu Town, Nandan County, Guangxi Province
Triplophysa huanjiangensis (Yang J., et al., 2011)	Chuanshan Town, Huanjiang County, Guangxi Province
Triplophysa langpingensis (unpublished)	Langping Township, Tianlin County, Guangxi Province
Triplophysa fengshanensis (unpublished)	Lintong Township, Fengshan County, Guangxi Province
Triplophysa dongganensis (unpublished)	Tonggan Village, Chuanshan Town, Huanjiang County, Guangxi Province
Triplophysa tianlinensis (Li J., et al., 2017a)	Tianlin County, Guangxi Province
Triplophysa luochengensis (Li J., et al., 2017b)	Luocheng County, Guangxi Province
Triplophysa rosa (Huang J., et al., 2013)	Stove Town, Wulong County, Chongqing City
Triplophysa xiangxiensis (He L., et al., 2006)	Huoyan Township, Longshan County, Xiangxi Autonomous Prefecture, Hunan Province

MATERIAL AND METHODS

Triplophysa lewangensis, collecting place Lewang Town, Wangmo County, Guizhou Province, specimen number 28.

Triplophysa nasobartula, collecting place Lijiangshui Cave, Jiarong Town, Libo County, Guizhou Province, specimen number 22.

Triplophysa zhenfengensis, collecting place Shuangrufeng Scenic, Zhenfeng County, Guizhou Province, specimen number 12.

Determination and selection of adult individuals, according to the report of Wang and Li (2001), the total length of 34 mm, males with atypical cave types over 28 mm have secondary sexual characteristics. Therefore, this study selected specimens with body length greater than 30 mm as comparatively mature individuals.

Three types of *Triplophysa* specimens with body length greater than 28 mm were examined.

No padding and spines were found on the lateral side of all *Triplophysa* crickets. Pectoral fins also found no thickened pads and spines. It was found that there are 17 males in *Triplophysa lewangensis*. Eleven *Triplophysa nasobartula* has nine males. 12 *Triplophysa zhenfengensis* has eight males, and four females. Three *Triplophysa* body length measurements were as is following: *Triplophysa lewangensis* body length 27.71-54.81 mm, full length 42.33-56.32 mm; *Triplophysa nasobartula* body length 50.70-91.31 mm, full length 62.46-109 mm; *Triplophysa zhenfengensis* body length 57.47-101.50 mm, full length 65.79-123.18 mm.

RESULTS AND DISCUSSION

Comparative results of morphological characteristics of the infraorbital line side of three species of genus *Triplophysa* in Guizhou Province.

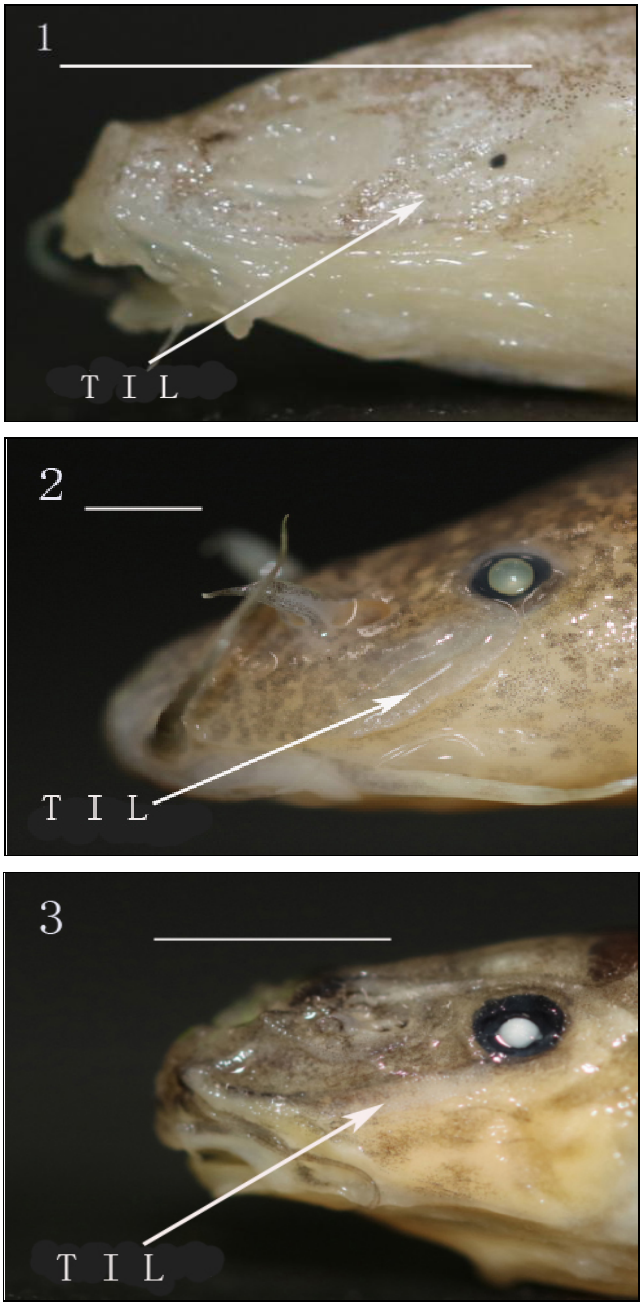

Figure 6: Infraorbital line; 1. *Triplophysa lewangensis*; 2. *Triplophysa nasobartula*; 3. *Triplophysa zhenfengensis*; Scalebars = five mm; TIL = the infraorbital line.

Comparison of morphological characteristics of pectoral fins of three kinds of genus caves in Guizhou Province.

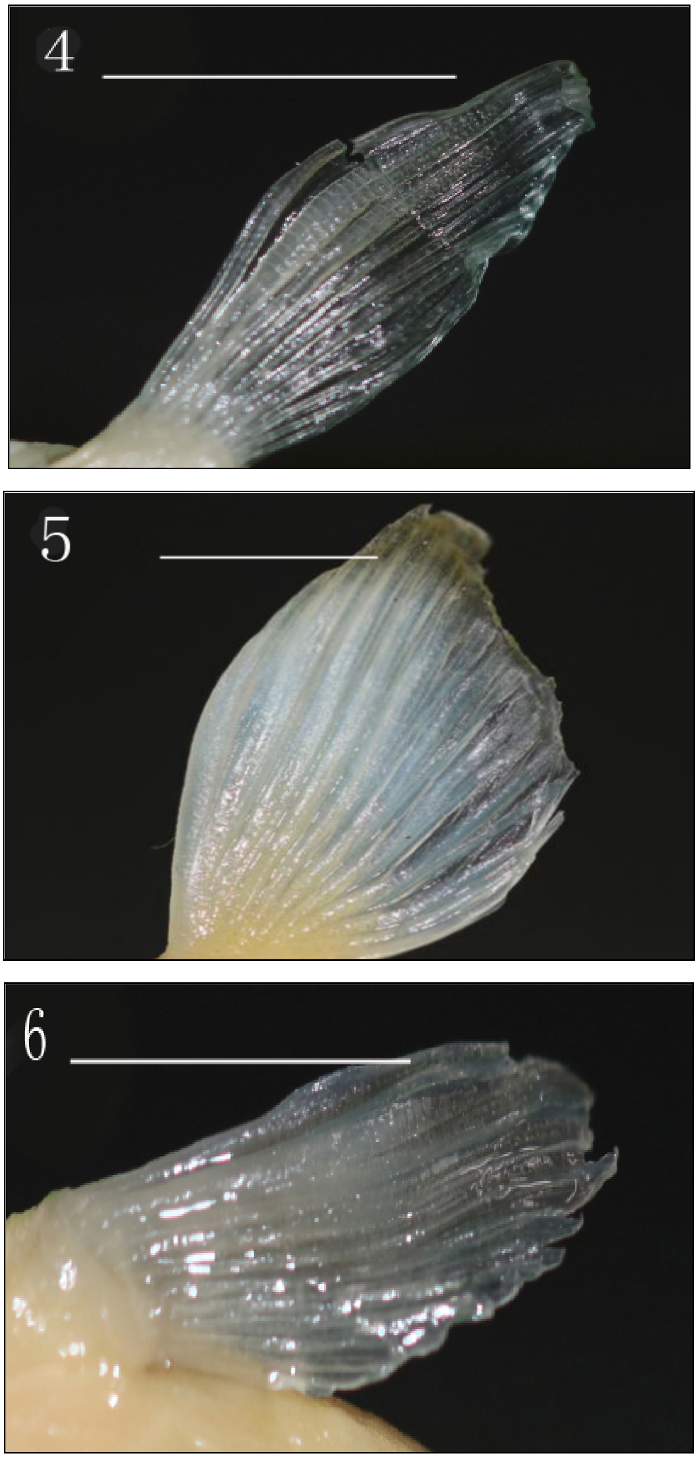

Figure 7: Pectoral fins; 4. *Triplophysa lewangensis*; 5. *Triplophysa nasobartula*; 6. *Triplophysa zhenfengensis*; Scalebars = five mm.

The secondary sexual characteristics of male individuals in three cave species of *Triplophysa* in Guizhou Province.

Among the three *Triplophysa* cave species with typical male individuals we observed: 1. *Triplophysa lewangensis* individual had smaller white transparent back with a little stain that does not recede, compared with the first two types of both sides of head lateral morphology. The subaxillary line tube is not obvious. There was no thickening of the upper and lower leaves of the male zygomatic line at the cheeks of the male, and no spines were distributed (Fig. 6). The thickened pectoral fins have disappeared.
The spines have also disappeared (Fig. 7). 2. The upper and lower mesophyll pads of the male *Triplophysa nasobarbatula*, and the inferior lateral line of male cheeks have disappeared. No spines distribution (Fig. 6). The thickened pectoral fins have disappeared, and the spines have disappeared (Fig. 7). 3. *Triplophysa zhenfengensis* male genital cheeks under the lateral line of the upper and lower leaves of the pad have disappeared; also, no spines distribution was observed (Fig. 6). The pectoral fin cushion has disappeared along with the spines (Fig. 7).

The sex determination of fish is very complicated. The current study on the sex determination of fish is still at an exploratory stage. For those who have obvious secondary sexual characteristics, wait until sexual maturity. And in the breeding season, we can accurately distinguish their sex by morphology. The disappearance of male secondary sexual characteristics in cave species will undoubtedly bring great difficulties to the population ecology studies of cave fishes. Therefore, it is necessary to study a new technical means to identify the gender of cave fish. At present, SD genes in fish with XX/XY sex determination system, five other SD-related genes, such as gsdf in *Oryzias luzonensis*, sox3 in *Oryzias dancena*, amhr2 in *Takifugu rubripes*, Amhy in *Odontesthes hatchery* and sdY in *Oncorhynchus mykiss*, were respectively identified from several teleost fish with XX/XY sex determination system (Mei and Gui, 2015). It is gradually progressing during the study of fish sex determination. But until now, the discovery of such a gene, which is a very stable characteristic of the sex determination of male fish, has not yet been established. Therefore, this work is very worthwhile to carry out.

According to Zhu Songquan’s research (1989), the surface species of the genus *Triplophysa* have the habit of chasing after breeding. It is presumed that the special structure of the male and pectoral fins contributes to the effective attachment of females in the flowing water environment and improves the fertilization rate. However, the disappearance of male secondary sexual characteristics in the typical cave species in *Triplophysa* is a reaction to the influence of the environment on the morphological characteristics of *Triplophysa*. Therefore, courtship behavior for typical cave fish is a very interesting issue.

CONCLUSIONS

Triplophysa cave fish species have lost the secondary sexual characteristics because of long-term living in the dark cave environment.

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HEAVY METAL CONCENTRATION IN EIGHT FISH SPECIES FROM EPE LAGOON (NIGERIA)

*Iyabode Olusola TAIWO *, Olaniyi Alaba OLOPADE ***
and *Nathanael Akinsafe BAMIDELE **

* Federal University of Agriculture IFSERAR, P. M. B., 2240, Abeokuta, Ogun State, Nigeria, NG-110212, Iomtai@yahoo.com, bamidelena@funnab.edu.ng
** University of Port-Harcourt, Choba, Department of Fisheries, P. M. B., 5323, Port-Harcourt, Rivers State, Nigeria, NG-500211, olaniyi.olopade@uniport.edu.ng

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KEYWORDS: fish muscle, heavy metals, maximum concentration, Epe Lagoon, Nigeria.

ABSTRACT

This research was undertaken to find out the levels of five heavy metals (Cu, Fe, Mn, Pb, and Zn) in the muscles of eight fish species from Epe Lagoon. The levels of heavy metals were determined by atomic absorption spectrophotometry after digestion of the samples using Kjldahl heating digester. The heavy metal concentrations among the fish species were statistically dissimilar ($P < 0.5$). The heavy metals of Pb, Fe, and Mn were above the FAO/WHO agreeable limits for human consumption.

ZUSAMMENFASSUNG: Schwermetallkonzentration in acht Fischarten der Epe Lagune (Nigeria).

Vorliegende Studie befasst sich mit den Ergebnissen einer Untersuchung, deren Ziel es war, die Höhe des Gehalts von fünf Schwermetallen (Cu, Fe, Mn, Pb und Zn) in acht Fischarten der Epe-Lagune zu bestimmen. Die Höhe des Schwermetallgehalts wurde mit Hilfe eines Atom Absorbtions-Spektrophotometers nach Digestion der Proben durch einen kjldahl geheizten Digester gemessen. Die Schwermetallkonzentration bei den Fischarten war statistisch unterschiedlich ($P < 0.5$). Die Pb-, Fe- und Mn- Konzentrationen lagen alle über den von der FAO/WHO akzeptierten Grenzwerten, die den Verzehr der Fische durch den Menschen erlauben.

REZUMAT: Concentrații de metale grele în opt specii de pești din laguna Epe (Nigeria).

Scopul prezentului studiu a fost determinarea gradului de contaminare cu cinci metale grele (Cu, Fe, Mn, Pb şi Zn) măsurat în muşchii a opt specii de pești din laguna Epe (Nigeria). Conținutul în metale grele a fost măsurat cu ajutorul unui spectrofotometru de absorbție atomică după digerarea probelor folosindu-se un aparat Kjldahl de digestie prin încălzire. Concentrația de metale grele la speciile de pești analizate a fost diferită din punct de vedere statistic ($P < 0.5$). Pb, Fe, and Mn au depășit la toate probele luate din pești valorile limită acceptate de FAO/WHO pentru consum alimentar.

INTRODUCTION

Heavy metal pollution is an important issue in a lot of aquatic and semi-aquatic habitats and the products obtained globally from them, particularly where there are industries which dispatch their waste into or close to the water bodies (Astratinei and Varduca, 2008; Zubcov et al., 2008; Iepure and Selescu, 2009; Aziz and Hashim, 2011; Akköz, 2016). Heavy metal pollution in the lagoons and estuaries in Nigeria has not been properly documented, including the fishery resources of this country.

Fish and fish products are an important part of a healthy diet, especially in developing countries, where it is a source of cheap animal protein. Fish also contain other essential nutrients, and they are low in saturated fat and contain omega three fatty acids (NSPFS, 2005).

Heavy metals are natural trace elements of the marine habitats, but they are also one of the most dangerous substances that could be accumulated in biota. Munoz-Olivas and Camara (2001) observed that commercially important fish species often live in coastal environments that contain high levels of heavy metals, which come from industrial and agricultural wastes or human activities. Marine organisms accumulate these metals from water, food, sediment and some suspended particulate materials (Kalay and Canli, 2000). It has also been observed that fish species accumulate heavy metals to concentrations many times higher than that present in the water or sediments in which they dwell (Khoshnood and Khoshnood, 2013). Therefore, they have been used for marine pollution monitoring (Agusa et al., 2005; Bat et al., 2012).

Humans who consume fish regularly may be exposed to relatively higher levels of heavy metals by eating fish contaminated with heavy metals. Edible fish are often contaminated with heavy metals as a result of agricultural technology, industrial pollution, sewage drainage and other sources, which could affect human health and cause chronic diseases when these metals exceed the tolerable limits (Zyadah and Abdel-Baky, 2000).

This study, therefore, assessed the levels of five heavy metals, zinc (Zn), lead (Pb), copper (Cu), iron (Fe), and manganese (Mn) in the sediment and muscles of eight fish species (*Alestes* sp., *Mormyrus* sp., *Tilapia zillii*, Tilapia "wesafu" *Gymnarchus niloticus*, *Sphyreana* sp. *Polydactilus quadrifilis* and *Chrysichthys nigrodigitatus*) from Epe Lagoon, Nigeria. The study also assessed whether the consumption of these fish species from Epe Lagoon could exceed the established total weekly intake of metals.

Epe Lagoon (Fig. 1) lies between 03°50' – 04°10'N and 05°30' – 05°40'E. It has a surface of over 243 km^2 and is located between two other lagoons, the Lekki Lagoon (freshwater) in the east and Lagos Lagoon (brackish water) in the west. The lagoon is connected to the sea through the Lagos Harbour (Uwadie, 2010). This lagoon has a six m maximum depth; still, some sectors of the lagoon are comparatively shallow with a minimum depth of one m. The vegetation surrounding the lagoon is of the mangrove swamp type (Fashina-Bombata and Megbowon, 2012).

MATERIAL AND METHODS

Fish samples were collected from catches of local fishermen in Ijede, Ikose, and Ejrin all in Epe Lagoon area.

All the fish samples were transported immediately to the laboratory in ice boxes.

All the sediments samples were collected from the three stations using core sampler and transferred into polyethylene bags and later transported to the laboratory in ice boxes.

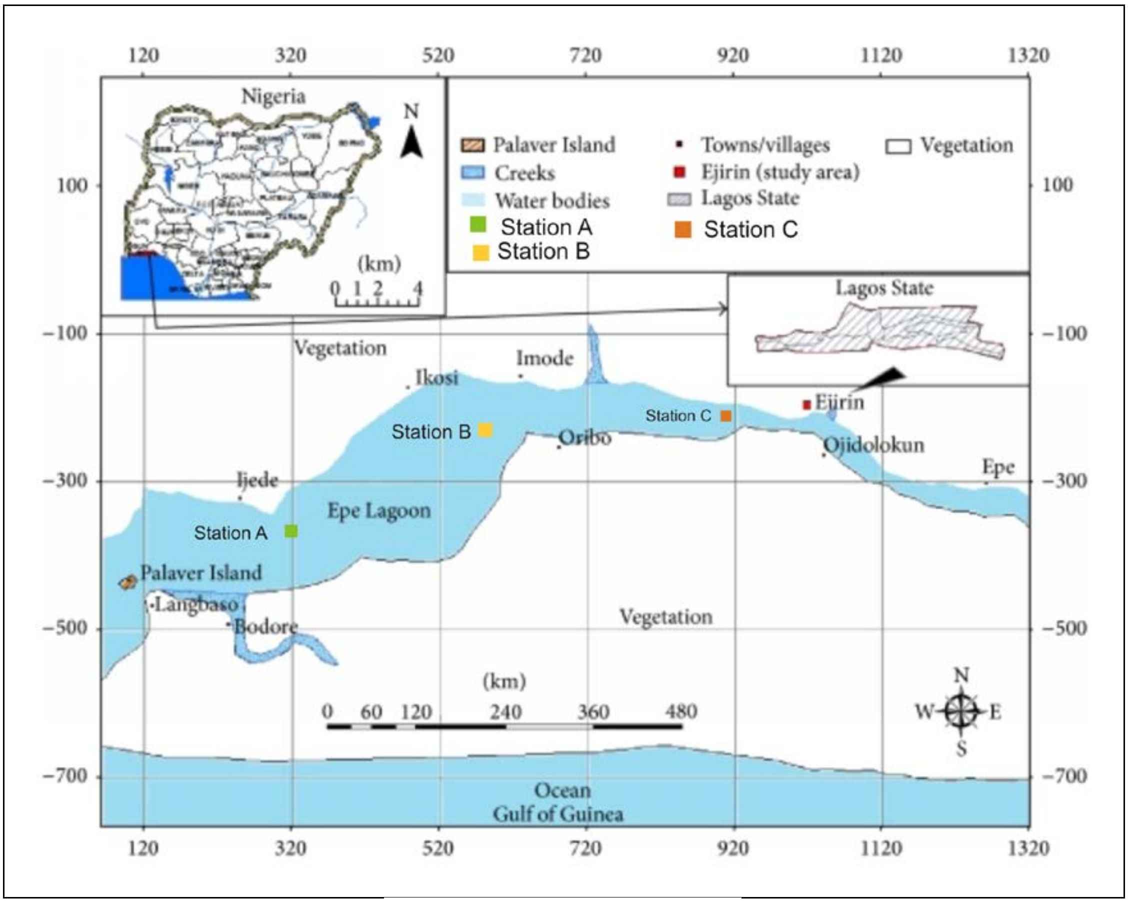

Figure 1: Map of Epe Lagoon.

The fish muscles analysed were collected in triplicates from different parts of the fish body. The fish samples were oven dried at 105^{o}C for about 12 hours. All glassware used was washed and rinsed with distilled water several times, then washed in 10% HCl before use to avoid contamination.

The fish samples were digested using the wet digestion procedure according to Asegbeloyin et al. (2010). Muscle tissues were taken from various parts of each fish and homogenized. Four g of the homogenized muscles (without skin) were taken from each specimen and placed in 300 ml Kjldahl digestion tubes. 10 g of each dried sample was digested in 60 ml of freshly prepared 1:1 HNO_3/H_2O_2 solution at 160°C on a hot plate for about one hour until the contents were reduced to five ml each. The residue was then filtered separately with Whatman filter paper (number 42) and the filtrates transferred to a standard flask and distilled, de-ionized water was added to achieve 25 ml. The Atomic absorption spectrometer (AAS) (Analyst 200, Perkin Elmer) was then used to determine the concentrations of Pb, Mn, Cu, Fe, and Zn in the fish samples.

Laboratory blanks were prepared to ensure that the samples and chemicals used were not contaminated. They were analysed by atomic absorption spectrophotometry before the samples, and their values were subtracted to ensure that the equipment read only the exact values of heavy metals. Each set of digestion had its own acid blank and was corrected by using its blank. The sediments were dried at 105ºC, grinding, sieving and about (1.0 gm) of the most fine dried grains were digested with a mixture of concentrated H_2O_2, HCl, and HNO_3 as the method described in Page et al. (1982) and preserved in a refrigerator until analysis.

SPSS statistical software was used to obtain indices like mean, standard deviation, and parameters correlation. The mean differences were divided at $P < 0.05$ levels of significance.

RESULTS

Heavy metal concentration in sediments and fish species

The mean heavy metals concentrations in the sediments and fish species are presented in table 1. Heavy metals concentration in sediment samples were in the range of 1.26 ± 0.01 recorded for Mn to 10.73 ± 0.04 recorded for Zn. These values were all below the permissible limits in soils. The results of heavy metals in the fish samples reveal that Zn recorded the highest values in all the fish species followed by Fe, Pb, Cu and Mn (Tab. 1).

There were slight differences among the heavy metal concentrations of the eight fish species sampled. The herbivore, *Polydactylus quadrifilis*, (Shiny nose) had the lowest concentration of metal in its muscle. None of the fish species sampled had a consistently high level for all the five metals analysed. *Gymnarchus niloticus* had the highest levels of zinc; Tilapia "wesafu" had the highest levels of lead and copper; *Mormyrus* sp. had the highest levels of iron and *Chrysichthys nigrodigitatus* had the highest levels of manganese. The overall average concentrations of Zn, Pb, Cu, Fe, and Mn in the muscles of the eight fish species were 11.32; 4.80; 2.76; 7.46 and 1.13 respectively. This gave a ranking of: Zn > Fe > Pb > Cu > Mn. The metal levels in the muscles of each fish species gave a similar ranking.

G. niloticus had a significantly higher ($P < 0.05$) mean concentration of Zn (15.78 ± 0.04) than all other species, followed by T. "wesafu" with an average concentration of 13.13 ± 1.10. The average concentration of Zn in the fish muscles was in the order *Mormyrus* sp. > *C. nigrodigitatus* > *Sphyreana* sp. > *Alestes* sp. > *T. zilli* > *P. quadrifilis* with values of 12.39 ± 1.58, 11.35 ± 0.05, 10.81 ± 0.03, 9.79 ± 0.05 respectively (Fig. 2).

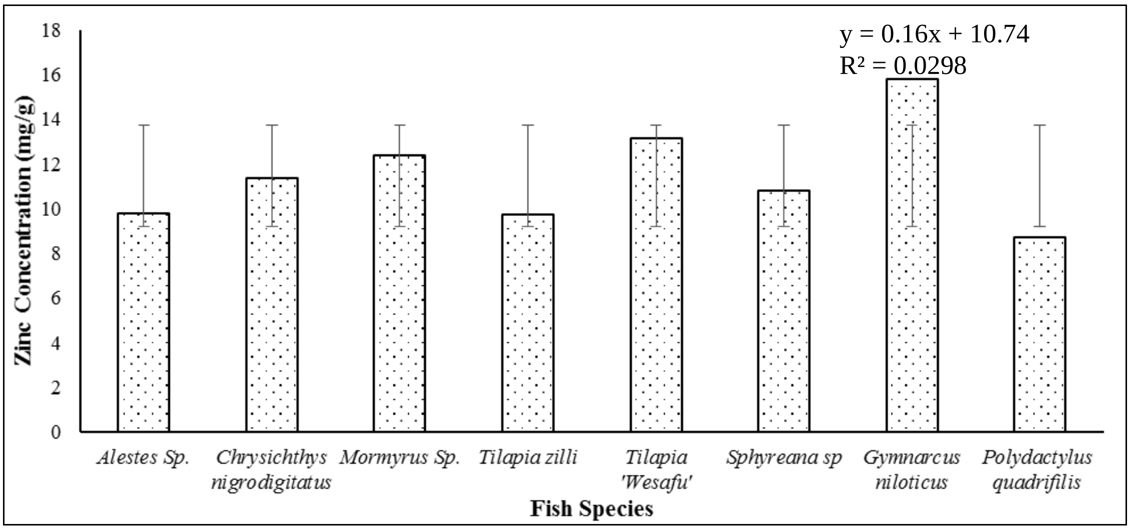

Figure 2: Concentration of Zn in the muscles of fish species.

Lead was detected in all eight fish species and higher than the WHO/FAO maximum limit of two mg/g. The concentration of Pb was significantly ($P < 0.05$) higher in T. "wesafu" with an average value of 5.88 ± 0.10 than the other fish species. The average concentration of Pb was in the following order *Mormyrus* sp. > *G. niloticus* > *C. nigrodigitatus* > *Sphyreana* sp. > *Alestes* sp. > *T. zilli* > *P. quadrifilis* with values of 5.83 ± 0.17, 5.69 ± 0.01 4.62 ± 0.02, 4.11 ± 0.12, 3.84 ± 0.21 respectively (Fig. 3).

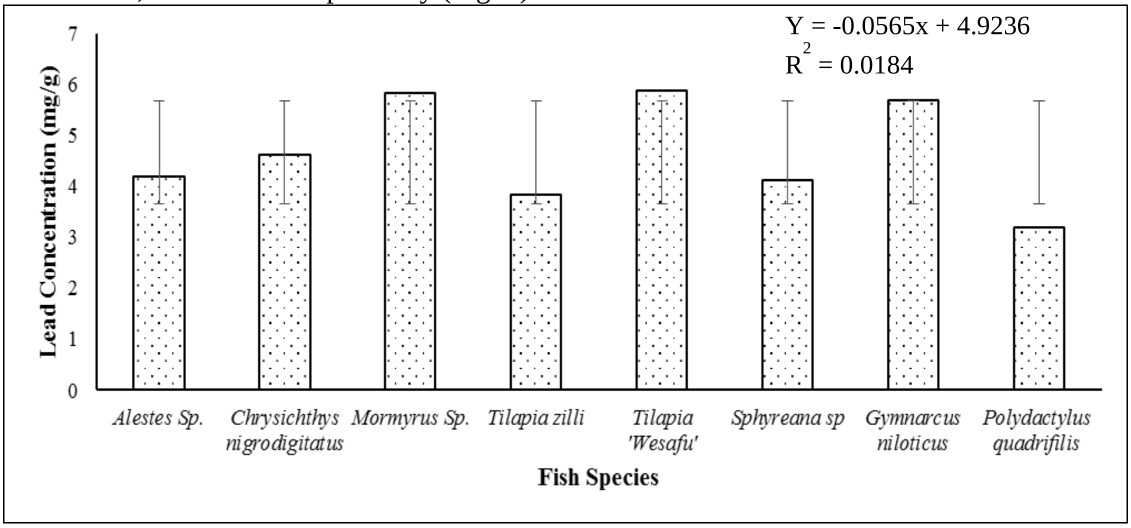

Figure 3: Concentration of lead in the muscles of fish species.

Cu concentration was significantly ($P < 0.05$) higher in T. "wesafu" than the other fish species with an average value of 3.31 ± 0.07 followed by *G. niloticus* with an average value of 2.97 ± 0.00. The average concentration of Cu in the muscles of the remaining fish species was *Mormyrus* sp. = *C. nigrodigitatus* > *Sphyreana* sp. > *Alestes* sp. > *T. zillii* > *P. quadrifilis* with values of 2.94 ± 0.34, 2.82 ± 0.00, 2.57 ± 0.14, 2.08 ± 0.03 and 2.04 ± 1.07 respectively (Fig. 4).

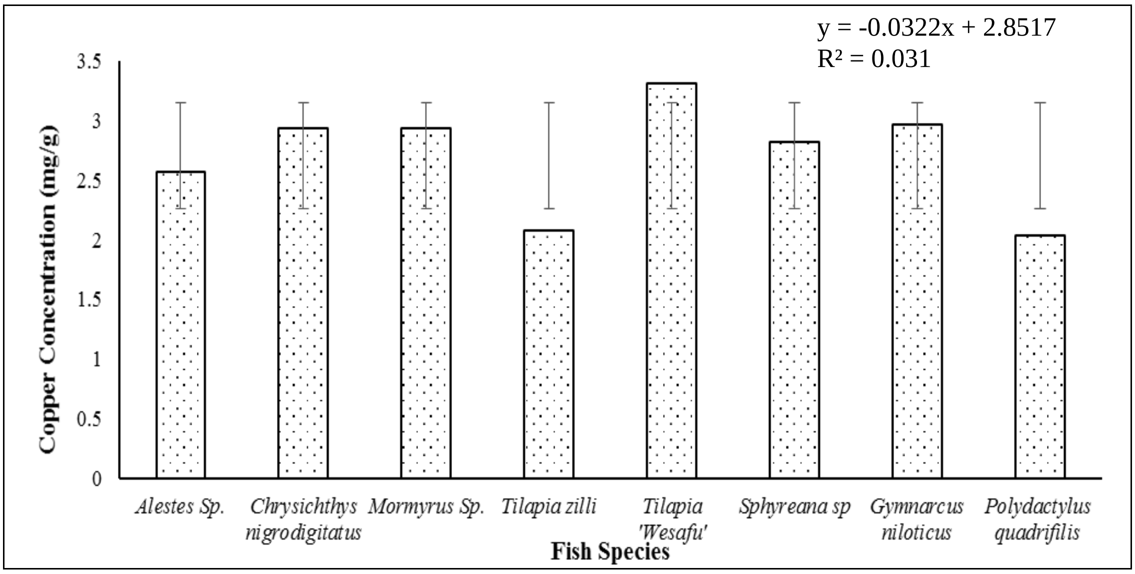

Figure 4: Concentration of copper in the muscles of fish species.

The average concentration of Fe was in the following order: *Mormyrus* sp. > *G. niloticus* > *C. nigrodigitatus* > T. "wesafu" > *Sphyreana* sp. > *T. zilli* > *Alestes* sp. > *P. quadrifilis*, with average values of 8.69 ± 0.09, 8.11 ± 0.01, 8.02 ± 0.02, 7.75 ± 0.37, 7.28 ± 0.08, 7.27 ± 0.16, 6.80 ± 0.03 and 4.37 ± 2.48 respectively. The average concentration of Fe in *Mormyrus* sp. was significantly (P < 0.05) higher than in the other fish species sampled (Fig. 5).

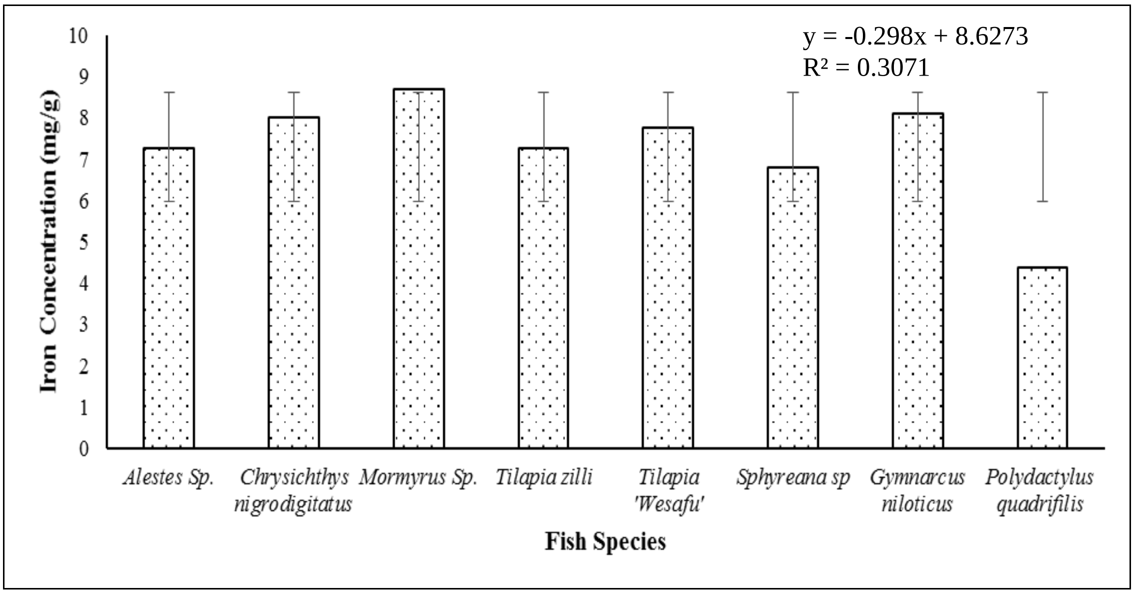

Figure 5: Concentration of iron in the muscles of fish species.

Average concentration of Mn was in the following order: *C. nigrodigitatus* > T. "wesafu" > *Mormyrus* sp. > *G. niloticus* > *Sphyreana* sp. > *Alestes* sp. > *T. zillii* > *P. quadrifilis* with the following values: 1.24 ± 0.24, 1.23 ± 0.03, 1.17 ± 0.08, 1.15 ± 0.00, 1.11 ± 0.00, 1.05 ± 0.04, 1.02 ± 0.05 and 0.87 ± 0.25 respectively. There were significant (P < 0.05) differences in Mn concentrations among fish species (Fig. 6).

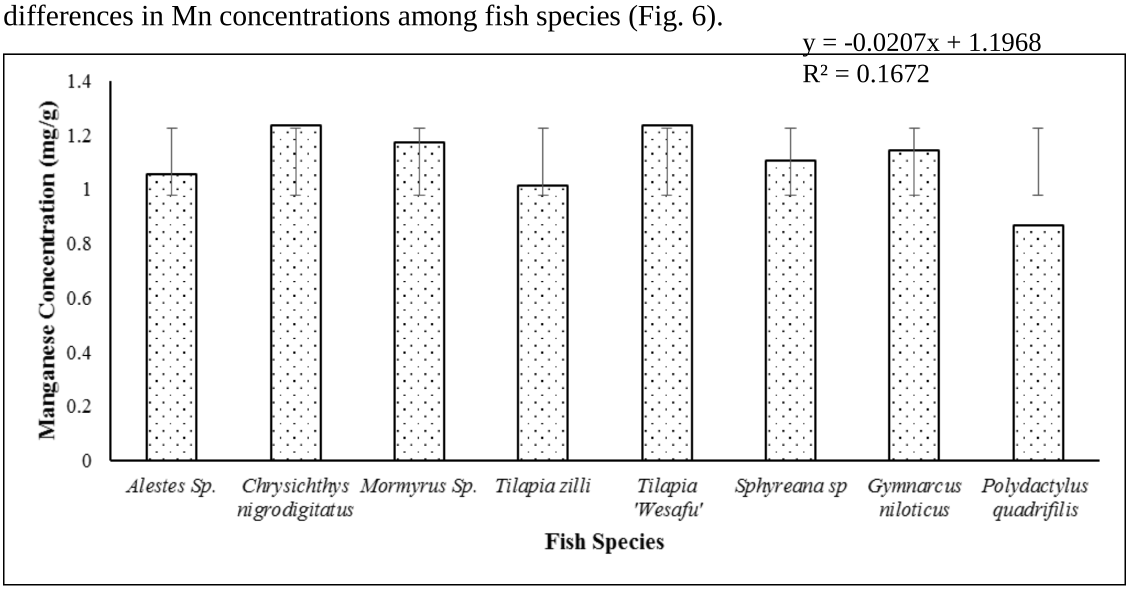

Figure 6: Concentration of manganese in the muscles of fish species.

Health-risk assessment for fish consumption

Table 2 shows the estimated average daily consumption and total health quotient (THQ) of heavy metals per person based on an average weight of 70 kg. The estimated daily intake of Zn, Pb, Cu, Fe, and Mn in all fish species in this study ranged from 0.0-0.023, 0.001-1.955, 0.0-0.052, 0.0-0.436, and 0.0-0.003 lg/day/person, respectively. The average daily intake of metals through fish consumption was as follows: Zn > Mn > Cu > Fe > Pb.

DISCUSSION

Heavy metal concentration in fish species

Bahnasawy et al. (2009a) observed that fish muscle is not an active tissue in accumulating heavy metals, but it is the most edible part of the fish that is consumed. It has also been documented that some fish in polluted water bodies may accumulate substantial amounts of metals in their muscles, and this could exceed the maximum acceptable limits (Kalay and Canli, 2000). An appreciable amount of scientific references is accessible on heavy metal concentrations in fish but not much in the various fish species from Epe Lagoon. This research dealt with eight different fish species from this lagoon. This study revealed that the eight different fish species had different mean concentrations of heavy metals in their muscles as shown in table 1. Heavy metal bioaccumulation in fish is species-dependent. Feeding habits and habitats where the species dwell are also linked to heavy metal accumulation in fish muscles (Al-Majed and Preston, 2000; Yilmaz, 2009). The variations of heavy metal concentrations in the different fish species could also be attributed to size (body weight and length), gender, age and growth rates, types of tissues analysed, and physiological conditions (Canli and Atli, 2003; Raja et al., 2009). The variation in the water body due to the type and level of water pollution, chemical form of metal in the water, water temperature, pH value, concentrations, oxygen concentration, and water transparency are also factors that influence heavy metal in the different fish species. The geographical location and season of catch could also give different metal concentrations even in the same fish species (Dural et al., 2007; Bahnasawy et al., 2009b).

The eight fish species contained Pb, Fe, and Mn above the acceptable limits recommended for human consumption as shown in table 1. Zn concentrations ranged from 8.73 mg/g to 15.78 mg/g among the fish species with a mean concentration of 12.26 mg/g. This concentration is much higher than that recorded by Hossam et al. (2012) from Gaza fishing harbour in the Mediterranean Sea along the Gaza coast, Palestine, in which the concentrations of zinc ranged from 13.56 µg/g to 40.43 µg/g with mean concentration of 26.9 µg/g (0.0269 mg/g). These levels of Zn concentration are much higher than the tolerable weekly intake (PTWI) of seven mg/kg body weight equivalent to 490 mg/week for a 70 kg adult (FAO/WHO, 2004). *G. niloticus* had the highest mean concentrations of heavy metals, potentially because it is at the peak of the food chain and a heavy carnivore. Taiwo et al. (2016) observed a similar seasonal trend in the same water body with regards to heavy metals in the muscle of *G. niloticus*, though in their study, T. “wesafu” had the highest metal content. There is no documented literature on the heavy metal content of *G. niloticus* in other water bodies in Nigeria. This fish species is indigenous to Africa and the only species in its family Gymnarchidae. The relatively undocumented T. “wesafu” had the second highest concentrations of Zn and Pb followed by *Mormyrus* sp. In a previous study, Taiwo et al. (2012) observed that T. “wesafu” raised in a rizi-pisciculture system were low in heavy metal content. However, a similar study conducted by Taiwo et al. (2016) on seasonal variation of heavy metals in Epe Lagoon showed that Tilapia “wesafu” had the highest concentration of heavy metals, indicating that this water body is relatively polluted (Hamza-Chaffai et al., 1996), at least in the area where they were caught. Elnabris et al. (2013) noted that due to interspecific differences, when assessing the levels of heavy metals in fish, it should be compared to results of the same species caught within the same water body.

The high levels of heavy metals in *Mormyrus* sp. are similar to the findings of Nwani et al. (2009) in Anambra River. This high metal content could also be influenced by its feeding habits, as it feeds on detritus, diatoms, algae, and microscopic invertebrates. It has been observed that animals which feed on such usually have high metal concentrations in their muscles (Kilgour, 1991).

The provisional tolerable weekly intake (PTWI) for lead is 0.3 mg/kg body weight (FAO/WHO, 2004). This result revealed that fish in Epe Lagoon contained lead above the FAO/WHO safe standard level for consumption. This is contrary to Stancheva et al. (2013) on heavy metal and proximate composition of Black Sea sprat and Goby where the concentration of lead is 0.08 mg/kg w. w. (wet weight) and 0.03 mg/kg w. w. respectively, which is lower than the concentration of Pb found in fishes from Epe Lagoon.

The proposed acceptable limits of Cu concentrations in fish species as recorded by FAO/WHO (1989), EU (2001) and Turkish guidelines (TFC, 2002) is about 30 μg/g (0.03 mg/g). It is prevailing the fact that, the concentrations of Cu found in tissues of all the fish species in the present study are over the recommended value. This finding agrees with previous observations recorded by Adedeji and Okocha (2011) on bioconcentration of heavy metals in prawns and water from Epe Lagoon and Asejire River in Southwest Nigeria that Epe Lagoon contains copper above the acceptable limit.

Mormyrus sp. had the highest concentration of iron (8.69 mg/g) while *Polydactylus quadrafilis* had the lowest concentration (4.37 mg/g). However, the maximum limit recommended by the IAEA (2003) is 146 mg/kg indicating that the concentrations of iron in the muscle of the fish species were far above the acceptable limits. The high levels of Fe in the muscle of the fishes analysed concur with the previous findings on assessment of heavy metals in muscles and bones of fish and shellfish from Epe Lagoon by Taiwo et al. (2016) where the concentration of Fe was over the maximum recommended level of WHO.

The concentrations of Mn ranged from 1.24 mg/g to 0.87 mg/g in the fish from Epe Lagoon. The permissible limit of manganese concentrations in fish by the Turkish Food Codes (TFC) is about 20 μg/g (TFC, 2002; Dural et al., 2007; Yilmaz, 2009; Türkmen et al., 2009). The concentration of Mn found in the tissues of the fish species was least in *Polydactylus quadrafilis*, which was higher than the acceptable TFC limit. The results of this study differ from that obtained by Taiwo et al. (2016) on the concentration of Mn from the same lagoon. However, Taoheed and Said (2014) observed very low levels of manganese in *Alestes* sp. and *T. zillii*, which were below the tolerable acceptable limits of metal consumption in river Challawa in Kano State, Nigeria. The metal concentrations levels of Fe, Pb, Cu, and Zn in *Alestes* sp. and *C. nigrodigitatus* from Afikpo, Ebonyi State, Nigeria were comparable to this study, which were above the maximum permissible limit (Oti-Wilberforce et al., 2016).

Demirezen and Uruc (2006) observed that Cu, Mn, Fe, and Zn are essential elements required by a wide variety of enzymes, other cell components, and vital functioning in all living organisms, but very high intakes can cause health problems. Lead has no biological role and is toxic to humans and other living organisms at very low concentrations. In this study, the overall average concentrations of metals were in the order of Zn > Fe > Pb > Cu > Mn. This was at variance with the study of Elnabris et al. (2013) where the concentrations of essential elements were higher than the non-essential elements.

Heavy metal concentrations vs. international dietary standards and guidelines

There are Nigerian food safety standards, but none are currently available regarding heavy metal concentration in fish. Therefore, the results obtained in this study for muscle samples of fish were compared with limit values and guidelines found in the literature. The levels of Zn and Cu were lower than the maximum levels and guidelines values described in the literature. The levels of Pb, Fe, and Mn tested in the muscles of the eight fish species were higher than the limit values for fish proposed by the European Community (EU, 2001). As a result of such high levels, it can be ascertained that the fish species in Epe are not entirely fit for human consumption.

Table 1: Heavy metal concentration in fish species from Epe Lagoon.

Fish species	Zn	Pb	Cu	Fe	Mn
Sediment	10.73 ± 0.04^{bc}	5.76 ± 0.03^{a}	3.32 ± 0.02^{a}	6.84 ± 0.06^{b}	1.26 ± 0.01^{a}
Alestes sp.	9.79 ± 0.05^{bc}	4.19 ± 0.29^{bc}	2.57 ± 0.14^{ab}	7.27 ± 0.16^{ab}	1.05 ± 0.04^{ab}
Chrysichthys nigrodigitatus	11.35 ± 0.05^{bc}	4.62 ± 0.02^{ab}	2.94 ± 0.01^{a}	8.02 ± 0.02^{ab}	1.24 ± 0.24^{a}
Mormyrus sp.	12.39 ± 1.58^{abc}	5.83 ± 0.17^{a}	2.94 ± 0.34^{a}	8.69 ± 0.09^{a}	1.17 ± 0.08^{ab}
Tilapia zillii	9.71 ± 0.35^{bc}	3.84 ± 0.21^{c}	2.08 ± 0.03^{b}	7.28 ± 0.08^{ab}	1.02 ± 0.05^{ab}
Tilapia “wesafu”	13.13 ± 1.10^{ab}	5.88 ± 0.10^{a}	3.31 ± 0.07^{a}	7.75 ± 0.37^{ab}	1.23 ± 0.03^{a}
Sphyreana sp.	10.81 ± 0.03^{bc}	4.11 ± 0.12^{bc}	2.82 ± 0.06^{ab}	6.80 ± 0.03^{b}	1.11 ± 0.12^{ab}
Gymnarcus niloticus	15.78 ± 0.04^{a}	5.69 ± 0.01^{a}	2.97 ± 0.06^{a}	8.11 ± 0.01^{ab}	1.15 ± 0.03^{ab}
Polydactylus quadrifilis	8.73 ± 4.04^{c}	3.19 ± 1.94^{c}	2.04 ± 1.07^{b}	4.37 ± 2.48^{c}	0.87 ± 0.25^{b}

* Means with different superscript along same column are significantly different ($P < 0.05$),
* ± value is the standard deviation.

Table 2: Comparison of heavy metals concentration in fish and Total Health Quotient.

Metal	Concentration (mg/kg)	EDI (mg/kg/person)	RDDA (mg/day/person)	THQ
Zn	12.225	0.0-0.023	70	0.019
Pb	5.755	0.001-1.955	0.25	1.715
Cu	3.726	0.0-0.052	0.35	0.044
Fe	7.616	0.0-0.436	56	0.404
Mn	1.436	0.0-0.003	9.8	0.002

* EDI – Estimated daily consumption RDDA – Recommended daily dietary allowance THQ – Total health quotient.

CONCLUSIONS

This study has provided information on the heavy metal concentrations on sediment and eight fish species from Epe Lagoon. The study indicated variations on the levels of heavy metals investigated (Zn, Fe, Pb, Cu, and Mn). Zn recorded the highest values in all the fish species followed by Fe, Pb, Cu, and Mn. *G. niloticus* had highest level of heavy metals concentration and *P. quadrafilis* had the lowest.

The concentration of the heavy metals tested in the muscles of the fish species from Epe Lagoon, Lagos State were above the recommended maximum acceptable limits in fish food consumption. Therefore, these fishes should not be eaten regularly or in large quantities, as it could be a source of health concern. It is essential that the PTWI of these metals is not exceeded. To assess public health risk of the Epe Lagoon fish consumption, comparison of metal levels in muscles of the current study with the maximum permissible limits (MPL) for human consumption established by different organizations was made.

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DE GRUYTER OPEN

GOBIO GENUS SPECIES INTEGRATED MANAGEMENT SYSTEM – TÂRNAVA RIVERS STUDY CASE (TRANSYLVANIA, ROMANIA)

*Angela CURTEAN-BĂNĂDUC *, Cristina-Ioana CISMAŞ ** and *Doru BĂNĂDUC ***

* "Lucian Blaga" University of Sibiu, Faculty of Sciences, Dr. Ion Raţiu Street 5-7, Sibiu, Sibiu County, Romania, RO-550012, angela.banaduc@ulbsibiu.ro, cristha_83@yahoo.com
** "Lucian Blaga" University of Sibiu, Applied Ecology Research Center, Dr. Ion Raţiu Street 5-7, Sibiu, Sibiu County, Romania, RO-550012, ad.banaduc@yahoo.com/Broward College, 3501 SW Davie Road, Davie, Florida, USA, dbanaduc@broward.edu

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KEYWORDS: *Gobio kessleri, Gobio albipinnatus, Gobio gobio*, habitat needs, human activities preassures and threats, management, lotic habitats improvement, Târnava Mare River, Târnava Mică River, Târnava River, Transylvania, Romania, European Union.

ABSTRACT

The lotic habitats quality indicative congeners species *Gobio gobio, Gobio kessleri* and *Gobio albipinnatus* populations' dynamic in time (2004-2019) and space revealed a decreasing trend in these rivers ecological status. The ADONIS:CE tool has been used to build a backing management system model, based on these indicative fish species habitat needs, indicators for favourable conservation status, pressures and threats. This management system implementation in the field will favour the amelioration of lotic habitats and the ecological status recovering of two of the local fish species of conservative interest (*G. kessleri* and *G. albipinnatus*).

RÉSUMÉ: Un système de gestion intégrée pour les espèces du genre Gobio – étude de cas pour les rivières Târnave (Transylvanie, Roumanie).

La dynamique spatio-temporelle (2004-2019) des populations des espèces congénères indicatrices de la qualité des habitats *Gobio gobio*, *Gobio kessleri* et *Gobio albipinnatus* (le changement des zones piscicoles caractéristiques des rivières Târnava Mare et Târnava Mică) a relevé une tendance à la dégradation de l'état écologique de ces rivières. Nous avons utilisé l'instrument ADONIS:CE pour concevoir un modèle de gestion intégrée, base sur les besoins et habitats des ces espèces (indicateurs pour un statut favorable de conservation), sur les pressions et menaces. La mise en pratique de ce système de gestion favorisera l'amélioration des habitats lotiques et le retour à l'état favorable de conservation pour les populations locales des deux espèces de poissons d'intérêt conservatif (*G. kessleri* et *G. albipinnatus*).

REZUMAT: Sistem integrat de management pentru speciile genului Gobio – studiu de caz râurile Târnave (Transilvania, România).

Dinamica în timp (2004-2019) şi spaţiu a populaţiilor speciilor congenere indicatoare a calităţii habitatelor *Gobio gobio, Gobio kessleri* şi *Gobio albipinnatus* (schimbarea zonelor ihtiologice caracteristice în râurile Târnave) relevă o tendinţă descrescătoare a stării ecologice a acestor râuri. A fost utilizat instrumentul ADONIS:CE pentru a construi un model de sistem de management, bazat pe necesităţile de habitat ale acestor specii (indicatori pentru un statut favorabil de conservare), pe presiuni şi ameninţări. Implementarea acestui sistem de management va favoriza ameliorarea habitatelor lotice şi refacerea stării favorabile de conservare pentru populaţiile locale ale celor două specii de peşti de interes conservativ (*G. kessleri* şi *G. albipinnatus*).

INTRODUCTION

The regular streams and rivers long-term monitoring activities which depends mainly on assessment of physico-chemical elements, can furnish only a partial view on the ecological conditions at the moment of sampling and usually fail to detect long term ecological problems (e.g. habitat fragmentation and alteration, pollution, etc.), and have to be supplemented with different taxa assessment and monitoring; fish being one of the most appropriate such taxa (Joy and Death, 2003, 2004; Jeeva et al., 2011; Potyó and Guti, 2012; Khoshnood, 2014; Rumana et al., 2015; Bănăduc et al., 2016a; Radhi et al., 2017; Kruk et al., 2017).

In the Lower Danube Basin, but not only, the fish can be one of the most important taxonomic group used for lotic systems ecological assessment and monitoring (Staicu et al., 1998; Bănăduc and Curtean-Bănăduc, 2002; Vassilev and Botev, 2008; Momeu et al., 2009; Trichkova et al., 2009; Florea et al., 2014; Bănăduc et al., 2014; Năstase and Oţel, 2017; Kruk et al., 2017). Among fish there are some taxa with particular and significant high ecological indicative values, the *Gobio* species being a very good example in this respect, they are well known indicators for different rivers' ecological zones, zonation based on these species relative abundance, each river being characterised by different *Gobio* species/*Gobio*-zones and/or another sequence of these zones (Bănărescu, 1956, 1964, 2000).

Gobio uranoscopus is the most rheophilic species, populating the sub-montane stony sectors of lotic ecosystems, where the water movement is rapid, at a velocity of 70-115 cm/sec. *Gobio kessleri* inhabits sandy stretches of lotic ecosystems, usually preferring water movement of 45 to 65 cm/sec in lowlands. *Gobio albipinnatus* lives in places with even slower running water, with movement ranging between 28 and 45 m/sec and sediments consisting of fine sand often mixed with mud and/or clay, but never mud only. *Gobio gobio* is a relatively common species, occupying diverse categories of lotic habitats among other brooks downstream the lower trout zone, as well as slow-flowing lotic habitats. It can also be found in dam lakes; this fish species is more common in the sub-mountain than in the lowland stretches of large lotic ecosystems but it will choose the sectors with slow-moving water, preferring stagnant water sectors, etc. It is the less rheophilic of these *Gobio* species and also the most resistant to pollution. Based on these specific ecological requirements of the *Gobio* species the Romanian rivers/lotic sectors in the Lower Danube Basin can be split/belong to eight different categories, with different ecologic characteristics. (Bănărescu, 1956, 1964; Bănăduc, 2007)

The studied Târnava Mare, Târnava Mică and Târnava rivers basin is characterised by three *Gobio* species zones, namely *Gobio kessleri*, *Gobio albipinnatus*, and *Gobio gobio* (Bănărescu, 1964; Bănăduc, 2005). The human impact (damming, pollution, water amount reduction, riverbed mineral overexploitation, poaching, etc.) has modified the distribution and local abundance of these three gudgeon species, namely the rarefaction of rheophilic species (*Gobio kessleri* and *Gobio albipinnatus*), favouring instead the ubiquitous species (*Gobio gobio*) (Bănăduc, 2005; Curtean-Bănăduc et al., 2001, 2007; Bănăduc and Curtean-Bănăduc, 2012).

Târnava River basin (Fig. 1) is located in the central part of the South-East Carpathian Mountains, in the inner Transylvania Depression, in the southern part of the Târnavelor Plateau. Lotic habitats vary from cool, clear, and forested headwater streams that have coarse volcanic bedrock with accentuated slopes in the mountainous area, transitional coarse substrates in the Sub-Carpathian area, to warmer, sluggish, meandering waters, with low slope gradients and sandy-silty substrates. (Tufescu, 1966; Roşu, 1980; Posea et al. 1983)

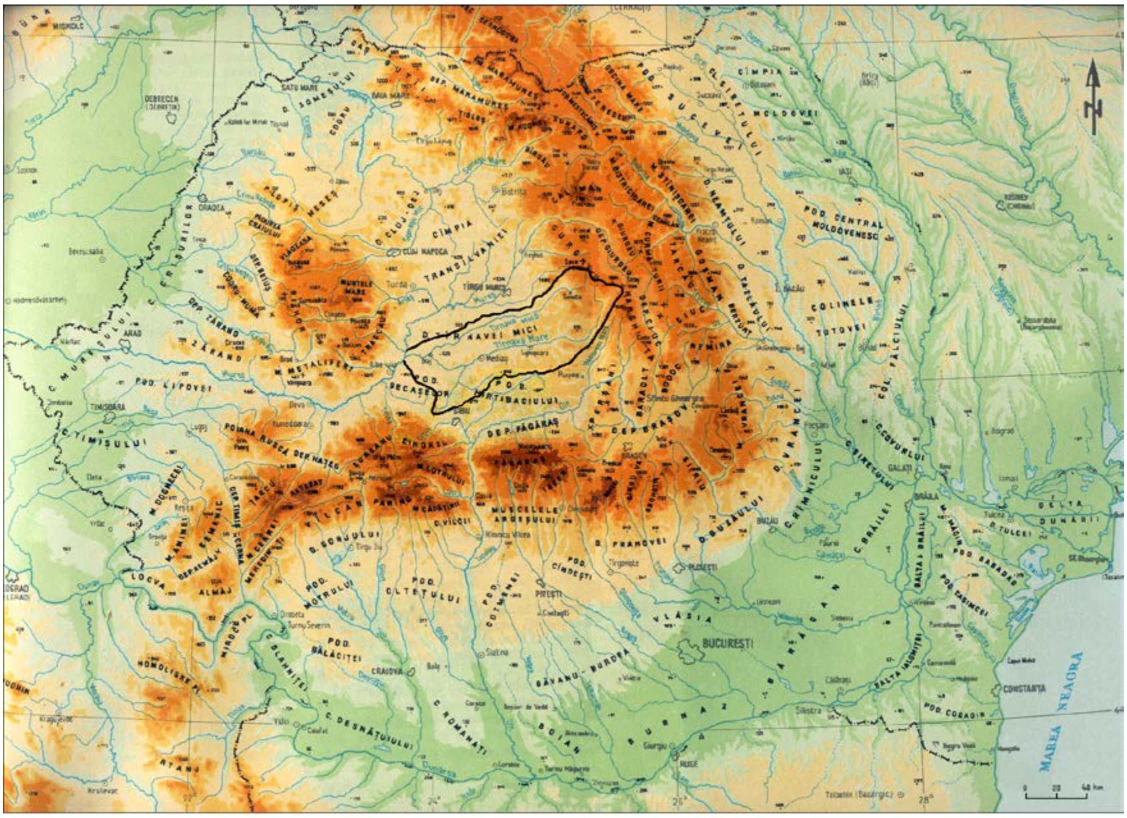

Figure 1: The Târnava River basin (Badea et al., 1983 – modified).

The European Union Habitats Directive, active since 1992, is used in order to shield the continuity of a high variety of plant and animal key species of the old continent. The joining countries have to secure that the indispensable environmental circumstances continue to exist, for the conservation of the species and habitats belonging to the Annex 2 of the Habitats Directive, along with the final goal of conserving (where it is achievable) and improving their ecological status. The studied basins are partially in the Sighişoara-Târnava Mare Natura 2000 site (ROSCI0227). The admission of the proposed Natura 2000 sites depend on clear criteria such as: permanent, pristine and healthy fish populations, typical habitats, favourable geographic positioning, and minimal human impact (Habitats Directive, 1992). A few key elements are promoted through the European Union Natura 2000 initiative to improve the condition of protected areas, including: elaborating specific information; widening the protected areas; institutional capacity progress; relevant specific assessment and monitoring; applicable management activities in complex management programs in the areas with preservation status and surrounding areas (Bănăduc, 2007; Bănăduc et al., 2012).

Gobio kessleri (Dybowski, 1862) (Ord. Cypriniformes; Fam. Cyprinidae), is under the protection of the Bern Convention Annex 3, Habitats Directive Annex 2, and the IUCN Red List. *Gobio albipinnatus* (Lukasch, 1933) (Ord. Cypriniformes; Fam. Cyprinidae) is under the protection of the Bern Convention Annex 3, Habitats Directive Annex 2, and IUCN Red List. (*, 1992; **, 1979).

Fish species communities in areas where *Gobio kessleri* and *Gobio albipinnatus* were found indicate a diminishing of these populations abundance as a result of human impact. This reduction highlights the diminishing of the natural status of the Târnava Watershed (Bănăduc, 2005; Bănăduc et al., 2016b). This pattern reflects a general degradation of lotic habitats, as a result of human activities and pressures (Bănăduc and Curtean-Bănăduc, 2012).

Stream and river ecosystems are very complex and each represent unique ecological systems (Vannote et al., 1980; Allan 1995; Angelier, 2003), and universal-like management schemes for entire basins are likely not be satisfactory (Boon and Raven, 2012).

In the best way possible, the main ecosystem elements of each basin should be evaluated at the starting point of any management construction procedure. Any universal-like management scheme needs to be adapted to maintain specific habitats and species that are present and need to thrive.

In nature conservation, modelling actions in order to achieve the desired results are for the most part used to acquire a "large-scale picture" of isolated systems and/or actions of distinct domains. The parts of these actions which belong to a process are beneficial in discerning different levels of proper species and habitat management. Using software such as ADONIS:CE, models that help understanding how area of interest management tasks can be developed. Models target on three areas of operation, all essential for the management of an area of interest: 1) to verify the actual status, 2) to evaluate the effects of changings and 3) to propose management systems to improve the present status in a desired way. Finally, various diagrams can be produced to present adapted management elements (Hall and Harmon, 2005).

This study, based on the decreasing favourable conservation status of *Gobio kessleri, Gobio albipinnatus* populations in Târnava Mare, Târnava Mică and Târnava rivers, highlights the human activities pressures and threats at the basin level. This study uses a particularly created management model to suggest management elements to sustain the improvement of the ecological status for the studied fish species by improving their habitats status. The obtained model integrates habitat initial conditions and specific indicators as a whole functional management system.

MATERIAL AND METHODS

An adaptable-responsive model of management was projected to build up a suitable management plan that would guard from harm the researched congeneric fish species that are present in the researched area lotic ecosystems, with a priority on indispensible processes. Here we used the software ADONIS:Community Edition (ADONIS:CE) created by the Business Object Consulting (BOC) Group. This software is a free and available type of ADONIS with few restraints (if we have to compare it with the commercial version); using a Business Process Model and Notation (BPMN), a standardized modelling language type those back recognizable processes to be prominenced. ADONIS:CE is usually used as an admission point to Business Process Management. Using compatible notation all these processes can be modelled. (***)

In order to create an overall vision of the *Gobio kessleri* and *Gobio albipinnatus* species – ecological requirements, possible indicators, their favorable conservation status, and management measures to maintain/achieve the favorable conservation state – we used ADONIS: Community Edition, software specialized in modeling business processes.

RESULTS AND DISCUSSION

Identified human pressures and threats

The main common pressures and threats on *Gobio kessleri* and *Gobio albipinnatus* populations are: changing/destroying characteristic aquatic habitats (higher or lower speed of water, water depth changes and substratum change negatively affect these species), water pollution, unselective poaching (with toxic substances, electrofishing, and/or illegal nets), the lotic continuum fragmentation due to hydrotechnical works.

Identified specific requirements

Both adults and juveniles need a significant/close to natural/moderate water flow and depth, with sandy substrata.

Proposed specific habitat indicators

In the studied lotic ecosystems, main habitat indicators are proposed as explanation for the presence/absence and relative abundance of *Gobio kessleri* and/or *Gobio albipinnatus*: average water flowing surface speed (60% proportion of the river), average water depth (60% proportion of the river), combined with sandy substratum (60% proportion of the river).

Management measures

Management elements have been a purpose for analytical research, and requirement for the basin managers have to decrease the effects of local and regional numerous pressures and threats. As a consequence there are numerous points of view and models which can vary due to different sources, system and construction intricacies. The indicators of a management system can be built within a six main steps process (Krause and Mertins, 1999): establishing a process value chain model, determining the key factors of success, describing the efficiency indicators, acquiring and confirmation of the information, assessment of the efficiency indicators, and enforcing a constant process.

This pathway relayed on a model based on the learning process which appears while preparing the process maps; and it sets up the need for management elements gathered around the record sheets of management measures. For that reason it is necessary to underline that constructing on the need to discover an indicator set to assess an entity's general performance, the proposed model finds the main value delivery process, to which an indicator set for process evaluation can be nominated, which are induced by identifying the success elements, for the process and for the entity's all-encompassing performance (Miricescu, 2011, 2014).

Corresponding with this model we advocate that the main management measures be: conservation of the natural morphology of the streams and rivers and their banks; riverbed exploitation should be done only outside the lotic habitats characterised by average flow speed, sandy substratum and medium deep water; preserving the vegetation of the basin for sediments control in the basin; conserving the riverine vegetation corridor on a minimum of 100-200 m on both banks for their sediment traps role; water pollution control; guarding a continuous medium level of the flowing water particularly in dry seasons through banning of important water removals; implementing an integrated monitoring system for local and regional fish fauna.

Adjusted model for the site management

The characteristics of the two species were modeled using three processes (Fig. 2) as follows: species *Gobio kessleri* and *Gobio albipinnatus* – the basic process, *Habitat indicators of Gobio kessleri and Gobio albipinnatus species* – (sub)process that present the possible indicators in the current status and favorable conservation status and the last (sub)process *Management measures for Gobio kessleri and Gobio albipinnatus habitat indicators* presenting the management measures that should be taken to preserve the favorable conservation status of species.

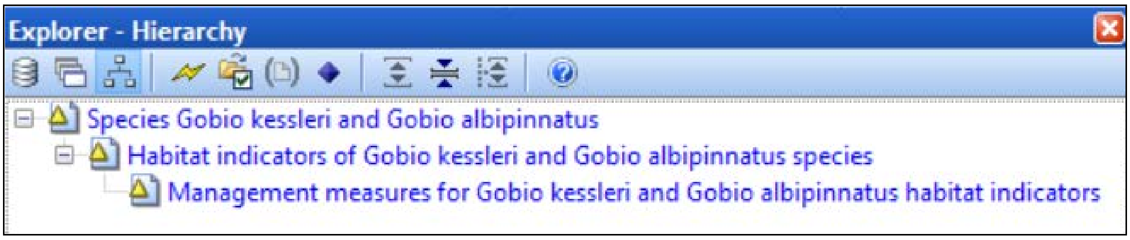

Figure 2: Species *Gobio kessleri and Gobio albipinnatus* – process hierarchy.

Model description

The main features of the *Gobio kessleri* and *Gobio albipinnatus* have been modeled using the most common objects in the ADONIS:CE library, namely the process start, activities, decisions, parallelism, merging, subprocess (all are processes that call inside another process, it works as a hyperlink) and end of the process.

The basic process is *Species Gobio kessleri and Gobio albipinnatus* (Fig. 3), a process in which are presented the habitat type, the possible requirements for habitats, field observations, pressures and threats to species. With parallelism and merging objects are modeled the possible indicators of the two species, according to the *Habitat indicators of Gobio kessleri and Gobio albipinnatus species* subprocess to be analyzed. The pressures and threats of the researched fish species are highlighted in the two borders ().

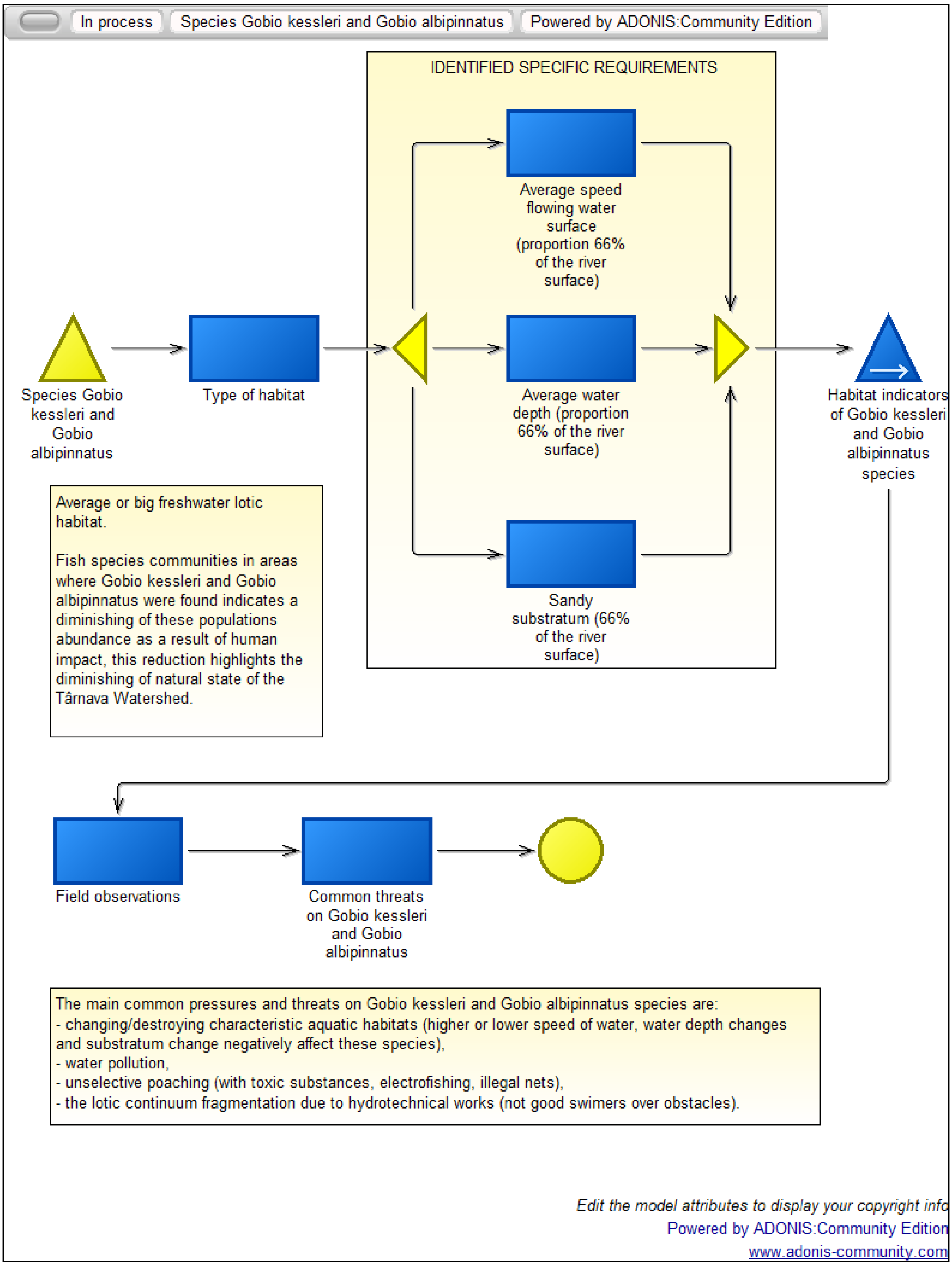

Figure 3: Species *Gobio kessleri* and *Gobio albipinnatus* – main process.

In the subprocess *Habitat indicators of Gobio kessleri and Gobio albipinnatus species* (Fig. 4) the possible indicators are shaped – measured on the ground or taken from other sources – to verify whether these species indicators fulfil the favourable conservation status. Each indicator is assigned a decision. Each decision is assigned a variable (indicator name) and a random generator (assigns value of the variable). For each indicator there are data such as the actual status percentage. This percentage is compared by decisions with the percentage of favourable conservation status. It is practically checked whether the actual status represents a favourable conservation status.

If the first indicator is in favourable conservation status (variable = "Speed_flowing_water_surface", probability on the "YES" branch = 66%), the process continues with the following indicator. If this indicator is not in favourable conservation status (variable = "Speed_flowing_water_surface", probability on the "NO" branch = 34%), then it must go through the subprocess with the management measures . The same goes for the second indicator: if it is in the favourable conservation status (variable = "Water_depth", probability on the "YES" branch = 66%), then the process continues with the third indicator (variable = "Sandy_substratum", probability on the "YES" branch = 50%, probability on the "NO" branch = 50%), and if not (variable = "Water_depth", probability on the "NO" branch = 34%), then call the subprocess with the management measures. This cycle repeats itself and only comes out when all indicators meet the favourable conservation status through the activity "Implementation of a seasonal integrated monitoring system" and the process ends.

The last subprocess modelled here is "*Management measures for Gobio kessleri and Gobio albipinnatus habitat indicators*" (Fig. 5). Based on the acquired data, the major management elements that should be followed to guarantee the favourable conservation status of the species have been underlined. Among the most important management measures we mention: preservation of the natural morfodynamics of the riverbeds – it is recommended to prohibit the construction/layouts which have the effect of changing the flow rate regime and the composition of the bed substrate; establish a complex system of fish ladders to diminish the negative effect of the loose discontinuities created by the existing dams, lakes and semi-lentic areas; the exploitation of mobile aggregates in riverbeds should not be allowed, with the aim of preserving the habitat characteristic of this species; in all sectors of interest rivers, the phenomenon of poaching is very intense and quasi-permanent, which makes it more effective to control; prohibition of abandonment of waste of any nature in the wetland and wetlands adjacent to the watercourses.

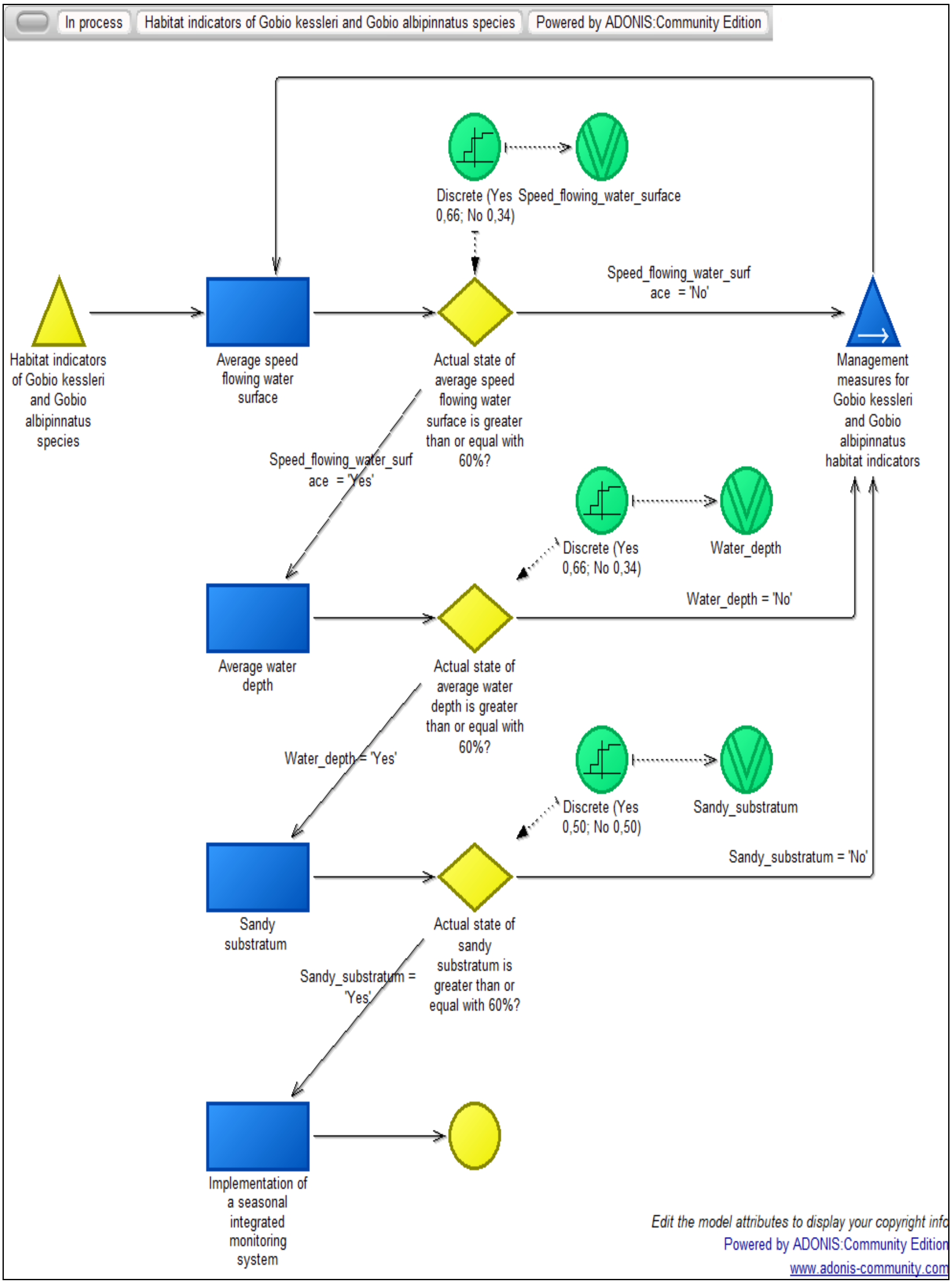

Figure 4: Habitat indicators of *Gobio kessleri* and *Gobio albipinnatus* species.

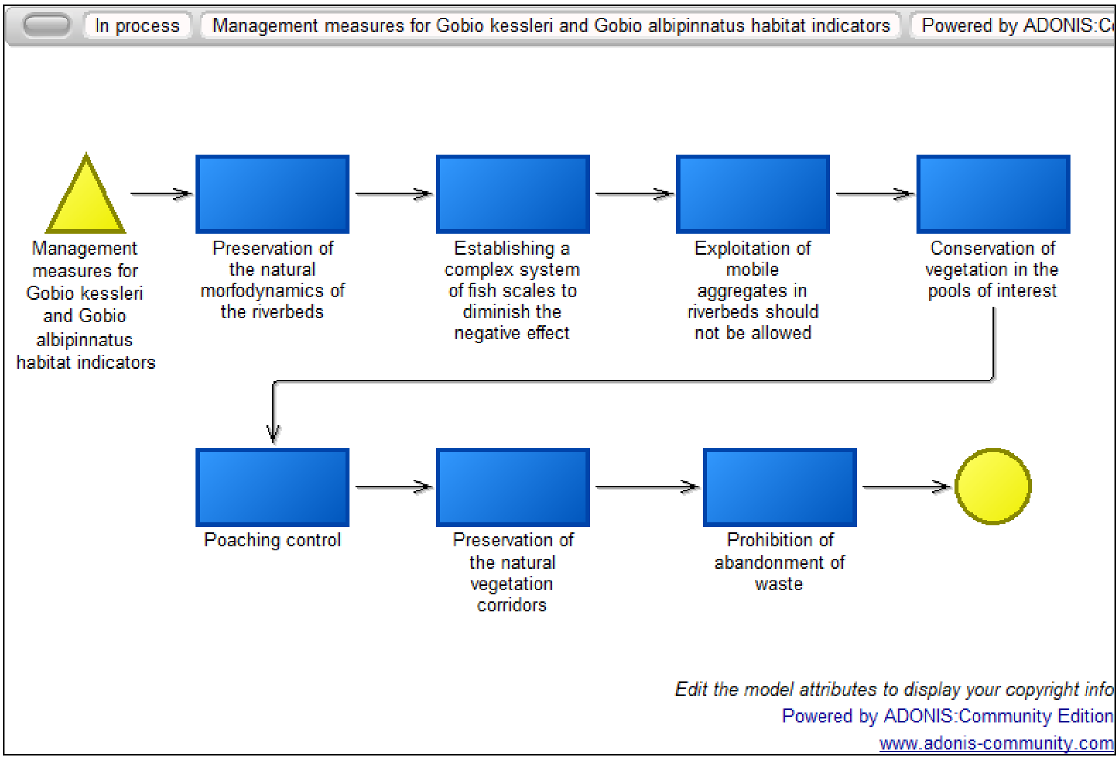

Figure 5: Management measures for *Gobio kessleri* and *Gobio albipinnatus* habitat indicators.

CONCLUSIONS

The lotic habitats quality indicative congeners species *Gobio gobio*, *Gobio kessleri* and *Gobio albipinnatus* populations dynamic in time (2004-2019) and space (shifting characteristic fish zones in Târnave rivers) reveals a decreasing trend in these rivers habitats ecologic status.

The ADONIS:CE tool has been used, to build a backing management system model, based on these indicative fish species habitat needs, the indicators for favourable conservation status, pressures and threats.

This management system implementation in the field will favour the ecological status recovering of the two of fish species of conservative interest (*G. kessleri* and *G. albipinnatus*) based on the amelioration of their natural lotic habitats ecologic status.

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