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The Wetlands Diversity

Editors

Angela Curtean-Bănăduc & Doru Bănăduc

Sibiu - Romania
2015

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IN MEMORIAM

Edward Forbes

(1814 – 1854)

Edward Forbes was born at Douglas, Isle of Man, Great Britain. In his childhood he collected insects, shells, fossils, plants and many other natural history objects.

The beginning of his education was as a day scholar at Athole House Academy in Douglas. In 1832, he pursued studies in the natural history of the Isle of Man.

In 1833 he made a journey in Norway, the botanical results of which were published in London's Magazine of Natural History for 1835–1836. In 1834 he dedicated time to dredging in the Irish Sea, and in the next year he journeyed in Switzerland, France and Germany.

A born naturalist, in 1836 he abandoned the idea of taking a medical degree, devoting himself to nature science. In 1836–1837 found him at Paris, where he was at the lectures at the Jardin des Plantes on natural history, mineralogy, geology, and comparative anatomy.

In 1837, he went to Algiers, and there acquired materials for a study on freshwater and land Mollusca, printed in the Annals of Natural History. In 1838 arose his first volume, Malacologia Monensis, a synopsis of the Manx species of Mollusca. During 1838 he visited Carniola and Styria in SE Austria and Slovenia, and made botanical collections. His Azoic hypothesis was disproved after a quarter of a century when starfish and worms were found on the deep bottom of the sea.

In 1838 he read before the British Association at Newcastle a report on the distribution of Pulmonata in Europe, and was nominee to produce a similar publication for the British Isles. In 1841 appeared his History of British star-fishes and, in the same year, he joined at Malta H. M. survey ship "Beacon" to which he had been appointed naturalist. Between 1841 and 1842 he was employed in studying the botany, zoology and geology of the Mediterranean area. The results of these studies were made known in his Report on the Mollusca and Radiata of the Aegean Sea, presented to the British Association in 1843, and in Travels in Lycia, in 1847. In the previous treatise he deliberated the influence of climate and of the nature and depth of the sea bottom upon marine organisms, and split the Aegean into eight biological areas.

Towards the end of 1842 ***Forbes*** gain the curatorship of the museum of the Geological Society of London. To the charges of that post he added in 1843 those of the professorship of botany at King's College London. In November 1844 he became palaeontologist to the Geological Survey of Great Britain.

In 1846, he wrote in the Memoirs of the Geological Survey, i. 336, his great essay "On the Connection between the distribution of the existing Fauna and Flora of the British Isles, and the Geological Changes which have affected their Area, especially during the epoch of the Northern Drift". It is therein pointed out that, in accordance with the theory of their origin from various centres, the plants of Great Britain may be divided into five well-marked groups.

In 1852 was published the fourth volume of ***Forbes*** and Hanley's History of British Mollusca; also his Monograph of the Echinodermata of the British Tertiaries.

In 1853 ***Forbes*** held the presidency of the Geological Society of London, and in 1854 he was appointed to the professorship of natural history at the University of Edinburgh. He lectured at Edinburgh that year. But he was sick just after he had started his winter course of lectures, and after some days he died at Wardie, near Edinburgh, on 18 November 1854.

In 1859, a previous student of ***Forbes*** dedicated Mount Forbes, Alberta, Canada to his greatly appreciated memory. He is commemorated too in the lily Fritillaria forbesii, the type specimen of which he collected in Lycia 1842.

Some works were published after his death: "On the Tertiary Fluviomarine Formation of the Isle of Wight" in 1856; and "The Natural History of the European Seas", in 1859.

The Editors

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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.

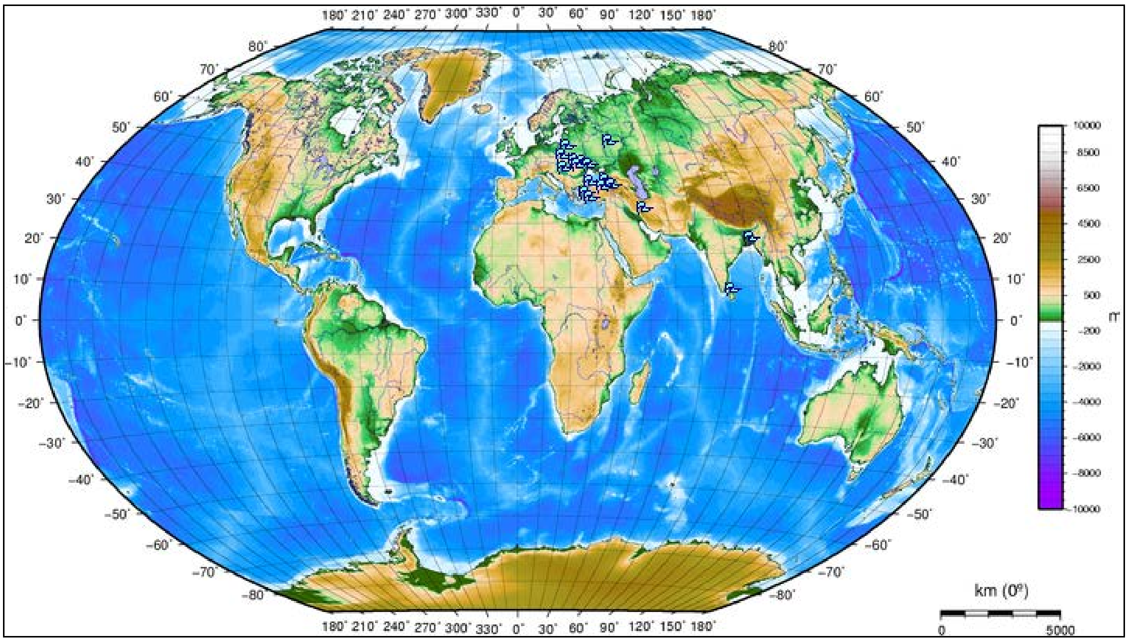
The causes, effects, trends and possibilities of human society to positively intervene to slow down this process or to adapt to it involve a huge variety of aproacess and efforts.

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 a second annual volumes dedicated to the wetlands, volumes resulted mainly as a results of the *Aquatic Biodiversity International Conference*, Sibiu/Romania, 2007-2015.

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* (*Transylv. Rev. Syst. Ecol. Res.*) started and continue this new 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 tenth dedicated volume included variated 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.

Acknowledgements

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USING AIRBORNE LIDAR FOR DETECTION AND MORPHOLOGIC ANALYSIS OF WATERBODIES OBSCURED BY THE FOREST CANOPY

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KEYWORDS: Arc Hydro Tools, Land Facet Corridor Designer.

ABSTRACT

The goal of this study was to map watercourses, watersheds, and small wetland features that are completely obscured by the forest canopy using airborne LiDAR (Light Detection and Ranging) within the archaeological site from Porolissum. This technology was used to generate a bare-earth Digital Terrain Model (DTM) with 0.5 m spatial resolution in order to map small depressions and concavities across 10 km^2 of forested landscape. Although further research is needed to determine the ecological, geological, and archaeological significance of the mapped waterbodies, the general methodology represents important progress in the rapid and accurate detection of wetland habitats in forested landscapes.

RÉSUMÉ: Utilisation de LiDAR aéroporté pour la détection et l'analyse morphologique des éléments hydrologiques occultés par la canopée.

Le but de cette étude était de cartographier les cours d'eau, les bassins hydrographiques et les zones humides qui sont complètement occultées par la canopée de la forêt, en utilisant la technologie LiDAR aéroportée dans la zone du site archéologique de Porolissum. Cette technologie a été utilisée pour générer un Modèle Numérique de Terrain (MNT) avec 0.5 m de résolution spatiale, afin d'identifier de petites dépressions et concavités, dans une zone boisée de 10 km^2. Bien que des recherches supplémentaires soient nécessaires pour déterminer l'importance écologique, géologique et archéologique des éléments hydrologiques cartographiés, la méthodologie générale représente un progrès dans la détection et la cartographie rapide et précise des habitats des zones humides dans les paysages forestiers.

REZUMAT: Utilizarea LiDAR aeropurtat pentru detecţia şi analiza morfologică a elementelor hidrologice acoperite de coronamentul pădurii.

Obiectivul acestui studiu a fost cartarea cursurilor de apă, a bazinelor hidrografice şi a zonelor umede, complet acoperite de coronamentul pădurii, prin folosirea unui sistem LiDAR aeropurtat în zona sitului arheologic de la Porolissum. Acest sistem a fost utilizat pentru a genera un Model Numeric Altitudinal al Terenului (MNAT), cu o rezoluţie spaţială de 0,5 m în vederea identificării unor depresiuni şi concavităţi de dimensiuni reduse, în cadrul unei zone împădurite, pe o suprafaţă de 10 km^2. Deşi, este necesară continuarea studiilor pentru a determina semnificaţia ecologică, geologică şi arheologică a elementelor hidrologice cartate, metodologia generală reprezintă un progres important în detecţia şi cartarea rapidă şi precisă a habitatelor de zone umede din zonele împădurite.

INTRODUCTION

Anthropogenic land use is likely to present a greater challenge to biodiversity than climate change in this century (Dale, 1997), especially along small streams and rivers (Wilson et al., 2014). Even if species are equipped with the adaptive capacity to migrate, in the case of a changing climate they will likely encounter a highly fragmented suitable habitat as a major dispersal barrier. Despite existing environmental protection and management strategies, expanding human land use is likely to further isolate natural/seminatural areas, decreasing landscape and biological connectivity and altering habitat quality (Wilson et al., 2014).

Forest streams are one of the most valuable resources that provide a habitat for many aquatic and riverine species (Curtean-Bănăduc et al., 2014), and represent an important cultural, economic, and ecological asset. Although long-term sustainable water resource management, forest harvest volume calculations, feasible harvest settings, and road location design at landscape or watershed levels are all critically dependent on reliable stream data. At this moment, the accurate high resolution data needed to properly delineate small streams are still lacking.

However, new mapping technologies provide the potential of deriving improved stream data from more detailed surface topology. LiDAR (Light Detection And Ranging) technology, which creates sub meter topographical maps, provides increased resolution in digital surface detail compared with the typical 100-200 meters resolution topographic maps (***, 1992) and permits the generation of more precise and accurate maps of stream networks and of suitable habitat for certain species. Preliminary analyses demonstrated that by using LiDAR data, a significant number of actual stream channels were localized and that their topographic positioning was correct. This ability to generate accurate stream locations and physical attributes using LiDAR allows more reliable long-term calculations of sustainable hydrological resources (Mouton, 2005).

Recent studies have drawn attention to the importance of information extracted by watershed delineation for aquatic biodiversity conservation (O'Keefe et al., 2012; Macedo et al., 2014) and sustainable landscape planning (Uzun and Gultekin, 2011; Hudak et al., 2009). Watersheds can be considered as landscapes that comprise the area drained by a river or stream and its tributaries (Karadağ, 2013). Accurate geospatial databases on the extent of wetlands, water bodies, and the surrounding landscape features are a goal shared by biological sciences, landscape planning, and ecological restoration activities (Frazier and Page, 2000; Lyon, 2003). The spatial organization of wetland key features, such as vegetation patches or surface water bodies, is of major importance for the scientific understanding of the ecology and hydrology of these ecosystems. These patterns can also be indicative of wetland health and development (Patience and Klemas, 1993; Adam et al., 2010).

Water resource management commonly requires investigation of landscape and hydrological features such as terrain slope, drainage networks, and catchment boundaries. Conventionally, water bodies and wetlands were mapped by laborious field surveys and manual cartography. The use of such source data is obviously tedious, time consuming, and error prone (Lyon, 2003). The traditional methodology involves determining and drawing the boundaries of drainage divides, peaks, and stream beds on the topographical maps by hand. However, modern methods are determining the boundaries by digitizing and analysing the contour lines developed by GIS (Geographic Information Systems). The advantage of GIS technology lies in its data synthesis, the geography simulation, and spatial analysis ability. Spatial analytical techniques, geographical analysis, and modelling methods are therefore required to analyse data and to facilitate the decision process at all levels within landscape planning (Gallant, 2015; Karadağ, 2013).

Geospatial information on wetland features can now be collected much more efficiently and accurately by new remote sensing technologies (Bilaşco, 2008; Dronova, 2015; Moffett and Gorelick, 2013; Adam et al., 2010). These techniques usually include aerial photography, multispectral and hyperspectral sensors, LiDAR, and synthetic aperture radar (SAR) that may be processed and analysed to provide source data used to map and characterize wetlands and related water dynamics (Silva et al., 2008; Adam et al., 2010). Aerial photography offers the high spatial resolution desirable for detecting many wetland features, but typically involves time and experience-intensive manual interpretation or manipulation, and repeated acquisitions have historically been limited.

Data from multispectral sensors has been widely used for classifying land cover, including wetlands (Klemas, 2012; Adam et al., 2010). LiDAR or Airborne Laser Scanning (ALS) is one of the high accuracy remote sensing techniques for measuring the height above sea level. By using this technology, it is possible to detect the ground surface and other objects like vegetation or buildings. LiDAR-derived data is used to obtain high-resolution topography and has opened avenues for the analysis of landslides, hill slope and channelization processes, river morphology, active tectonics, volcanic landforms, and anthropogenic signatures on topography (Tarolli, 2014; Sofia et al., 2014). However, the detection of points in water areas is difficult because water (particularly standing waters) does not provide reflectance for the laser scanner. Nevertheless, some reflectance of the water is possible when there are waves or some objects above the water surface. Moreover, the interpretation and extraction of remote sensing data into detailed wetland maps remains a challenge because it is difficult to infer the vegetation types or landscape features and their spatial configuration from the electromagnetic radiation patterns that the image captures from the ground. Furthermore, if the wetlands are hidden under the vegetation canopy, mapping these habitat's morphological and ecological parameters is even more difficult to achieve by using only aerial images.

The goal of this study was to map watercourses, watersheds, and wetlands that are completely obscured by the forest canopy using airborne LiDAR technology, also known as Airborne Laser Scanning (ALS), in order to offer topographical support for sustainable land-use stakeholder level management options and to protect the biodiversity and cultural heritage at the landscape level.

MATERIAL AND METHODS

Study Area

The study area covers 10 km² within the Dacian-Roman archaeological site from Moigrad-Porolissum (Sălaj County, Romania), 47°11'49" N, 23°08'37" E, 504 m a.s.l., on the frontier of the Roman Empire (Dacia Province), also called the Roman Limes (Fig. 1). The area is mostly forested (Fig. 1) with oak, hornbeam, and beech; having different undergrowth. Regarding slope, more than half of this territory is strongly inclined (5°-15°), over 35% of it being steep and very steep terrain (15°-55°), and about 10% gently inclined (< 5°). The average slope is about 14°. The climate is warm and temperate, the annual averages being a temperature of 9.2°C and 647 mm of precipitation. Concerning the hydrographical classification (Gravelius system), the research area comprises three smaller order watersheds (Fig. 2): Agrij (Order 2), Jac (Order 3) and Ortelec (Order 3) belonging to the 1st order watershed of the Someş River (***, 1992).

During the interdisciplinary research project Porolimes (started in 2011), the existing topographical information was centralized and all the known archaeological structures and relevant environmental features were mapped.

This project had also scheduled geophysical mapping and aerial surveys (Opreanu et al., 2013; Opreanu et al., 2014; Roman et al., 2015 manuscript), archaeological excavations (Opreanu and Lăzărescu, 2012; Opreanu et al., 2013), and paleo-environmental studies (Grindean et al., 2014; Roman et al., 2014).

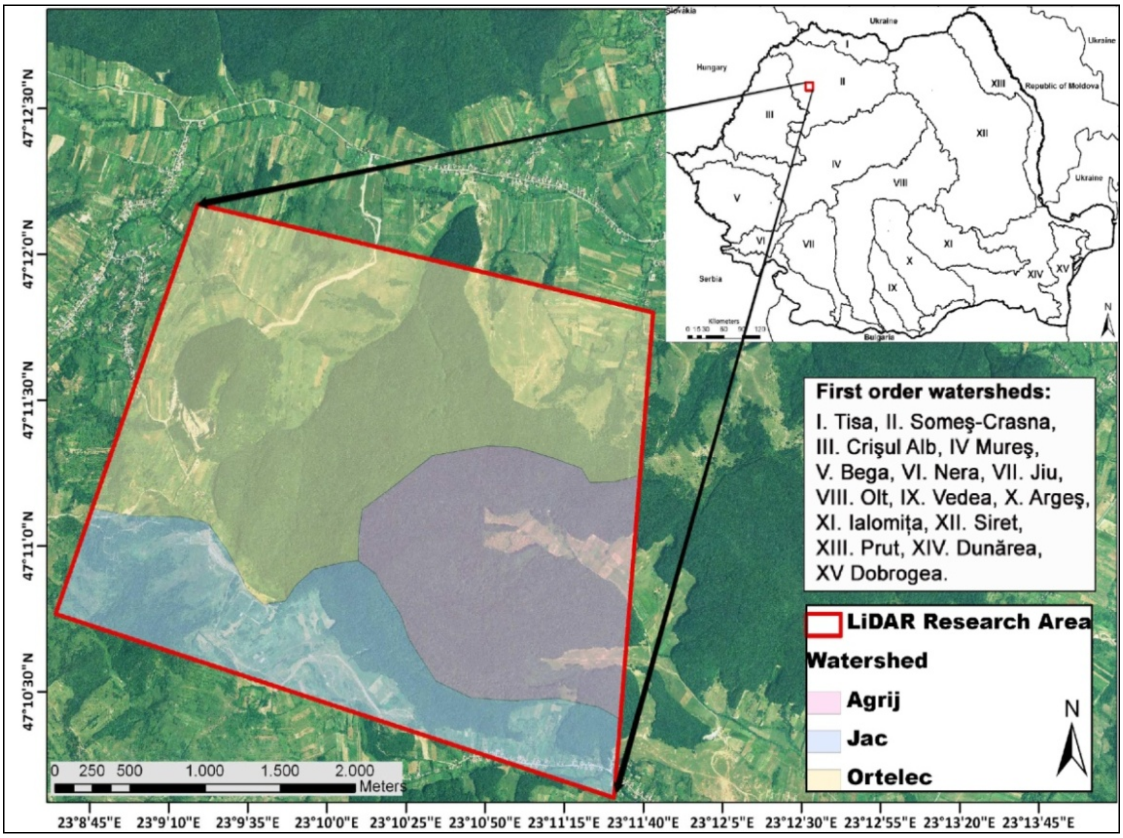


Figure 1: The airborne LiDAR research area located in the north-western part of Romanian territory in the Someş-Crasna first order watershed and the encompassed smaller order watersheds.

Data and Analysis

Aerial laser scanning in the area of interest was carried out for archaeological purposes on 20th March 2013, during the leaf-off season, when the local ground was without snow cover.

LiDAR data (Tab. 1) ensured a 10 km^2 total surface coverage, and was collected by ArcTron GmbH using a D-EBMW/C207 helicopter. The raw LiDAR data (point cloud data) was filtered into ground and non-ground points by the provider and was delivered to us as separate xyz files. The LiDAR bare ground data set was used to generate a 0.5 m resolution DTM using a natural neighbour interpolation algorithm within ArcGIS 10 software (ESRI, 2011).

Table 1: Parameters of the LiDAR flight and instrument used in this paper.

Parameter	Performance
Sensor	RIEGL LMS-Q560
Laser pulse frequency	240,000 Hz
Flying altitude	600
Beam divergence	≤ 0.2 mrad = ≤ 20 cm
Scanning angle	60° (± 30º)
Sampling density	≈ 40-60 returns/m^2

The watersheds were delineated using the Arc Hydro Tools (Maidment, 2002; Mervade, 2012) within ArcGIS 10 software (ESRI, 2011). This geospatial and temporal data model is a conceptualization of surface water systems and describes features such as river networks, watersheds, and channels. Using the Topographic Position Index (TPI) (Weiss, 2001; Guisan et al., 1999; Jones et al., 2000) calculator within the Land Facet Corridor Designer software version 1.2.884 (Jenness et al., 2010) – a plug-in application for ArcGIS, we further detected small depressions and concavities that may represent temporary or permanent wetland features.

In order to ascertain whether the delineated watersheds and watercourses on the LiDAR-derived DTM are water features, we performed a visual comparison with the existing topographical maps of the study area (scale 1:25,000) and with the hydrological information from the Romanian Water Cadastre. Also, in situ ground-inspection was performed in specific areas, selected to encompass features from all morphological types. The polyline shapefile was exported as a keyhole markup language (kml) file. This file was converted to a Garmin Mapsource® GPS waypoint file (gdb) and uploaded to a Garmin GPSMap® 60s Global Positioning System (GPS) which was used to spatially locate the features.

The water surfaces, small watersheds, and wetland habitats (small depressions and concavities) obscured by the forest canopy were detected and accurately mapped using airborne LiDAR-derived topographical data, Spatial Analysis Tools, Arc Hydro Tools, and Land Facet Corridor Designer from the ArcGIS. In order to *see* under the closed canopy we performed the following stages:

a. Generating the DTM from the airborne LiDAR

The LiDAR data was filtered by the data provider to remove the returns from above ground surface objects such as buildings and vegetation (first returns), revealing the bare earth surface (last returns) without the forest cover. Filtering algorithms for separating ground and vegetation returns have been in development for decades and, whilst not perfect, are capable of handling even dense understory (Sofia et al., 2014). We used these ground elevation points to generate a high spatial resolution DTM (0.5 m) by using the Natural Neighbor toolbox from ArcGIS software (Fig. 2). This topographical data enabled us to extract the following information on the study site: the average height is 353 m a.s.l., with a minimum of 239 m a.s.l., and a maximum of 519 m a.s.l. The average slope is 15º, with a minimum of 0º and a maximum of about 87º. Also, using DTM visualization techniques, the underground archaeological structures belonging to The Roman Limes (hill fort, defence walls and watchtowers) from the forested landscape at Porolissum were mapped (Opreanu et al., 2013; Opreanu et al., 2014; Roman et al., 2015). The high spatial resolution LiDAR-derived topographical data was also used to detect watersheds, water surfaces, small valleys and depressions and to accurately map these features in steep terrain.

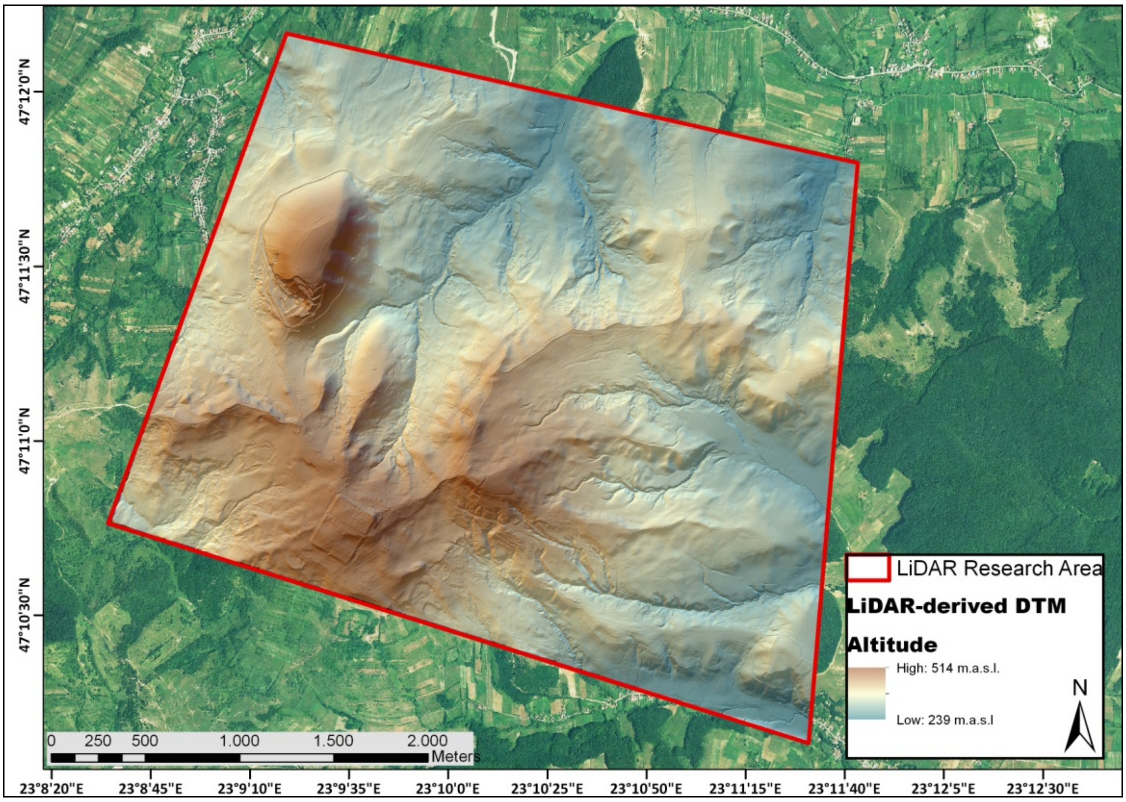


Figure 2: The LiDAR-derived Digital Terrain Model (DTM).

b. Watersheds and watercourses delineation

The process employed to analyse data and to facilitate mapping involves 11 spatial/geographical analyses and modelling methods using Arc Hydro Tools for ArcGIS 10 software, grouped in four stages. The first stage of Archydro Model is *Terrain Preprocessing*, which must be completed before watershed boundary delineation. It involves two analyses; *DTM reconditioning* and *Fill sink*, which are confirmation and preparation processes that should be performed in sequential order. The *DTM reconditioning* increases the degree of agreement between stream networks delineated from the DTM and the existing input vector stream networks (Mervade, 2012; Ayhan et al., 2012). The *Fill sink* analysis fills the sinks in a grid, which are areas surrounded by higher elevation cells where the water is trapped and cannot flow. The *Fill Sinks* function readjusts the height value to eliminate these problems. Within the second stage, *Flow direction*, *Flow Accumulation*, *Stream Definition*, and *Stream Segmentation* analysis were carried out, which involve evaluations concerning surface flow. The third stage comprises *Catchment Grid Delineation* and *Catchment Polygon* processing analysis, by which catchment areas are determined. The last stage involves *Drainage Line Processing*, *Drainage Point Processing*, and *Batch Watershed Delineation* analysis, which define watershed boundaries by evaluating drainage systems according to surface flow and catchment areas.

The delineation consisted in deriving smaller order watershed boundaries and small streams like Luncile Brazilor Stream, Valea Pometului Creek, Ursoaiei Stream, Peste Vale Stream, and Valea Moigrad Stream; all these watercourses being tributary to Agrij and Ortelec valleys, in their turn tributaries to the Someş River. Also, some temporary watercourses and watersheds were identified. The hydrologic modelling involved delineating the network of streams and watersheds, and extracting basic watershed properties such as area and flow length. Employing the high resolution LiDAR-derived DTM and Geographic Information Systems (GIS) technology enabled the accurate mapping of 21 permanent and/or temporary watercourses (with a total length of 20.54 km) and of the corresponding watersheds (covering an area of 901.82 ha) in the research perimeter from Moigrad-Porolissum (Tab. 2; Fig. 3).

Table 2: The watersheds and watercourses mapped using the LiDAR derived-DTM. The fields highlighted in grey represent higher-order watersheds; data were extracted from Water Cadastre of Romania (1992).

No.	Watershed name/ Code	Watershed area (ha)	Watercourse name	Watercourse length (km)
*	Agrij/II-1.49	15,957.25	Agrij River	48.00
1	Luncile Brazilor	153.62	Luncile Brazilor Stream	6.92
2	Luncile Brazilor 1	15.77	Tributary Luncile Brazilor 1	0.58
3	Luncile Brazilor 2	77.88	Tributary Luncile Brazilor 2	3.10
*	Jac/II-1.49.5b	868.56	Pometului Valley (Jac)	8.00
4	Valea Pometului	5.90	Valea Pometului Creek	0.18
5	Temporary Pometului	8.42	Temporary Pometului	0.37
6	Pometului 1	33.63	Tributary Pometului 1	1.00
7	Pometului 2	25.91	Tributary Pometului 2	1.12
8	Pometului 3	8.15	Tributary Pometului 3	0.35
9	Pometului 4	48.39	Tributary Pometului 4	1.83
10	Pometului 5	29.18	Tributary Pometului 5	1.04
*	Ortelec/II-1.49.6	3,882.73	Ortelec Valley	15.00
11	Ursoaiei	279.07	Ursoaiei Stream	11.42
12	Peste Vale	81.65	Peste Vale Stream	2.79
13	Valea Moigrad	43.91	Valea Moigrad Stream	1.78
14	Ortelec 1	7.91	Tributary Ortelec 1	0.17
15	Ortelec 2	16.34	Tributary Ortelec 2	0.49
16	Temporary Ortelec 1	13.43	Temporary Ortelec 1	0.55
17	Temporary Ortelec 2	15.57	Temporary Ortelec 2	0.65
18	Moigrad	21.03	Valea Moigrad Stream	1.78
19	Temporary Moigrad 1	4.99	Temporary Moigrad 1	0.42
20	Temporary Moigrad 2	4.55	Temporary Moigrad 2	0.11
21	Temporary Moigrad 3	6.52	Temporary Moigrad 3	0.38
Total	–	901.82	–	20.54

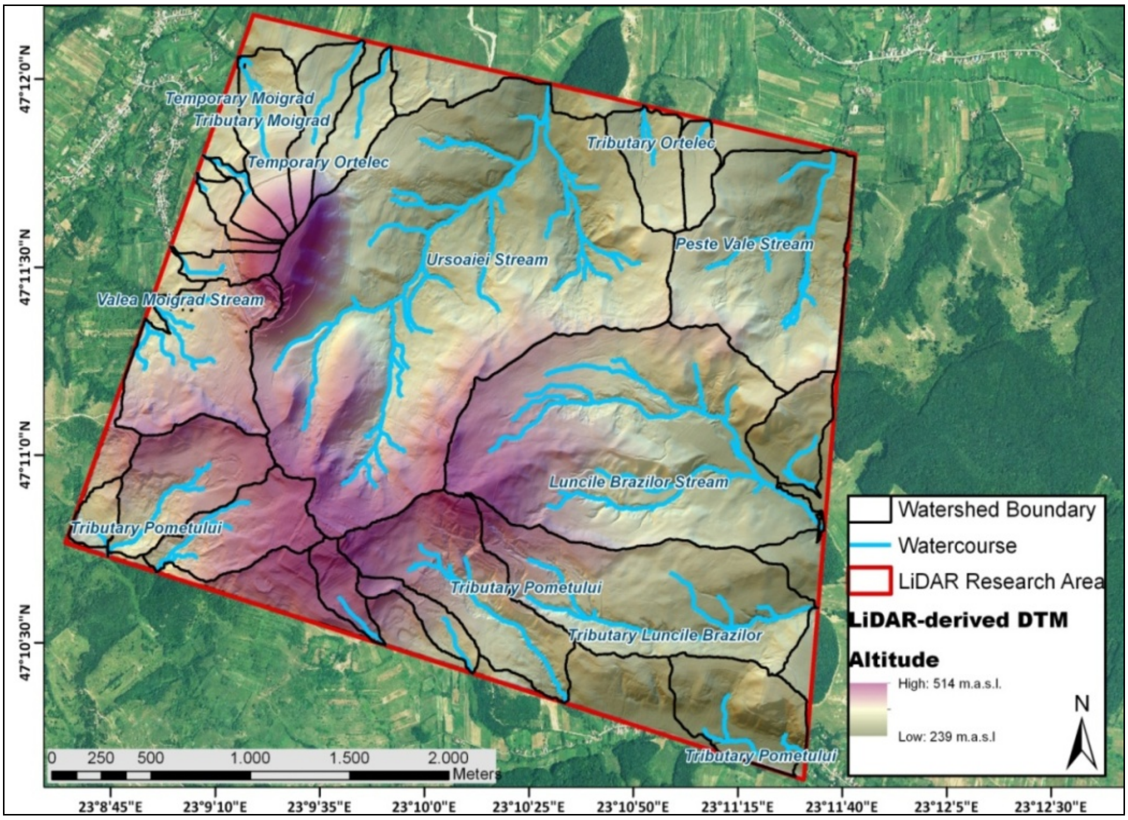


Figure 3: The LiDAR-derived DTM and the delineated watershed and watercourse features.

The validation of the delineated watercourse features was performed by visual comparison using the existing topographical maps (L-34-35-A-d, scale 1:25,000) and hydrological data from the Romanian Water Cadastre (1992). As illustrated in figure 4, the high spatial resolution of the LiDAR-derived DTM (0.5 m) offers the capability of improving the existing information from the Romanian Water Cadastre by increasing the number of hydrological features and the quality of this data. Also, in situ ground-inspection and validation was performed in relevant areas, selected to encompass waterflow features of different morphological shapes.

The accurate mapping of watercourses and watershed boundaries is important because rainwater drenches most of the terrain and, in a domino effect, any local disturbance would be reflected in the whole system (Karadağ, 2013). A watershed is the area drained by a river or stream and its tributaries, while sub-watersheds (micro-watersheds) are defined as catchment areas comprising drainage lines in various sizes which feed watersheds and river watersheds (Karadağ, 2013). The watersheds are complex ecosystems in which land use, surficial geology, climate, and topography are interrelated with biological components such as vegetation communities (O'Keefe et al., 2012).

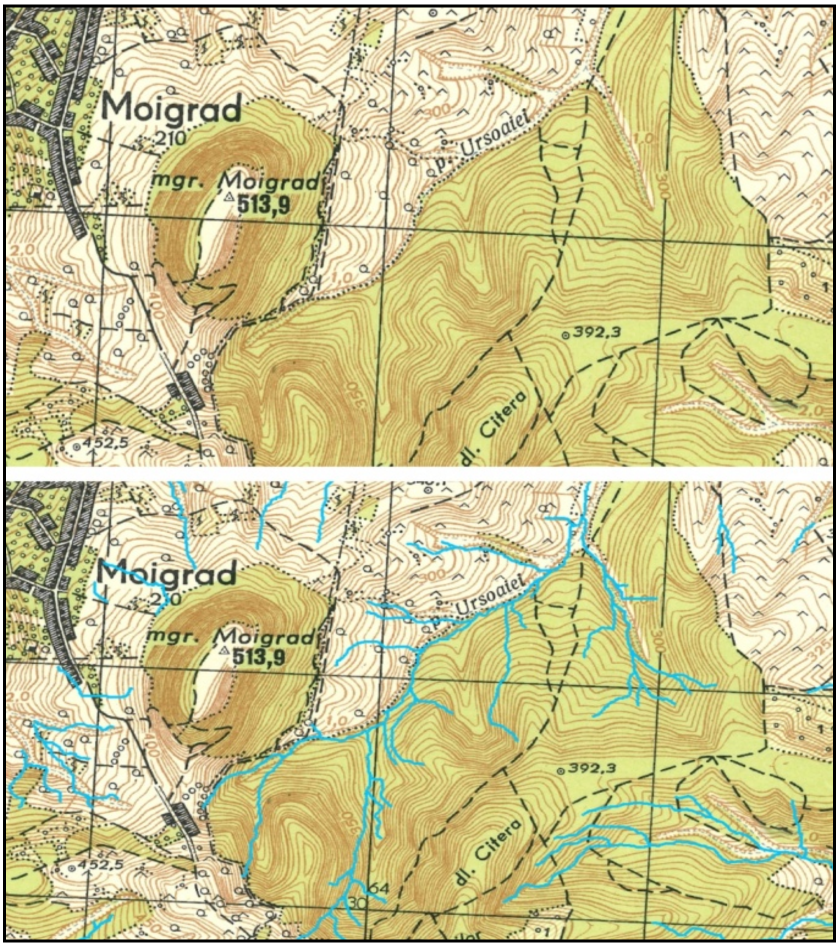


Figure 4: Validation of the LiDAR-derived DTM mapping of watercourse features against the existing topographical map (1956, L-34-35-A-d; scale 1:25,000).

The complex boundaries existing within a landscape can be untangled by analysing watersheds. Considering the importance of water for all life forms, its effect on establishing, developing, and even collapsing civilizations, it is clear that watersheds can also serve as effective boundaries in landscape planning. Water provides the interaction between the space of natural and cultural life, while generating socio-cultural and economical life by its presence. This situation enables watersheds to act not only as a natural boundary, but also as a borderline that affects people's life. Hydrological systems, along with ecological units, have been viewed as a natural basis for division of the earth's surface. Thus, the watershed or catchment has often been proposed as the most appropriate division for landscape planning. Key reasons have been its relative self-containment in terms of flows of water, other materials, and energy; its relationship to geomorphic processes and the consequent recognisability of landform characterizing individual catchments; and the importance of water, often in short or excess supply, to human settlements. Increasingly, landscape ecologists also recognize the importance of water catchments in influencing the nature and functionality of ecosystems through their role not only in supplying moisture, but also in moving chemical nutrients within the ground and along rivers (Selman, 2006).

c. Detection of the small wetland features

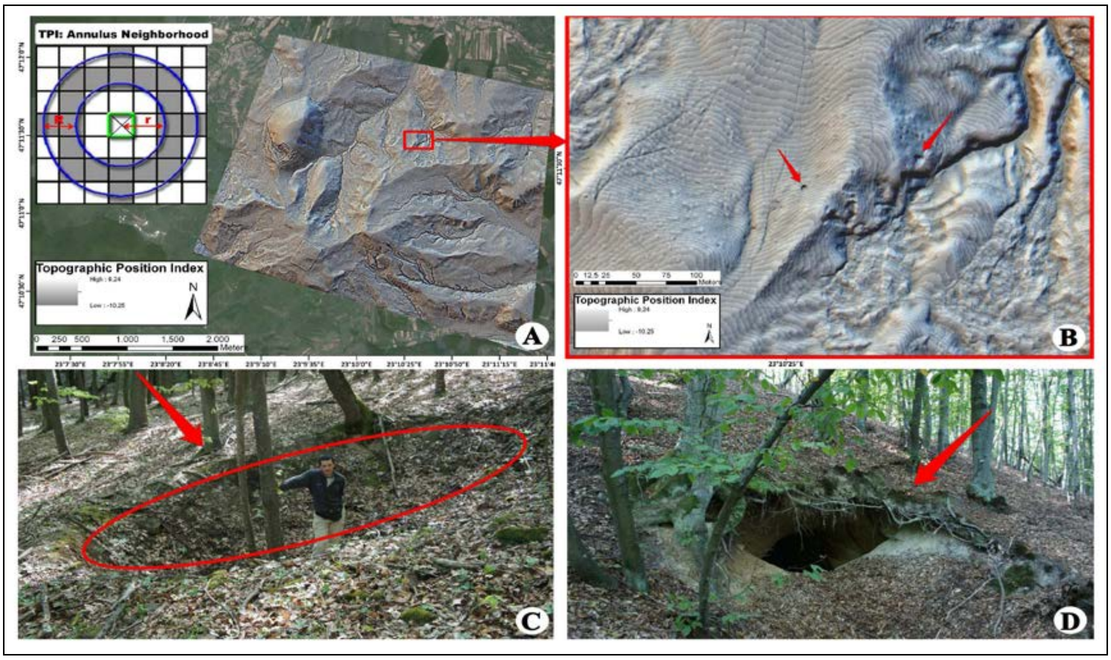
The small wetland features (steep depressions and concavities) were detected using the Topographic Position Index (Guisan et al., 1999; Jenness et al., 2010) that measured elevation contrast in the LiDAR-derived DTM. For each focal cell, the TPI is the difference between the elevation of the focal cell and the average elevation of all the cells in the neighbourhood.

The TPI is the basis of the classification system and is simply the difference between a cell elevation value and the average elevation of the neighbourhood around that cell. Positive values mean the cell is higher than its surroundings, while negative values mean it is lower. The degree to which it is higher or lower, plus the slope of the cell, can be used to classify the cell into slope position. If it is significantly higher than the surrounding neighbourhood, then it is likely to be at or near the top of a hill or ridge. As with TPI values in general, neighbourhood size is also a critical component of the Slope Position classification process.

Small neighbourhood values capture small and local hills and valleys while large neighbourhoods capture larger-scale features. Significantly low values suggest the cell is at or near the bottom of a valley. TPI values near zero could mean either a flat area or a mid-slope area, so the cell slope can be used to distinguish the two. TPI units are expressed as elevation, therefore a TPI value of 10 would mean that this particular cell is 10 units (meters) higher than the average elevation of the neighbourhood. We used an annulus shape to define the neighbourhood (Fig. 5A) cells whose centre points fall between the inner radius ($r = 2.5$ m: 5 DTM horizontal units) and outer radius ($R = 5$ m: 10 DTM horizontal units). An annular neighbourhood looks like a ring or doughnut, defined by an inner and outer radius length extending outward from the cell centre. This neighbourhood is composed of all cells whose cell centres lie within this ring. The annulus shape amplifies the difference between the focal cell and the surrounding ring.

Pixels or grid cells with TPI values < -5 were identified in the DTM image as potential depressions and concavities (Fig. 5B). This depth allowed shallow reservoirs and small depressions to be identified in the forested study area. We have also identified eight concavities (diameter range 1.5 m – 3.5 m), more or less circular. These may be the result of ruined ancient Roman structures, most probably watchtowers judging both by their shape as well as their position in relation to the Roman advanced defence system recently documented and accurately mapped by means of LiDAR survey (Roman et al., 2015).

Several of the recorded depressions were validated in the field during the spring and autumn of 2015 (Figs. 5C and 5D). During spring time, or rain season, these small depressions and concavities retain water, representing potential habitats for many wildlife species. One of the concavities proved to be a cave entrance (Fig. 5D). Such caves are nowadays habitats for bats, frogs and spiders, but in the past were used by Christian hermits. Although in Dobrudja such discoveries are clearly dated in Late Antiquity (6th-7th century AD), in this case, we must presume that we are dealing with a structure dating back to the Middle Ages as the earliest documents mentioning a Christian community in this particular area seems to indicate. Also, other recent studies revealed the potential of the LiDAR-derived DTM to map cave openings (Weishampel et al., 2011). Given the scanning angle of the LiDAR pulse, it is likely that some concavities with side or horizontal openings would not be evident on the models. Also, concavities smaller than the DTM horizontal resolution (0.5 m), would most likely not be detected.



Figures 5A-D: Topographic Position Index and the extracted small depressions and concavity features; (A) The TPI using the Annulus Neighbourhood, (B) Potential depressions and concavities detected with the TPI, (C) In-situ validation of a small circular concavity, (D) In-situ validation of a small depression – cave opening.

CONCLUSIONS

This study employed LiDAR based methods and processing techniques that enabled the detection of watershed features, water bodies, and wetlands hidden below the forested landscape surrounding the archaeological site from Moigrad-Porolissum and translated the remote sensing data into terrain maps. Also, this research reveals the effectiveness of the airborne LiDAR and GIS processing tools (Arc Hydro Tools, Land Facet Calculator) for delineation of watershed boundaries, small streams, and water bodies in forested, steep terrain.

The hydrologic modelling involved delimiting stream networks and watersheds, and extracting some basic watershed properties such as area and flow length. Traditionally this was done manually by using topographic/contour maps, but this process can be automatized. It can be performed faster and render more accurate results by using a high spatial resolution LiDAR-derived DTM and analysing the data with GIS specialized software such Arc Hydro Tools for ArcGIS. Also, by generating the TPI from the LiDAR-derived DTM, small depressions and concavities that represent temporary or permanent water bodies can be detected and mapped.

Although further research is needed to determine the ecological, geological, and possibly the archaeological significance of the mapped depressions and concavities, the general methodology represents an important progress in rapid and accurate detection of water bodies in forested landscapes. These spatial data are necessary, particularly for sustainable landscape planning, because the complex boundaries existing within a landscape can be untangled by analysing watersheds. Considering the importance of water for all life forms, its effect on establishing, developing and even collapsing civilizations, it is clear that watersheds can also serve as effective boundaries in landscape planning. Watersheds act not only as a natural boundary, but also as a borderline that affects people's life.

ACKNOWLEDGEMENTS

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LANDSCAPE FACTORS INFLUENCING DIVERSITY OF HABITAT CONDITIONS ACROSS A WATERCOURSE IN THE VICINITY OF TOMASZÓW LUBELSKI CITY IN THE ROZTOCZE REGION (POLAND)

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KEYWORDS: river, hydromorphology, River Habitat Survey, RHS, HQA, HMS, purity classes.

ABSTRACT

The aim of the study was a hydromorphological valorisation of the river valley in the Roztocze region using the British method – River Habitat Survey (RHS). As a result of field research two numerical indicators HMS (Habitat Modification Score) and HQA (Habitat Quality Assessment) were identified and purity water classes were defined. The river did not fulfil the requirements of the Water Framework Directive, because its state was defined as poor and moderate. On the base of physical and chemical parameters, in the majority of water studied the watercourses were classified to the first class of purity. Only in one segment waters were below the first class, or even out of class.

ZUSAMENFFASSUNG: Die Vielfalt von Lebensraumbedingungen in Fließgewässern beeinflussende Landschaftsfaktoren in der Nähe der Stadt Tomaszow Lubelski der Region Roztocze (Polen).

Ziel der Untersuchung war eine hydromophologische Bewertung des Flusstales der Region Roztocze unter Anwendung der britischen Methode zur Habitat Erfassung – River Habitat Survey RHS. Als Ergebnis der Geländeuntersuchungen wurden zwei numerische Indikatoren HMS (Stand der Habitatveränderung HMS) und Habitat Qualitätsbewertung (HQA) identifiziert sowie Wassersauberkeits Klassen definiert. Der Fluss erfüllt nicht die Anforderungen der Wasserrahmenrichtlinie, da sein Zustand als arm und moderat definiert wurde. Anhand von physikalischen und chemischen Parametern wurde das Wasser der untersuchten Fließgewässer mehrheitlich in die erste Sauberkeitsstufe eingegliedert. Lediglich in einem Abschnitt war das Wasser unterhalb der ersten Klasse, oder gar außerhalb jeglicher Klasseneinteilung.

REZUMAT: Factorii de peisaj care influențează diversitatea condițiilor de habitat de-a lungul unui curs de apă (râu) în apropierea orașului Tomaszow Lubelski, în regiunea Roztocze (Poloniei).

Scopul studiului a fost valorificarea hidromorfologică a văii râului din regiunea Roztocze, folosind metoda britanică de evaluare – River Habitat Survey RHS. Ca rezultat al cercetărilor de teren, au fost identificați doi indicatori numerici HMS (Habitat Modification Score/Modificarea Scorului Habitatului) și HQA (Evaluarea Calității Habitatului), precum și definită o clasă de puritate a apei. Râul nu a îndeplinit cerințele Directivei-Cadru privind apa (Directiva Cadru-Ape), pentru că starea sa a fost definită ca fiind proastă și moderată. Pe baza parametrilor fizico-chimici, în cazul majorității apelor cursurilor de apă studiate, acestea au fost clasificate de la prima clasă de puritate. Numai în cazul unui segment de râu apele au fost mai jos de prima clasa de puritate, sau chiar din afara acestei clase.

INTRODUCTION

All components of aquatic ecosystems, including river valleys, play important roles (Sender and Maslanko, 2014) in nature. River valleys act as a natural stripes of increased displacement of matter, energy and biological information in the landscape (among others, flow of water and erosion material, the movement the air mass, species migration) (Chmielewski, 2004a; Curtean-Bănăduc et al., 2014). To fulfil functions as ecological corridors, waters should maintain natural or semi-natural character; lead water must not be polluted, should be permeable, and uninterrupted by barrier structures (Chmielewski, 2004b, 2005; Allan et al., 1997). In human history river valleys have always played and still play important functions, including supplying public with water, provision of fish, recreational use, and maintain balance in water management (Byczkowski, 1999; Bajkiewicz-Grabowska and Mikulski, 2007). In past centuries, first civilizations were closely associated with aquatic ecosystems. However, human activities often cause degradation of these sensitive ecosystems. Incorrect management of catchment can cause disturbance or prevent performance of above mentioned functions.

Requirements imposed under the regulations of the Water Framework Directive (Directive 2000/60/EC of 23 October 2000) by the European Union on Member States postulated achieving at least a good ecological status of rivers by 2015. In order to plan river renaturalisation treatments, a unified system of rivers morphological evaluation that allows their comparison on the local or regional level was introduced (Newson et al., 1998; Szoszkiewicz et al., 2009b). Nowadays in Poland the application of a British method called River Habitat Survey (RHS) is increasing (River, 1997, 2003). River Habitat Survey allows the characterisation of rivers and their classification based on hydromorphology. It is a method based on recording elements of the environment (Osowska and Kalisz, 2011).

Protection appears to have had a favourable influence on watercourse function within the respective area. For this reason, studies were undertaken to determine the impact of human activities on the river valley ecosystem. For this reason, studies were undertaken to determine the impact of human activities on the river valley ecosystem. The study area included the Tomaszów watercourse flowing through the city area, as well as the municipality of Tomaszów Lubelski. The studies included: analysis of changes in land use in the catchment area between 1992 and 2012, the basic characteristics of physical and chemical parameters of water, together with an indication of purity class and indication of degradation threats affecting the ecosystem. The ecological status of this watercourse was assessed to determine if it meets the minimal criteria intended by the Water Framework Directive, and to identify areas in need of renaturalisation treatments

MATERIALS AND METHODS

Study area

The research area is located in the Roztocze region, in the North-East from the Tomaszów Lubelski city center. The Roztocze is a physico-geographical macroregion situated within Eastern Lesser Poland Upland. It forms a range of gentle hills, stretching over approximately 185 kilometers, from Kraśnik in Poland to Lviv in Ukraine. Hills reach a height of 300-400 meters above sea level, with maximum 150 meters height differences. Hydrographically the region divides the river systems of the Wieprz and the Bug rivers from those of the San and the Dniester rivers (Chmielewski et al., 2014). The research within these studies focussed on the Tomaszów watercourse with its catchment (Fig. 1). The total length of this watercourse is 2,128 m, while the study area, coinciding with the catchment area encompassed 190,034 ha.

In the vicinity of the study area there are different forms of environment protection. The oldest reserve was established in 1962 called "Piekiełko" near Tomaszów Lubelski, this was followed by the creation of Krasnobród Landscape Park in 1988, and the "Zarośle" reserve in 1998. Most recently the four areas of Natura 2000 network were formed (Fig. 2).

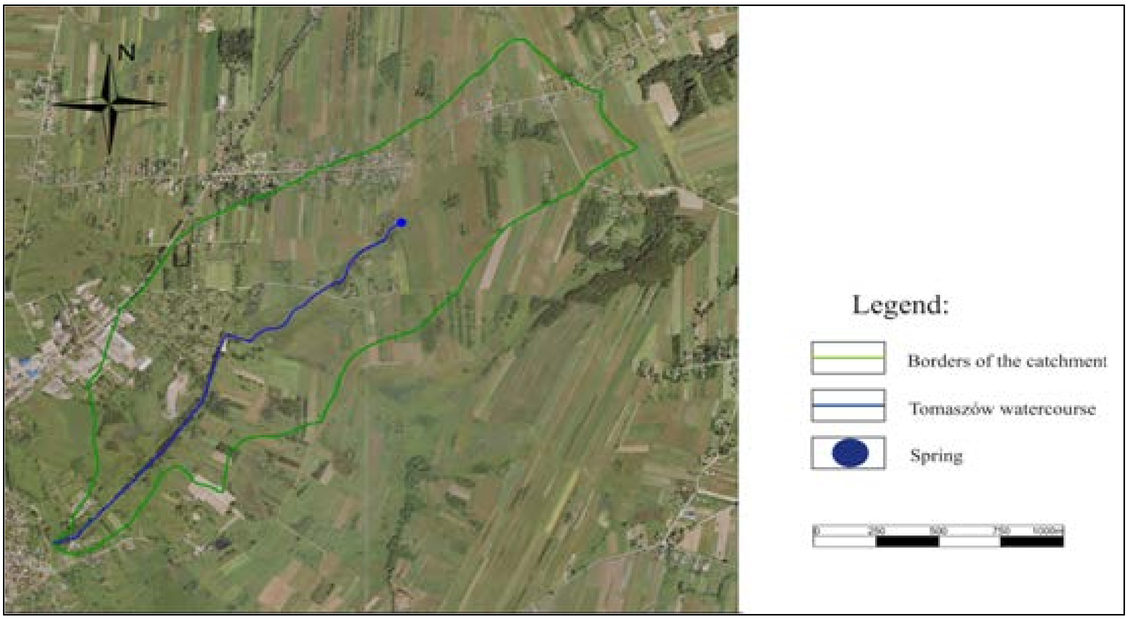

Figure 1: Location of the watercourse and its catchment on the background of orthophotomap (source: www.geoportal2.pl).

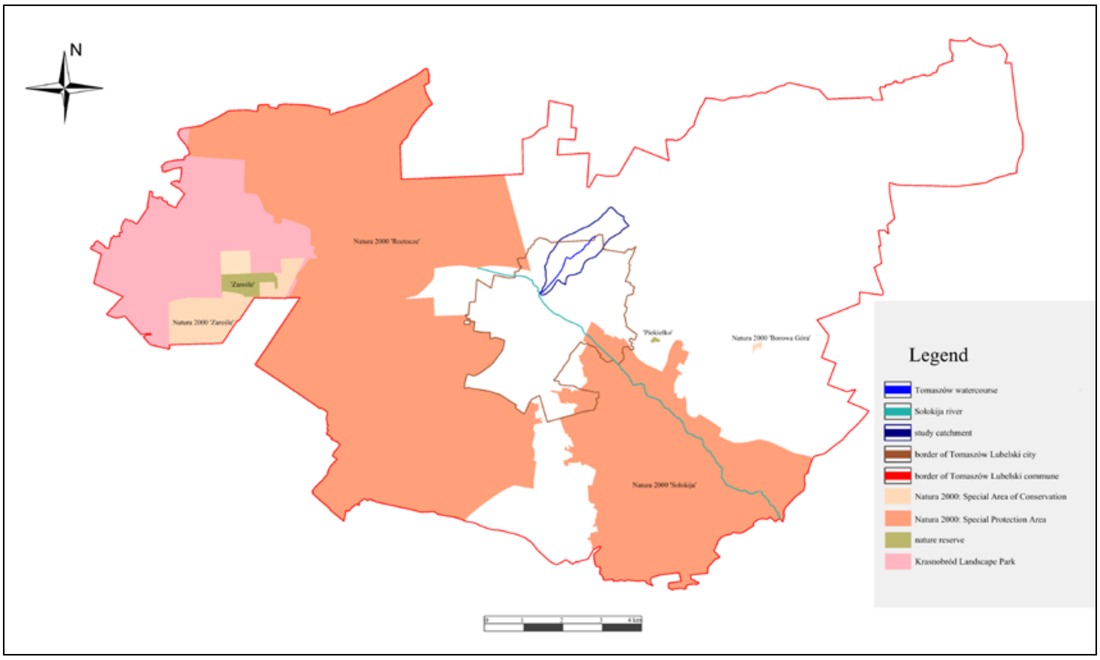

Figure 2: Distribution of protected areas on the background of research area.

Methodology

The first part of the study focused on the assessment of environmental characteristics of the river landscape. The analysis of land use changes for the watercourse' catchment area in a period of 20 years was undertaken. For this purpose the following materials were used:

- a topographic map in a scale 1:10,000 – year 1992,
- an orthophotomap in a scale 1:10,000 – year 2012.

Maps were taken from Geoportal service by Geoxa Viewer programme, 2.0.0.6275 version. PowerDraft V8i programme by Bentley Company was used to perform the analysis.

Qualification of the environmental state of river landscape

Environmental conditions of the river landscapes were expressed using the ecological stability coefficient (ESC). The value of ecological stability of the area was expressed by the following formula (Jakubinsky, 2014):

$$ESC = \frac{pn \times Kpn}{p}$$

where: pn – is area of mapped long term land use; p – an area of whole territory; Kpn – value of the coefficient of environmental land use significance.

The ESC values were calculated for the entire catchment areas in 1992, as well as in 2012. It let us describe the ecological stability of the river landscape along the watercourse and indicate tendency in land management.

Qualification of ecological state of a watercourse

The River Habitat Survey (RHS) classification was carried out by a standard method along the entire length of the river, divided into seven segments, spaced about 300 m from each other (Fig. 3). Choices of these segments were dictated by a different degree of their naturalness and types of anthropogenic transformations.

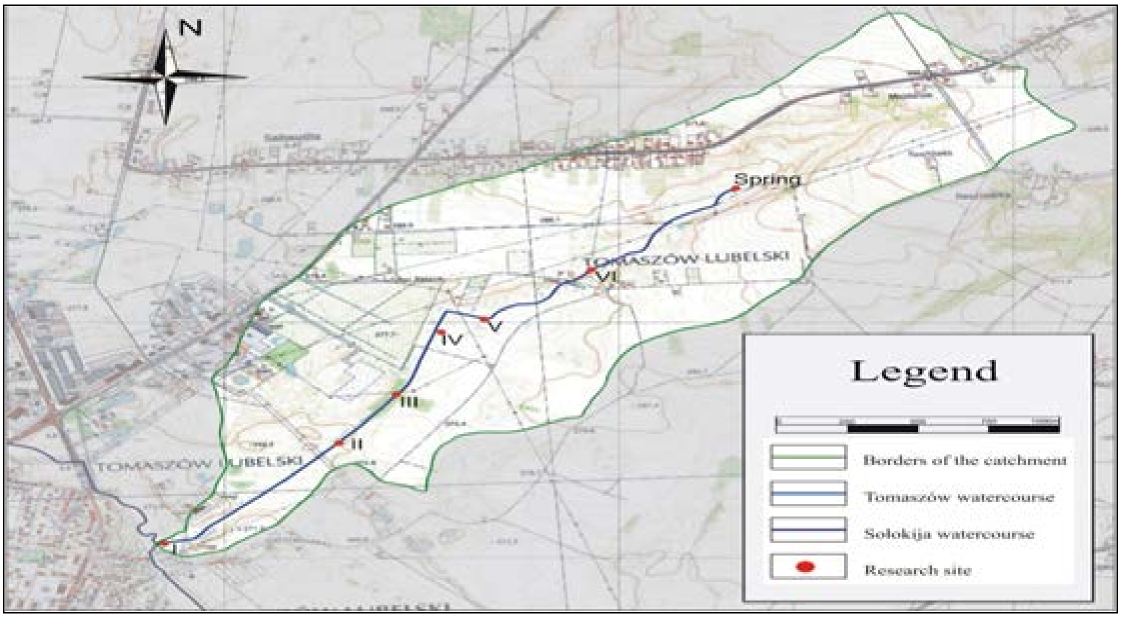

Figure 3: Catchment area and distribution of research sites along the watercourse.

Fieldwork was conducted in May, July, and September 2012. This included a standard set of analyses covered by the RHS method, which consisted of RHS field work form as the basis. These results were then transformed into numerical values allowing for assessment of hydromorphological status of surveyed segments of the river and their classification (Szoszkiewicz et al., 2009a). For this purpose, the indicators as the result of many individual parameters were used, i.e. indicator of watercourse naturalness (Habitat Quality Assessment – HQA) based on the presence and diversity of the natural elements of the stream and the river valley, as well as indicator of habitat transformation (Habitat Modification Score – HMS), defining the scope of transformation in the stream morphology (Raven et al., 2000).

Analysis of the reach started at the river spring (N 50.469408, E 23.445672) and finished in the estuary to the Sołokija River (N 50.456445, E 23.423195).

For HQA and HMS synthetic indexes limits of five classes of the hydromorphological status were specified (Ławniczak and Gebler, 2011; Raven et al., 1998; Walker et al., 2002).

For HQA the ranges of each class were proposed: I: ≥ 57, II: 56-50, III: 49-37, IV: 36-31, V: ≤ 30, whereas for HMS index: I: 0-2, II: 3-8, III: 9-20, IV: 21-44, V: > 45.

Qualification of physico-chemical parameters

The studies of physical and chemical parameters were carried out in seven research sites: no. 1 – just 1.5 m before the estuary of the watercourse to the Sołokija River (watercourse flowed through wetlands overgrown with bushes and low trees); no. 2 – about 200 m from the garbage dump, marshy area, a line of trees along the watercourse; no. 3 – the closest point to the garbage dump; no. 4 – watercourse transformed into flooding, adjacent allotment gardens; no. 5 – watercourse flows out of wetlands, no. 6 – a fishing pond combined with the watercourse; no. 7 – a spring of the river (Fig. 3).

In each research site the following measurements were carried out:

- pH of water (by a microprocessor pH-meter SP3000, Slandi Company);
- electrolytic conductivity;
- oxygen content (by a microprocessor oxygen meter with a thermometer So3000, Slandi Company);
- nitrate and nitrogen;
- phosphates.

Water samples were analyzed using microchip SlandiSP. In order to determine water purity class ranges the Regulation of the Minister of Environment from nine November 2011 was used (Regulation of the Minister of the Environment, 2011) (Tab. 1).

Table 1: Ranges of water purity classes.

Indicator	Unit	Purity classes		
		I	II	Unclassified
Dissolved oxygen	mg O_2/dm^3	≥ 7	≥ 5	Limit values are not established
Dissolved oxygen	mg O_2/dm^3	≥ 7	≥ 5	Limit values are not established
Dissolved oxygen	mg O_2/dm^3	≥ 7	≥ 5	Limit values are not established
Dissolved oxygen	mg O_2/dm^3	≥ 7	≥ 5	Limit values are not established
Dissolved oxygen	mg O_2/dm^3	≥ 7	≥ 5	Limit values are not established
Dissolved oxygen	mg O_2/dm^3	≥ 7	≥ 5	Limit values are not established

RESULTS AND DISCUSSION

Analysis of the catchment under study

The south-western and central part of the catchment area is located in the borders of Tomaszów Lubelski city, while the rest is located on municipal land, among a few villages: Sabaudia, Majdanek and Resztówka.

Height above the sea level increases gradually from the South-West to the North-East. Gorges are located in the northern and north-western part of the catchment.

The southern part of the study area was occupied by agriculture fields, meadows and highly hydrated wastelands. In the western part there were industrial buildings (building warehouses, publican warehouse, and garbage dump), garden plots, as well as urban and rural residential buildings. In the north and east parts there were agriculture fields, meadows, forests and rural buildings. The area gradually rose up until the White Mountain Hill (Fig. 4).

Analysis of catchment land use forms in 1992 and 2012 revealed the direction and rate of changes. In the 1990s the analysed study area was dominated by agriculture fields and meadows. Based on the analysis of the 2012 year, the study area had comparably decreased in land occupied by agrocoenoses. More than half the surface of meadows have overgrown, and much of the agricultural land is now forested (Tab. 2).

In areas with high water content, fish ponds have been created, consequently forming numerous backwaters and ponds in the watercourse valley (Fig. 4). In the study area there is now significant diversification of land use forms with a predominance of natural forms. Anthropogenic infrastructure is also beginning to replace cultivated fields. Due to the location of the watercourse, it is difficult to avoid such a trend.

Changes associated with an increase in the ecological stability of the watercourse catchment were confirmed by ESC indicator. Indicator values rose from 0.32 in 1992 to 0.42 in 2012, and although low, they showed a growth trend.

In general, areas dominated by agricultural land and built-up areas are referred to as unstable landscape matrix. Only areas dominated by natural elements are described as ecologically stable. Unfortunately, the current dominant land use within the catchment, as well as the ESC value led to the classification of this wastercouse as unstable.

Table 2: Land use forms in studied catchment in 1992 and 2012.

Land use forms/year	1992	2012	1992	2012
Farmlands	Area (ha)		Area (%)	
Meadows	104.14	81.47	55	43
Forest/shrubs	47.60	27.59	25	14
Water body/wetlands	8.06	27.12	4	14
Urban area/build-up area	6.01	22.06	3	12
ESC indicator	24.23	32.80	13	17

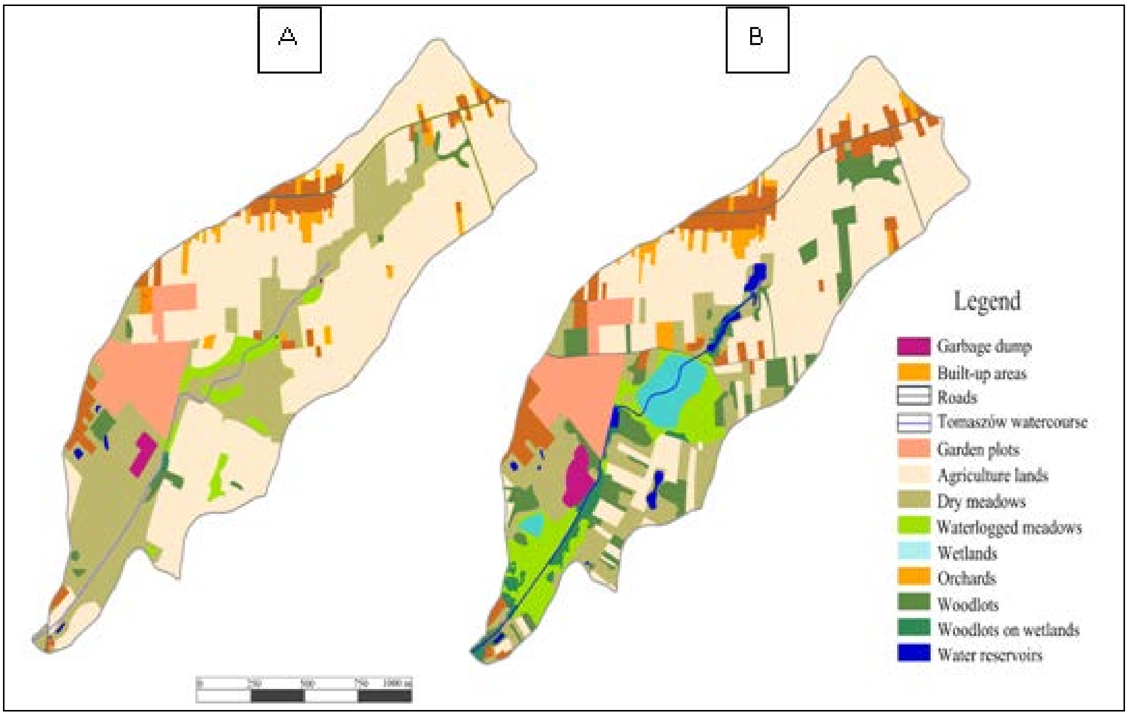

Figure 4: Analysis of land use forms in studied river valley catchment A) 1992, B) 2012.

Watercourse and river valley's naturalness assessment based on HQA index

The data obtained from field measurements was used to assess naturalness of the watercourse and the river valley (Tab. 3).

Table 3: Results of ranking hydromorphological parameters in the calculation of the HQA natural habitat index.

Hydromorphological parameters/studied river segments	1	2	3	4	5	6
Type of flow	5	4	4	4	2	6
Natural material of trough' bottom	4	3	3	3	3	4
Natural morphological elements of trough	2	1	0	0	2	0
Natural morphological elements of banks	3	3	3	3	3	3
Structure of shoreline vegetation	13	13	14	13	8	11
Groups of aquatic plants	3	0	1	6	4	6
Land use in 50 m belt from banks	2	2	3	1	3	0
Plantings and accompanying morphological elements	8	10	10	7	0	5
Valuable natural elements of the river environment	0	0	1	5	1	4
Sum = HQA	40	36	39	42	26	39
Naturalness of the watercourse and river valley	moderate	poor	moderate	moderate	very poor	moderate

Values of HQA index for the Tomaszów watercourse ranged between 26 and 42. The highest values of this index were achieved in segments no. I and IV, which is related to the occurrence of natural material in the trough bottom, natural morphological elements of bottom and banks, plantings in the immediate surroundings and wetlands. The lowest value of the index was indicated in segment no. V, in which the watercourse flows close to the ponds complex and to the vicinity of build-up area.

Assessment of the anthropogenic transformation degree of the watercourse and the river valley on the basis of HMS index

Values of HMS index of the Tomaszów watercourse ranged from three (segment IV) to 21 (segment I) (Tab. 4).

Table 4: Results of ranking anthropogenic modifications in the calculation of the HMS habitat modification index.

Hydromorphological parameters/studied river segments	1	2	3	4	5	6
Transformations observed in the control profiles	13	4	4	3	8	5
Water structures not recorded in the control profiles	8	0	0	0	8	0
Transformations observed during the assessment of synthetic profiles, not registered in the control	0	0	0	0	0	1
Sum = HMS	21	4	4	3	16	6
Degree of river' modification	Signif.	poor	poor	poor	moderate	poorly

Four of the analysed segments of watercourse were characterized by low anthropogenic transformations. The estuary watercourse, located near to the leachate of the disused garbage dump was the most transformed of all the segments assessed (Fig. 5).

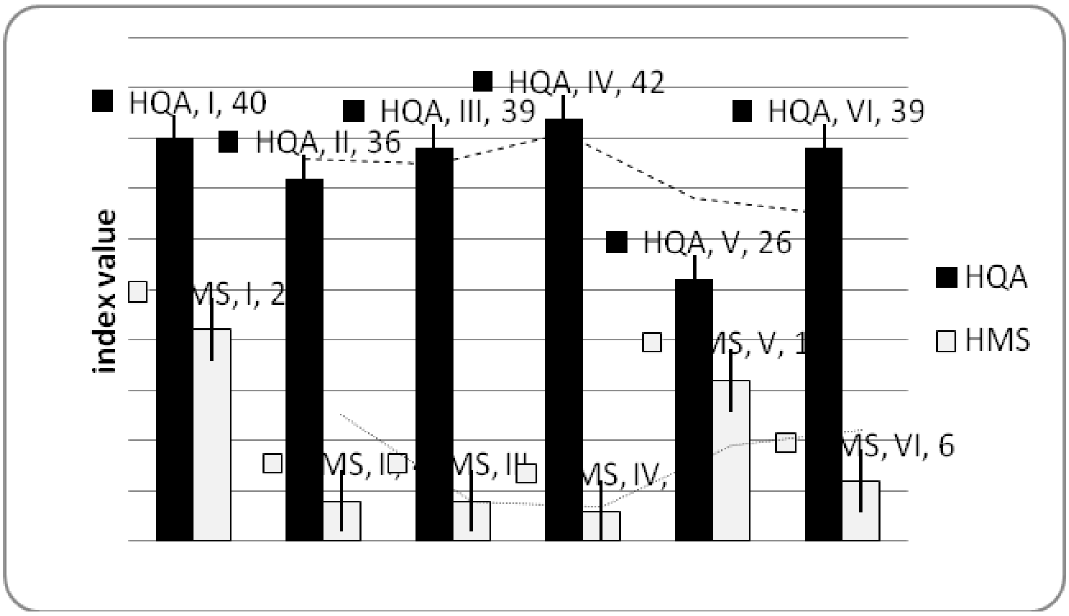

Figure 5: HQA and HMS values in particular research sites.

Banks along the entire length of the watercourse consisted of natural materials, with small fragments of concrete structures. The dominant material of the bottom was clay and river sediments, as well as sand. Edge transformations were minimal along the entire length of the watercourse, however, garbage did occur in a few segments. Water structures were present on each of the segments, of which, culverts were the most common. For almost the entire length of the watercourse smooth flow type dominated. Typical water vegetation occurred in only four segments, whereas numerous species of liverworts and mosses occurred in the fourth segment, and rooted plants with trailing shoots in water occurred along the shores of most segments. In segments close to built-up areas, especially garbage dump and fish ponds, an invasive plant species frequently occurred.

Evaluation of hydromorphological status of studied river segments

The final classification of the hydromorphological status of the watercourse (Bielak et al., 2012) was made based on the HQA and HMS numerical indexes. Where each of the studied segments were assigned a Roman numeral representing the state of classification (Tab. 5).

The analysis showed that 62% of the investigated watercourse was characterized by moderate hydromorphological state, whereas a poor state was observed in 38% of the watercourse length. Unfortunately, no areas were characterized as having good or very good status withinin this assessment.

Table 5: Hydromorfological classification of studied river segments based on the RHS classification diagram; I – very good state, II – good, III – moderate, IV – poor, V – very poor. Numbers 1-7 refer to the river segments within this study (Bielak et al., 2012).

		Categories of HQA index values				
		≥ 57	56-50	49-37	36-31	≤ 30
Value of HMS index	0-2	I	II	II	III	III
	3-8	II	II	III-3, 4, 6	III-2	IV
	9-20	III	III	III	IV	IV-5
	21-44	III	IV	IV-1	IV	V
	45-100	IV	IV	V	V	V

Assessment of purity water class of studied watercourse

Based on the physical and chemical parameters the majority of the watercourse was classified as belonging to the first class of purity, in all but two cases (Tab. 6). The first of which was observed in one of the fish ponds, where water quality could not be classified. In the vicinity of the pond, cultivated fields were also located on the slopes, above Sabaudia Village. The second discrepancy occurred within a garbage dump leaching into the watercourse, which was classified as a second class of water purity (Fig. 6).

Table 6: Chosen physical and chemical properties of water and purity classes.

Parameters/ research site		A spring	VI	V	IV	III	II	I
Water reaction pH	Mean value	7.87 ± 2.2	7.7 ± 2.6	7.87 ± 3.3	7.66 ± 2.3	7.73 ± 3.1	7.88 ± 3.5	7.72 ± 1.9
	Water quality	I	I	I	I	I	I	I
Carbonat-hardness mg $CaCo_3/dm^3$	Mean value	219.6 ± 12.5	180.3 ± 7.8	156.2 ± 14.9	198.2 ± 22.3	164.9 ± 31.7	212.8 ± 15.9	211.9 ± 14.9
	Water quality	I	I	I	I	I	I	I
Oxygen O_2/dm^3	Mean value	10.2 ± 2.7	14.7 ± 3.8	10.3 ± 3.2	12.9 ± 4.1	18.3 ± 4.4	18.1 ± 4.9	7.5 ± 1.4
	Water quality	I	I	I	I	I	I	I
Conductivity $\mu S/dm^3$	Mean value	383.7 ± 21.4	510.3 ± 32.2	472.7 ± 33	534.3 ± 45	615 ± 47.9	736.3 ± 63.1	696.3 ± 52.1
	Water quality	I	I	I	I	I	I	I
Phosphates mg PO_4/dm^3	Mean value	0.047 ± 0.03	0.32 ± 0.02	0.127 ± 0.005	0.057 ± 0.001	0.044 ± 0.003	0.273 ± 0.05	0.167 ± 0.096
	Water quality	I	uncla-ssified	I	I	I	II	I
Nitrate mg NO_3/dm^3	Mean value	1.155 ± 0.7	1.027 ± 0.56	0.075 ± 0.078	0.07 ± 0.004	0.118 ± 0.021	0.4 ± 0.015	0.191 ± 0.056
	Water quality	I	I	I	I	I	I	I

According to the current Water Framework Directive, member states of the European Union are required, inter alia, to protect water and aquatic ecosystems maintaining a good condition, as well as to improve water quality of degraded waters by human activities. This can maintain a balance of aquatic ecosystems, both for the direct benefit of humans, as well as to preserve natural water heritage. The Tomaszów watercourse did not fulfil the requirements of the Water Framework Directive, because its state was defined as poor and moderate. In a similar study, only one of seven studied segments within the Bochotniczanka River was in a good state (Maślanko and Sender, 2014).

The garbage dump is one of the main anthropogenic elements degrading the Tomaszów watercourse. Former garbage dump sites are a nationwide problem (Allgaier and Stegmann, 2006; Goran and Dušan, 2012; Laner et al., 2012). Despite the passing time, both on the closure of the garbage dump, as well as the introduction of the Water Framework Directive, this dump is in a state of deep neglect. Weaknesses have been observed in regards to the position of the dump, as it is located at a distance of approximatively five meters from the current watercourse, and its slope descends almost directly to the water.

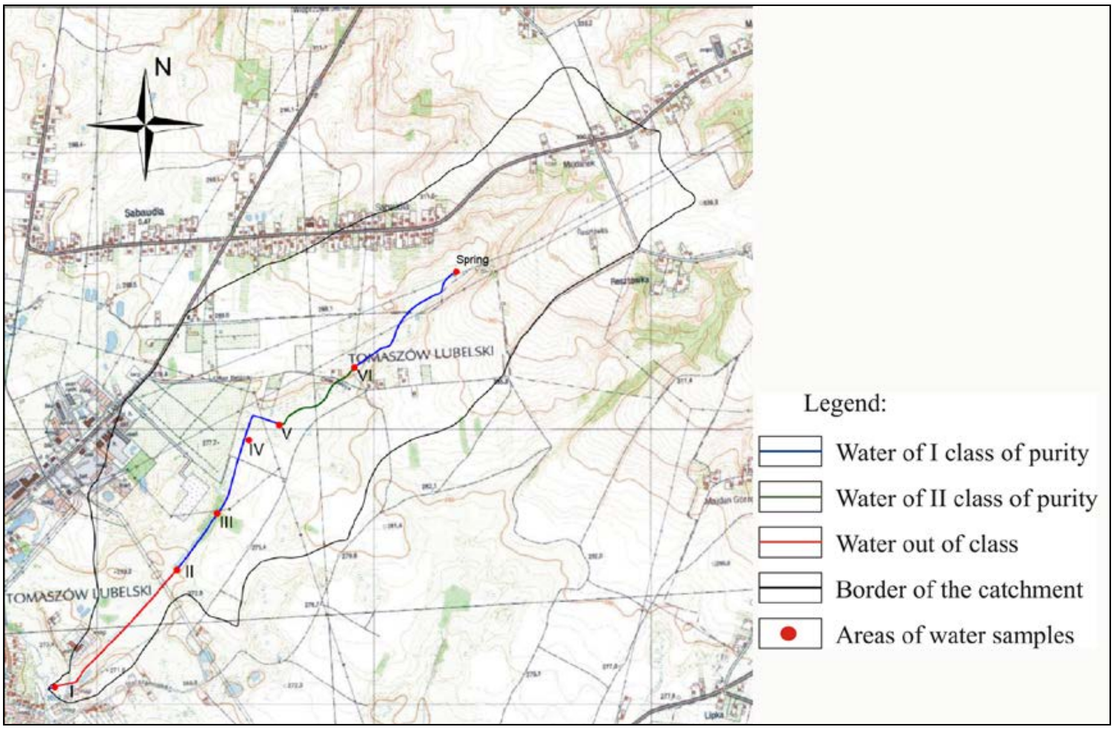

Figure 6: Purity classes in particular segments of studied watercourse.

This dump was also not fully subjected to any reclamation between 1992 and 2012. Its southern slope has not been covered by soil, and rubbishes scattered around the dump, visible from a far distance. In spring 2014 a pollutant leachate was clearly visible flowing from the bare slope to the stream. Upstream of the garbage dump, nearby water has increased turbidity, and in the bottom and middle layers water appeared as a rusty brown sludge.

Fish ponds were also found to be a degrading influence on the water purity and environment quality of the Tomaszów watercourse (Rzętała, 2008; Carr and Goulder, 1990; Boaventura et al., 1997; Wiesmann et al., 1988). The watercourse in the upper part flows through the land used for fish farming, and the impact of this economy can be seen in the form of increased concentration of nutrients, which resulted in the unclassified status of these segmenting terms of physical and chemical parameters.

These arguments proved that in the protection of surface water significant neglects occurred. The absence of dump reclamation in the study area is contrary to the main requirements of the Minister of the Environment, including the location, construction, exploitation and closure, which should correspond to the different types of garbage dumps from 24 March 2003 (Journal of Laws from 2003, no. 61, item 549), as well as to the Water Framework Directive, according to which member states should take care to protect water quality in all its aspects. The overriding purpose for conducting garbage dump reclamation process should be minimizing its potential negative impact on the environment.

Surroundings of Tomaszów Lubelski constituted areas with a high natural potential. A large number of protected areas exist, among which only four were founded in the 21st century; one in 2011 and three in 2007. Many various hiking and educational trails occur within the area, and protection is subjected to many species of plants and animals living in suitable habitats. Continuity of protected areas and areas of nature attractiveness of the whole Roztocze region, are suggested based on the existence of an important ecological corridor in this region. Despite this, human activities carried out in this area indicated serious negligence, leading to environmental degradation. As a consequence, this may lead to a deterioration of the quality of life and human health risks.

The results of the assessment by the RHS method allowed an increased attention to the potential of the area, but it has been weakened. According to the HQA index, the best result was a moderate value of the watercourse naturalness. In some segments the state was defined as poor or very poor. The area defined as very poor, however, includes the section where water flows from ponds followed by wetlands, which are valuable due to the presence of water purifying plants characteristic for such habitats. On this segment water flows calmly, spilling into several themes, which contributes to water purification, and after passing through this area the water returns to a first class of purity (Barling and Moore, 1994; Dhote and Dixit, 2009). Unfavourable results of RHS index again highlighted neglects towards the protection of this area, and a lack of efforts to achieve standards established by the Water Framework Directive.

The evaluation of purity water class of the Tomaszów watercourse indicated it is in much better condition than described by RHS method. The condition of each segment range from the first class of waters to unclassified water class. Of the measured water quality variables, a high concentration of phosphate was a limiting factor. Based on data from the Report of District Environment Programme, the Sołokija River, to which waters of the Tomaszów watercourse flows, in 2005 was assessed as V water class purity. Increased phosphate content in this river was also one of the factors determining the water purity class. Despite the ecological potential of the area, water from the Tomaszów watercourse and the Sołokiji River do not fulfill conditions set out in the Water Framework Directive, which indicates neglect of the entire catchment area (Report on the implementation of the tasks set out in the District Environment Programme).

CONCLUSIONS

Within the years spanning the comparison of conditions (1992-2012) land use change and anthropogenic development have occurred within the study area. A gradual intensity of natural succession has also been observed. Agriculture fields have overgrown and transformed into meadows, whereas former meadows and pastures are overgrown by bushes and trees, while simultaneously intensive building process have increased. Despite the position of the watercourse in the potentially favourable areas, outside a compact urban built-up, values of HMA and HQA indicators were defined as moderate or average.

The current biggest threats for the Tomaszów watercourse are point emitters of pollutants spaced along the entire length of the watercourse. Sanitary conditions should be promptly improved, and in particular adjacent garbage dump requires reclamation. This dump also affects the aesthetics of riparian areas. Additional threats include fishing and pollution from agriculture. Among ways to prevent pollution of river waters, it is important to exclude these threats from the hydrological line course with ponds, reducing fisheries management and implementation of trees and shrubs on steep slopes to reduce surface water runoff from farmland.

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THE DISTRIBUTIONAL DATA OF SIMULIIDAE (INSECTA, DIPTERA) SPECIES IN YEŞİLIRMAK RIVER (TURKEY)

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KEYWORDS: Blackflies, habitat degradation, running water, Simuliidae, Turkey, water quality, Yeşilırmak River basin.

ABSTRACT

This research aims to investigate the Simuliidae fauna of Yeşilırmak River basin and determine the species composition of the collecting sites. The study was carried out in July 2008 and June 2009. One genus and eleven species (*Metacnephia* sp., *Metacnephia subalpina, Simulium (Eusimulium) angustipes, Simulium (Nevermannia) costatum, Simulium (Simulium) argenteostriatum, Simulium (Simulium) bezzii, Simulium (Simulium) ornatum, Simulium (Simulium) trifasciatum, Simulium (Simulium) variegatum, Simulium (Wilhelmia) balcanicum, Simulium (Wilhelmia) lineatum* and *Simulium (Wilhelmia) pseudequinum*) were recorded from 16 collecting sites. The distribution and abundance of Simuliidae species reflect the changes in water quality of Yeşilırmak River, due to agricultural activities and urban areas.

RESUMEN: Datos sobre distribución de Simulidos (Insecta, Diptera) en el Río Yeşilırmak (Turquía).

En este trabajo se determinó la composición específica de la fauna de simúlidos en la cuenca del Río Yeşilırmak en diversos sitios de colecta. El estudio fue llevado a cabo entre junio de 2008 y junio de 2009. En 16 puntos de muestreo se colectaron once especies pertenecientes a un género (*Metacnephia* sp., *Metacnephia subalpina, Simulium (Eusimulium) angustipes, Simulium (Nevermannia) costatum, Simulium (Simulium) argenteostriatum, Simulium (Simulium) bezzii, Simulium (Simulium) ornatum, Simulium (Simulium) trifasciatum, Simulium (Simulium) variegatum, Simulium (Wilhelmia) balcanicum, Simulium (Wilhelmia) lineatum* and *Simulium (Wilhelmia) pseudequinum*). La distribución y abundancia de simúlidos refleja cambios en la calidad del agua en el Río Yeşilırmak, debidos a actividades de agricultura y de áreas urbanas.

REZUMAT: Distribuția simuliidelor (Insecta, Diptera) pe Râul Yeşilırmak (Turcia).

Prezentul studiu are ca scop cercetarea faunei de simuliide din bazinul hidrografic Yeşilırmak și determinarea compoziției la nivel de specie, din stațiile de colectare. Studiul s-a desfășurat în perioada iulie 2008 – iunie 2009. În cele 16 stații de colectare a fost identificat un gen cu 11 specii (*Metacnephia* sp., *Metacnephia subalpina, Simulium (Eusimulium) angustipes, Simulium (Nevermannia) costatum, Simulium (Simulium) argenteostriatum, Simulium (Simulium) bezzii, Simulium (Simulium) ornatum, Simulium (Simulium) trifasciatum, Simulium (Simulium) variegatum, Simulium (Wilhelmia) balcanicum, Simulium (Wilhelmia) lineatum* și *Simulium (Wilhelmia) pseudequinum*). Distribuția și abundența simuliidelor sunt caracteristice pentru calitatea apei râului Yeşilırmak, influențată de activitățile agricole și de ariile urbane traversate.

INTRODUCTION

The species composition of Simuliidae is important when measuring environmental quality of freshwater ecosystems. Specially, filter feeding larvae of blackflies which use dissolved organic matter and plays a key role in nutrient cycle in rivers (Bernotiene, 2006; Zhang et al., 1998).

Several studies demonstrated that the effects of anthropogenic activities have heavily disturbed the aquatic ecosystems in Turkey.

Simuliidae species that respond to various environmental degradations are bioindicators and they are a very useful tool for assessing the quality of running waters. The species composition of Simuliidae can be used as an indicator of agricultural, industrial and urbanization impacts on aquatic ecosystems (Curtean-Bănăduc, 2012; Kazancı, 2006; Lautenschlager and Kiel, 2005; Feld et al., 2002).

The amount of data that has been gathered, in Turkey, on their relationships with habitat quality, habitat preferences and response to degradations is insufficient. However, there has recently been a significant increase in these studies (Ertunç, 2009; Kalafat, 2008; Kazancı, 2006; Şirin, 2001; Adler and Şirin, 2014; Başören and Kazancı, 2012; Başören (Ertunç) and Kazancı, 2011; Başören (Ertunç) and Kazancı, 2012; Başören and Kazancı, 2013; Clergue-Gazeau and Kazancı, 1992; Crosskey and Zwick, 2007; Kazancı and Clergue-Gazeau, 1990; Kazancı and Ertunç, 2008a; Kazancı and Ertunç, 2008b; Kazancı and Ertunç, 2008c; Kazancı and Ertunç, 2010; Başören et al., 2013; Ertunç et al., 2008; Şirin et al., 2015).

This research aims to investigate the Simuliidae fauna of Yeşilırmak River basin and to determine the species composition of the collecting sites and the effects of pollution and degradation on Simuliidae fauna.

MATERIAL AND METHODS

Yeşilırmak River is located in Northern Turkey and it is the third largest basin (38,730 km^2) in Turkey. The catchment covers approximately 5% of Turkey's total area and its length is 519 km. It runs from Eastern Anatolia and into the Black Sea in Samsun (Fig. 1).

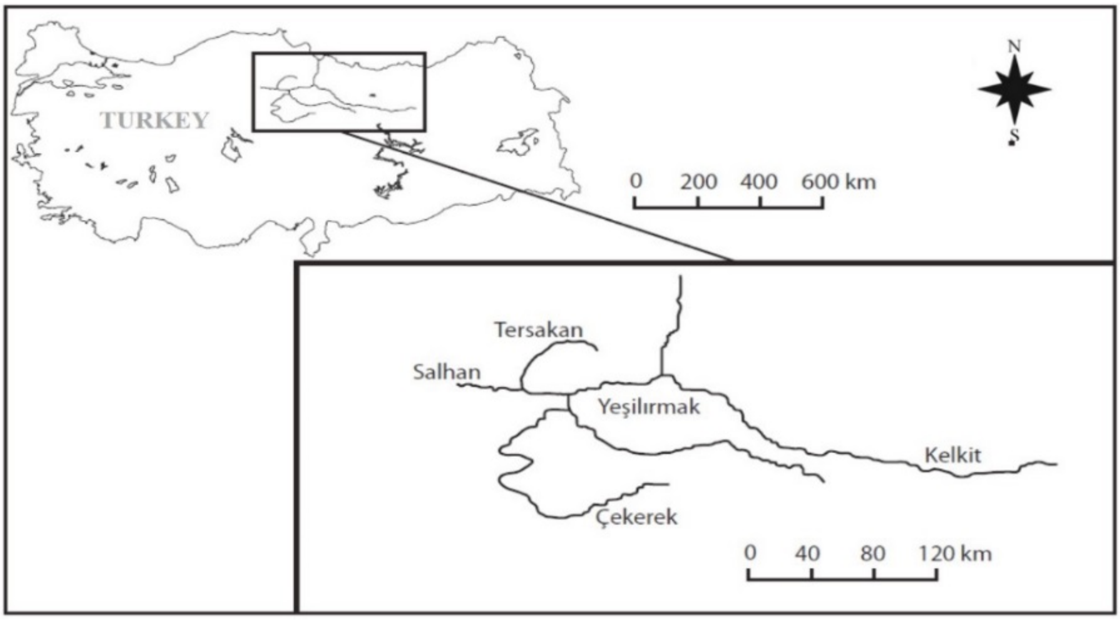

Figure 1: Yeşilırmak River basin.

The habitat quality of the Yeşilırmak River has been affected by various anthropogenic activities such as urban sewage, physical degradation, agricultural and industrial activities (Figs. 2a, b, c). Hydroelectric power plants, regulators and dams are also serious threats to water and habitat qualities of Yeşilırmak River. All these activities have negative impacts on Simuliidae fauna and this was clearly visible in some of the investigated sites.

Larvae and pupae of Simuliidae were collected by a standard pond net and by hand from different types of habitats at each site. Samples were preserved in 80% ethyl alcohol (ethanol). The Leica MZ75 stereomicroscope and Olympus CX21FS1 binocular microscope were used for identification. Individuals of Simuliidae were identified according to Rubtsov (1990), Lechthaler and Car (2005), Crosskey and Zwick (2007).

Water temperature, dissolved oxygen and pH were measured in the field by an YSI 556 multiparameter system. Water samples were also taken from the sites to analyze levels of PO_4-P, NO_3-N, NO_2-N and NH_4-N. These parameters were measured by a Hach DR/890 Datalogging Colorimeter (Tab. 1).

Figure 2a: Some studied sites of Yeşilırmak River.

Figure 2b: Some studied sites of Yeşilırmak River.

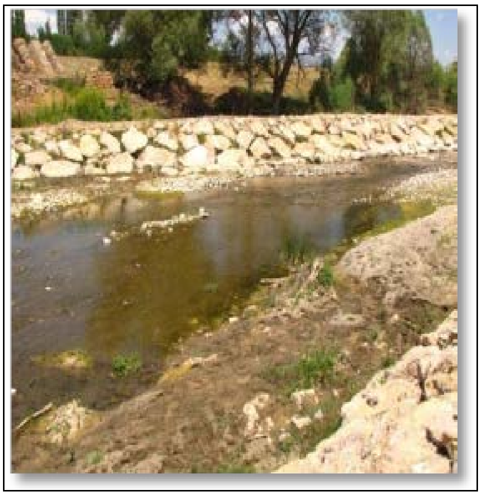

Figure 2c: Some studied sites of Yeşilırmak River.

Klee (1991) and "Regulations of Surface Water Quality Management" prepared by Ministry of Forestry and Water Management (2012) were used to determine the water quality class of the collecting sites.

Blackfly samples were collected from the Yeşilırmak River and tributaries in July 2008 and June 2009. A total of 20 collecting sites (12 sites in 2008, eight sites in 2009) were studied, but Simuliids were found at only 16 sites (10 sites in 2008, six sites in 2009).

RESULTS AND DISCUSSION

Site 1 (08), 2 (08), 3 (08), 4 (08), and 13 (09) were influenced by agricultural activities and urban pollution. The concentrations of PO_4-P and NO_2-N were high in the river due to sewage from urban areas and agricultural runoff. The water qualities of sites 1 (08) and 4 (08) were Class III, site 13 (09) was Class III-IV, site 2 (08) and 3 (08) were Class IV because of two variables (PO_4-P and NO_2-N). Also, all of these sites were physically disturbed. Simuliidae fauna was affected negatively by these deteriorations.

The flow rate of sites 5 (08), 7 (08) and 8 (08) was low because the water level was low due to seasonal conditions. For this reason, the water temperature was high and dissolved oxygen levels were low. Also, agricultural pollution and physical destruction were detected in the stream bed of site 5 (08). The water qualities of these sites were Class III.

The dam is located before site 9 (08), site 10 (08) and site 11 (08). When physicochemical variables were measured and samples were collected, the water was released from the floodgate. The water qualities of these sites were high (Class I and II) because the concentrations of pollutants decreased and values of physicochemical variables were altered. Also, Simuliidae species may have drifted downstream. It is impossible to gather accurate information about the species composition and the water qualities in these sites.

Although there are no agricultural and urban areas around site 14 (09), site 15 (09), site 16 (09), site 17 (09) and site 18 (09), the water qualities of these sites were low (Class III-IV and IV). In these sites, the PO_4-P concentration was high and pH value was low because of snow-melt and rainstorms. This situation is observed seasonally and is defined as episodic acidification (Kazancı, 2009; Wellington and Driscoll, 2004). Simuliidae species as several other aquatic organisms are not able to tolerate acidic waters and they leave their habitat. For this reason, the water quality class and species composition can be misleading in this period.

Table 1: Physicochemical parameters of the collecting sites.

	Water temp. (°C)	Dissolv. oxygen (mg/l)	pH	PO_4-P	NO_3-N	NO_2-N	NH_4-N	Water quality class
1 (08)	23.32	8.15	8.15	0.222	0.294	0.030	0	III
2 (08)	21.52	3.11	7.87	0.378	0	0.073	0.465	IV
3 (08)	23.34	6.71	8.23	0.391	0.294	0.081	0.271	IV
4 (08)	20.81	8.45	8	0.052	0	0.039	0.047	III
5 (08)	25.41	7.24	8.27	0.020	0.023	0.009	0	III
7 (08)	25.06	6.81	8.5	0.150	0.068	0.007	0	III
8 (08)	25.79	5.48	8.72	0.153	0.045	0.006	0	III
9 (08)	18.97	8.75	8.1	0	0	0	0	I
10 (08)	19.75	8.83	8.35	0.147	0.045	0.002	0	II
11 (08)	18.94	7.97	8.35	0.330	0.023	0.006	0	II
13 (09)	14.28	9.04	6	1.94	0	0.0015	0.078	III-IV
14 (09)	19.47	8.81	7.2	2.23	0.023	0.0018	0	IV
15 (09)	15.91	8.94	6.5	1.77	0.113	0.0024	0	III-IV
16 (09)	17.99	8.43	6.9	2.71	0.045	0.0043	0	IV
17 (09)	8.65	12.18	6.3	2.53	0.045	0.0034	0	IV
18 (09)	14.88	10.78	6	2.30	0.113	0.0055	0	IV

As a result of this study, one genus and eleven species (*Metacnephia* sp., *Metacnephia subalpina, Simulium (Eusimulium) angustipes, Simulium (Nevermannia) costatum, Simulium (Simulium) argenteostriatum, Simulium (Simulium) bezzii, Simulium (Simulium) ornatum, Simulium (Simulium) trifasciatum, Simulium (Simulium) variegatum, Simulium (Wilhelmia) balcanicum, Simulium (Wilhelmia) lineatum* and *Simulium (Wilhelmia) pseudequinum*) were recorded from 16 collecting sites (Tab. 2a, b).

The most common species in the Yeşilırmak River were *Simulium (S.) bezzii, Simulium (W.) balcanicum* and *Simulium (W.) pseudequinum*. These three species have a wide-spread distribution in Palearctic Region and they were recorded in many regions in Turkey (Ertunç, 2009; Kalafat, 2008; Kazancı, 2006; Şirin, 2001; Clergue-Gazeau and Kazancı, 1992; Crosskey and Zwick, 2007; Kazancı and Ertunç, 2008a; Kazancı and Ertunç, 2008b; Kazancı and Ertunç, 2008c; Kazancı and Ertunç, 2010; Başören (Ertunç) and Kazancı, 2011; Başören (Ertunç) and Kazancı, 2012; Başören and Kazancı, 2012; Başören and Kazancı, 2013; Başören et al., 2013; Ertunç et al., 2008).

Simulium (S.) bezzii has the ability to survive in eutrophic waters and it can live in physically degraded habitats (Kazancı, 2006; Kazancı and Ertunç, 2010; Lechthaler and Car, 2005). This species prefers mainly oligosaprobic and betamesosaprobic environments (Car et al., 1995). *Simulium (S.) bezzii* was collected from eight sites (site 5 (08), site 8 (08), site 9 (08), site 10 (08), site 11 (08), site 13 (09), site 15 (09) and site 16 (09)). It is expected that this species is found in these sites.

Table 2a: Simuliidae list of collecting sites.

	1 (08)	2 (08)	3 (08)	4 (08)	5 (08)	7 (08)	8 (08)	9 (08)
Metacnephia sp.								
Metacnephia subalpina								
S. (E.) angustipes					*		*	
S. (N.) costatum							*	
S. (S.) argenteostriatum							*	
S. (S.) bezzii					*		*	*
S. (S.) ornatum							*	
S. (S.) trifasciatum							*	
S. (S.) variegatum								
S. (W.) balcanicum	*	*	*	*	*		*	
S. (W.) lineatum						*		
S. (W.) pseudequinum	*		*	*	*		*	

Simulium (W.) balcanicum and *Simulium (W.) pseudequinum* which are other common species, live in similar environmental conditions and do not prefer special habitats (Lautenschlager and Kiel, 2005; Feld et al., 2002). *Simulium (W.) balcanicum* and *Simulium (W.) lineatum* are resistant to temperature changes and they can tolerate increasing temperature (Kazancı, 2006; Stangler and Halgos, 2007). *Simulium (W.) balcanicum* prefers small running waters and it survives in disturbed environments while *Simulium (W.) lineatum* prefers medium-sized and sand-bottom lowland rivers and it survives in hydromorphologically undisturbed sites (Rubtsov, 1990). *Simulium (W.) pseudequinum* can be found in many different freshwater habitats (Feld et al., 2002). These three species prefer mainly betamesosaprobic and alphamesosaprobic environments (Car et al., 1995). *Simulium (W.) balcanicum* and *Simulium (W.) pseudequinum* were collected from the same sites (site 1 (08), site 3 (08), site 4 (08), site 5 (08), site 8 (08) and site 10 (08)). In site 2 (08), *Simulium (W.) balcanicum* was found alone. *Simulium (W.) lineatum* was collected from only site 7 (08). These sites are suitable for the survival of the three species.

Table 2b: Simuliidae list of collecting sites.

	10 (08)	11 (08)	13 (09)	14 (09)	15 (09)	16 (09)	17 (09)	18 (09)
Metacnephia sp.								*
Metacnephia subalpina							*	
S. (E.) angustipes								
S. (N.) costatum								
S. (S.) argenteostriatum								
S. (S.) bezzii	*	*	*		*	*		
S. (S.) ornatum					*	*		
S. (S.) trifasciatum				*	*	*		
S. (S.) variegatum					*			
S. (W.) balcanicum	*							
S. (W.) lineatum								
S. (W.) pseudequinum	*							

Simulium (S.) ornatum has not specific habitat requirements and the distribution of this species is not dependent on water temperature, flow rate and substrate structure (Bernotiene, 2006). It can survive in both in polluted freshwaters and in clean waters (Lechthaler and Car, 2005; Ignjatovic Cupina et al., 2003). For this reason, *Simulium (S.) ornatum* is one of the most common species of Simuliidae family in Europe (Crosskey and Howard, 2004). This species prefers mainly alphamesosaprobic and betamesosaprobic environments, but it is also found in oligosaprobic environments (Car et al., 1995). *Simulium (S.) ornatum* was collected from site 8 (08), site 15 (09) and site 16 (09) and these sites are suitable for the survival of this species.

Simulium (S.) trifasciatum spreads almost all over Europe (Crosskey and Howard, 2004). It is mostly found in small and clean streams (Bass, 1998). The larvae prefer streams with low organic pollution (Bernotiene, 2006). This species is generally found in oligosaprobic and betamesosaprobic environments (Car et al., 1995). It was collected from site 8 (08), site 14 (09), site 15 (09) and site 16 (09). It is expected to find this species at these sites.

Simulium (S.) variegatum is well adapted to high currents and it is found in upland streams (Kiel, 2001). Also, it was determined that this species can live in degraded sites (Lautenschlager and Kiel, 2005). This species prefers mainly oligosaprobic and betamesosaprobic environments, but it is also found in xenosaprobic and alphamesosaprobic environments (Car et al., 1995). It was collected only from site 15 (09), this site is suitable for the survival of this species.

Simulium (E.) angustipes is widely spread all over Europe (Crosskey and Howard, 2004). This species inhabits small, lowland streams which are rich in nutrients (Lechthaler and Car, 2005). It prefers mostly betamesosaprobic environments and is found in epirhithron and metarhithron of running waters (Car et al., 1995). *Simulium (E.) angustipes* was collected from site 5 (08) and site 8 (08). It is to be expected to find this species in these areas.

Simulium (N.) costatum can be found throughout Europe (Crosskey and Howard, 2004). This species prefers small springs and attaches onto plants (Rubtsov, 1990). Also, *Simulium (N.) costatum is* very resistant to low current velocity (Jensen, 1997). It is generally found in oligosaprobic and betamesosaprobic running waters (Car et al., 1995). This species was collected from only site 8 (08) and this site is suitable for the survival of this species.

Simulium (S.) argenteostriatum lives in fast-flowing mountain streams (Lechthaler and Car, 2005). This species prefers mainly oligosaprobic environment but it can also be found in xenosaprobic environments (Car et al., 1995). It was collected only from site 8 (08) like *Simulium (N.) costatum.* The water quality of site 8 (08) was Class III. According to the results of this study, *Simulium (S.) argenteostriatum* can also inhabit moderately polluted sites.

The saprobic level of the *Metacnephia* species is unknown, but species of this genus are usually found in unregulated streams with high water flow (Malmqvist, 1999) and prefer oligosaprobic environments in Spain (Gallardo-Mayenco and Toja, 2002) and in Turkey (Kazancı and Ertunç, 2010). *Metacnephia subalpina* was collected only from site 17 (09) and *Metacnephia* sp. was collected only from site 18 (09). Water quality of these sites was Class IV due to the level of PO_4-P concentration and the site' pH values. These variables were affected by snowmelt and rainstorms. Individuals may have drifted downstream to sampling sites.

The current velocity is very important for many passive filter feeding Simuliidae larvae (Bernotiene, 2006). The larvae and pupae of Simuliidae are affected by any change in river conditions and they could leave their habitat because of these changes (Rubtsov, 1990).

This study shows that the species composition may have been affected by various abiotic and biotic factors. Community structures of Simuliidae were negatively affected by dam impacts in particular.

CONCLUSIONS

According to the results of this study, environmental impacts and pollution were observed in Yeşilırmak River and tributaries. Dams and hydroelectric power plants on the river caused changes in temperature, dissolved oxygen concentrations and flow regime. Other effects of dam and hydroelectric power plants are habitat loss and sedimentation. Also, Yeşilırmak River and surrounding area have been threatened by agricultural pollution and domestic wastes. Due to all these activities, 16 collecting sites located on the Yeşilırmak River were characterized as mainly betamesosaprobic (Class III) and alphamesosaprobic (Class IV).

The community structures of Simuliidae and water qualities of their habitats were negatively affected in the Yeşilırmak River basin. If this continues, diversity of species of Simuliidae and other benthic macroinvertebrates will start to decline. Therefore, the long term physicochemical and biological monitoring of the water quality and controlling the pollution caused by agricultural and domestic wastes is crucially important.

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REVIEW OF PARASITIC COPEPODS RECORDED IN FISH FROM TURKEY

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KEYWORDS: review, parasitic, copepod, fish, Turkey.

ABSTRACT

This review presents the occurrence of 62 parasitic copepod species from 72 different fish species (64 wild, two cultured, seven from aquarium) from Turkey.

The parasite species list is arranged by providing parasite species name, host fish, location of host fish capture and author, date of published record.

All parasites and their hosts are confirmed with the recent systematic accounts and full taxonomic account according to literature and internet database. Siphonostomatoida with 47 species and Caligidae with 12 species are the dominant order and family among parasitic copepoda with regard to species diversity, host distribution and location.

ZUSAMMENFASSUNG: Übersicht parasitärer in Fischen festgestellter Copepoden.

Vorliegende Übersicht bezieht sich auf das Vorkommen von 62 als Parasiten in 72 verschiedenen Fischarten lebender Copepoden Arten (64 wildlebende, zwei in Fischzuchtanlagen, sieben in Aquarien) in der Türkei.

Die Liste der Parasiten umfasst den Namen der parasitierenden Art, den Wirtsfisch, Fangort des Fisches, Name des Sammlers und Veröffentlichung des Belegs.

Alle Parasiten und deren Wirte werden nach den rezenten systematischen und taxonomischen Beschreibungen angegeben. Die Siphonostomatoida sind mit 47 Arten und die Caligidae mit 12 Arten die dominanten Ordnungen und Familien unter den parasitischen Copepoden im Hinblick auf die Artendiversität, Verteilung der Wirte und der Fundorte.

Die wissenschaftlichen Namen aller Parasiten, der Wirtsfische und deren Synonyme wurden anhand von Fachliteratur und Internet Datenbanken überprüft.

REZUMAT: Recenzia copepodelor parazite pe peşti înregistrate în Turcia.

Această recenzie prezintă apariția a 62 de specii parazite copepode pe un număr de 72 de specii diferite de peşti din Turcia (64 sălbatice, două de cultură, şapte de acvariu).

Lista de specii parazite cuprinde numele speciilor parazite, a peştilor gazdă, locația din care au fost colectați peştii, autorul, datele publicate în care a fost semnalată apariția lor.

Toți paraziții împreună cu gazdele lor sunt confirmați și actualizați cu cele mai recente elemente de sistematică și taxonomie în vigoare. Ordinul și familia ce domină sunt: Siphonostomatoida cu 47 de specii și Caligidae cu 12 specii (Copepoda) cu privire la diversitatea speciilor, distribuție și areal.

Denumirile științifice ale paraziților, peștii gazdă și sinonimele lor au fost verificate după literatura de specialitate și bazele de date de pe internet.

INTRODUCTION

Parasitic crustaceans are common on fish hosts in coastal marine and also brackish waters. Three major groups of Crustacea contain fish parasites; Isopoda, Branchiura and Copepoda (Öktener and Sezgin, 2000).

Parasitic copepods belong to the suborder Siphonostomatoida (75%), some 20% to Poecilostomatoida, and only about 5% to Cyclopoida according to Kabata (1988). Parasitic copepods occur on several hosts such as the sponges, cnidarians, chinoderms chordates, sea squirts, fishes and mammals (Boxshall, 2005). Parasitic copepods damage their hosts directly by their attachment mechanisms and by their feeding activities. Infestation by any parasitic copepod may result in loss of condition of the host (Boxshall, 2005). Lester and Hayward (2006) explained effect on host, morphology and life cycle, infection of different parasitic copepods on freshwater and marine habitats.

In Turkey, the total length of the sea coast is 8,333 km, having the Black Sea, the Mediterranean Sea, the Aegean Sea and the Marmara Sea. Among these, the Black and Mediterranean shores have no recessed-protruding structures, instead the Aegean Sea has indented coastline, including bays, gulfs, deltas and islands. The Marmara Sea connects the Mediterranean Sea to the Black Sea (Kılıç, 1999).

The examination of literature on marine and inland water habitats (lake, river) of Turkey by Bilecenoğlu et al. (2014), Çiçek et al. (2015) has revealed the report of 512 marine fish species and 368 freshwater fish species.

This review plans to show the parasitic copepods reported from marine, freshwater, and aquarium fish of Turkey.

MATERIAL AND METHODS

Information from all available references on parasitic copepod of fishes in Turkey (journal publications, reports of research projects, thesis, proceedings of congress, symposium proceedings) from 1931 to 2015 was gathered to provide parasite-host lists.

The scientific names of all parasites, host fishes and their synonyms were checked according to Bilecenoğlu et al. (2014), Çiçek et al. (2015) and the electronic sites; Eschmeyer (2015); Froese and Pauly (2015), ITIS (2015); WoRMS Editorial Board (2015), concerning with the classification (Tabs. 1 and 2).

Table 1: Change of synonymies and incorrect spellings of parasitic copepod species to current valid names.

Synonyms and incorrect spellings	Valid Names
Lernanthropus mugilis Brian, 1898	*Lernanthropsis mugilis* (Brian, 1898)
Lernanthropus trachuri Brian, 1903	*Lernanthropinus trachuri* (Brian, 1903)
Neobrachiella impudica Nordmann, 1832	*Thysanote impudica* (Nordmann, 1832)
Neobrachiella bispinosa Nordmann, 1832	*Parabrachiella bispinosa* (Nordmann, 1832)
Eubrachiella exigua Brian, 1906	*Parabrachiella exigua* (Brian, 1906)
Hatschekia pagellibogneravi Hesse, 1879	*Hatschekia pagellibogneravei* (Hesse, 1878)
Ergasilus nanus van Beneden, 1870	*Ergasilus lizae* Krøyer, 1863
Tracheliastes stellifer Nordmann, 1832	*Pseudotracheliastes stellifer* (Kollar, 1835)
Clavellopsis fallax Heller, 1868	*Clavellotis fallax* (Heller, 1865)
Caligus fugu Yamaguti and Yamasu, 1959	*Caligus lagocephali* Pillai, 1961
Hatschekia mulli van Beneden, 1851	*Hatschekia mulli* (Van Beneden, 1851)

Table 2: Change of synonymies and incorrect spellings of fish to current valid names.

Synonyms and incorrect spellings	Valid Names
Carassius auratus auratus	*Carassius auratus*
Chondostroma regium	*Chondrostoma regium*
Leuciscus cephalus	*Squalius cephalus*
Leuciscus cephalus orientalis	*Squalius cephalus*
Vimba vimba tenella	*Vimba vimba*
Chalcalburnus chalcoides	*Alburnus chalcoides*
Rhodeus sericeus amarus	*Rhodeus amarus*
Rhodeus sericeus	*Rhodeus amarus*
Pomatomus saltator	*Pomatomus saltatrix*
Sparus auratus	*Sparus aurata*
Spondyliosoma cantharus	*Spondyliosoma cantharus*
Trigla lucerna	*Chelidonichthys lucerna*
Platichthyes flesus	*Platichthys flesus*
Pleuronectes flesus luscus	*Platichthys flesus*

RESULTS

Review list on parasitic copepod of fish from Turkey is arranged by providing parasite species name, host fish, location of host fish capture, infestation site and author, date of published record (Tab. 3). Although parasitic copepods at species and genera level were reported from marine fish, only species level will be considered here.

This review presents the occurrence of 62 parasitic copepod species from 72 different fish species (64 wild, two cultured, seven from aquarium) of Turkey.

Diversity of parasitic copepods according to order are as follows: Cyclopoida with two species; Poecilostomatoida with 14 species; Siphonostomatoida with 46 species (Fig. 1).

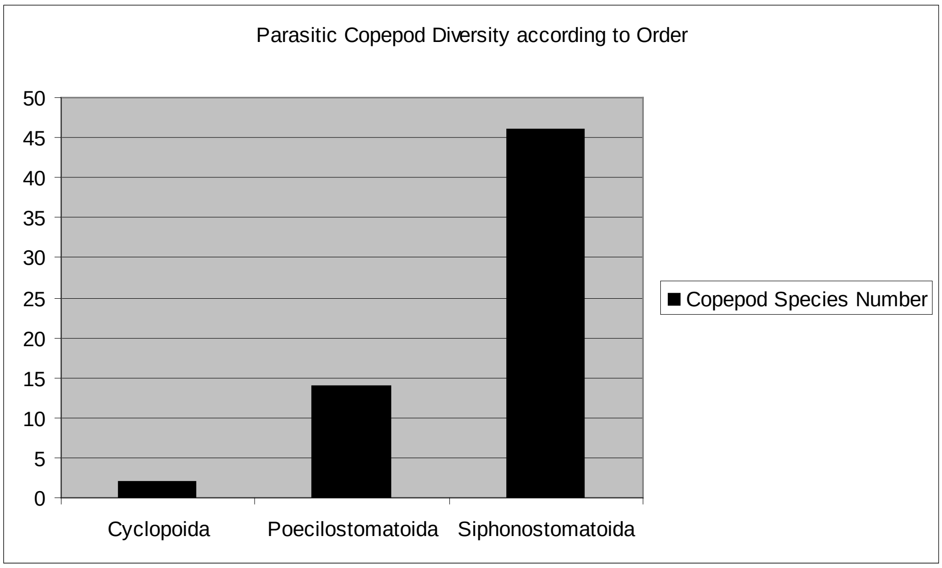

Figure 1: Parasitic copepod species diversity according to order.

Five families are dominant in terms of diversity of parasitic copepods according to family such as: Lernaeopodidae with 15 species, Caligidae with 12 species, Lernanthropidae with 10 species, Ergasilidae with nine species, Pennellidae with six species (Fig. 2).

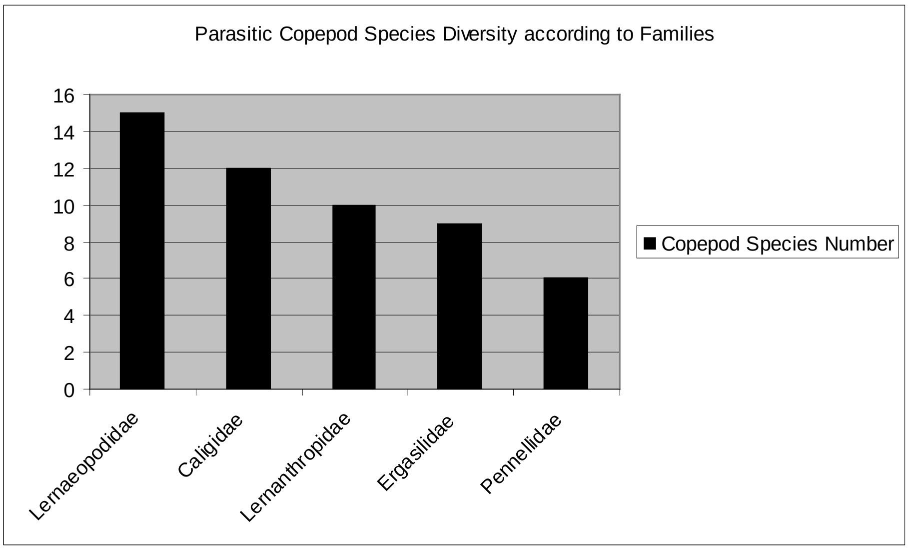

Figure 2: Parasitic copepod species diversity according to dominant families.

Reports of parasitic copepods from Turkey are compatible according to literature in terms of infestation site on host fishes such as caligids from gill filaments, body surface, lernanthropids from gill filaments.

Ergasilidae species were reported from 25 different host fish species; Lernaeidae from 16 different host fish species; Caligidae from 15 different host fish species; Lernaeopodidae from 15 different host fish species; Lernanthropidae from eight different host fish species and Pennellidae from six different host fish species (Fig. 3).

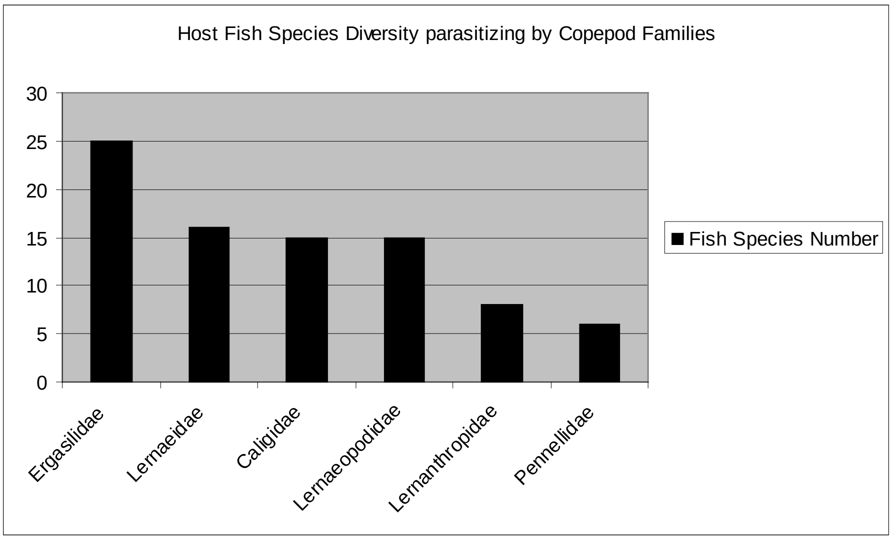

Figure 3: Host fish species diversity parasitizing by copepod families.

Parasitic copepods were reported 40 marine fish species; 20 freshwater host species; seven aquarium fish; three transitional species; two culture fish species. Only two copepod species (*Lernaeopoda galei*, *Pandarus bicolor*) were recorded as parasitic on the two chondrichthyans species (Fig. 4).

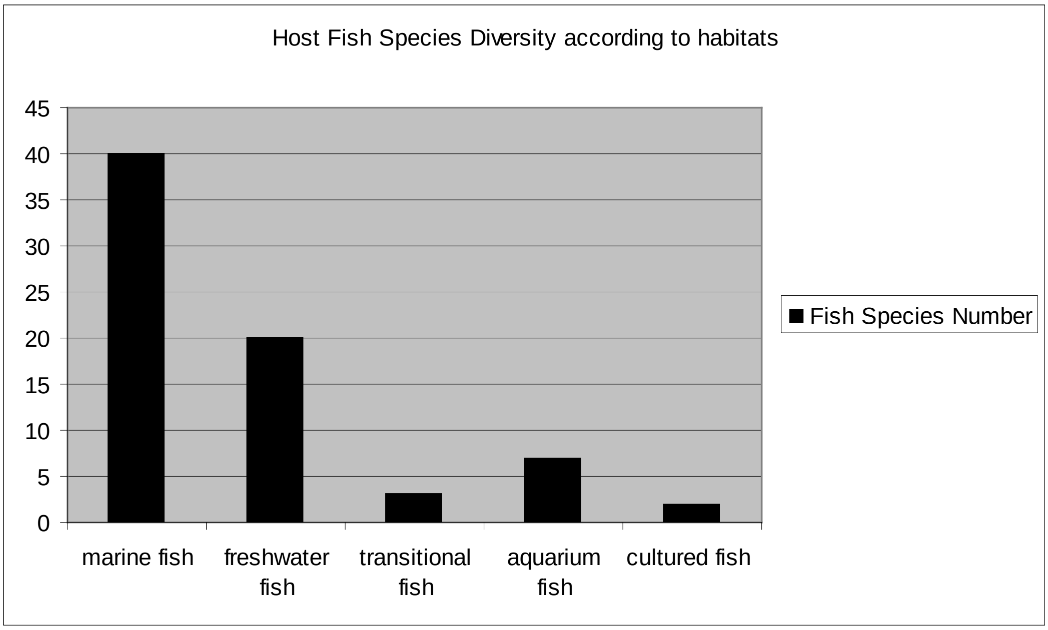

Figure 4: Host fish species diversity examined according to habitats.

Host species belonged to the following functional group categories: one benthopelagic, 21 demersal, 11 pelagic species (Fig. 5).

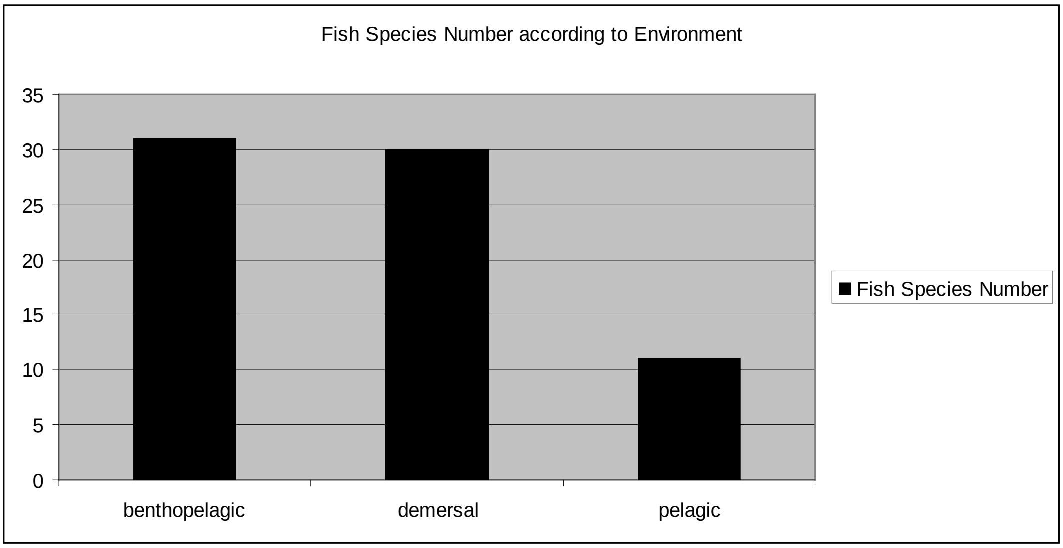

Figure 5: Host fish species diversity examined according to functional group.

Table 3: Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
Class Copepoda			
Order Cyclopoida			
Family Lernaeidae			
***Lernaea cyprinacea* Linnaeus, 1758**			
Carassius carassius			Geldiay and Balık (1974)
Esox lucius	gill	Sapanca Lake	Soylu (1990)
Silurus glanis	gill	Sapanca Lake	Soylu (1990)
Rhodeus sericeus	body surface	aquarium fish producers (Ankara)	Murat (2000)
Pterrophylum scalare	body surface	aquarium fish producers (Ankara)	Murat (2000)
Poecilia reticulata	body surface, muscle	aquarium fish producers (Mersin)	Koyuncu (2002)
Poecilia latipinna	body surface, muscle	aquarium fish producers (Mersin)	Koyuncu (2002)
Xiphophorus hellerii	body surface, muscle	aquarium fish producers (Mersin)	Koyuncu (2002)
Xiphophorus maculatus	body surface, muscle	aquarium fish producers (Mersin)	Koyuncu (2002)
Carassius auratus	body surface, muscle	aquarium fish producers (Mersin)	Koyuncu (2002)
Ctenopharynodon idella	body surface	Adana DSI	Tabakoğlu (2004)
Cyprinus carpio	body surface	Adana DSI	Tabakoğlu (2004)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
Poecilia reticulata	body surface, muscle	aquarium fish producers (Mersin)	Koyuncu and Dönmez (2006)
Poecilia latipinna	body surface, muscle	aquarium fish producers (Mersin)	Koyuncu and Dönmez (2006)
Xiphophorus hellerii	body surface, muscle	aquarium fish producers (Mersin)	Koyuncu and Dönmez (2006)
Xiphophorus maculatus	body surface, muscle	aquarium fish producers (Mersin)	Koyuncu and Dönmez (2006)
Cyprinus carpio		Fish Research Unit, University of Cukurova	Şahan and Duman (2010)
Cyprinus carpio		Karacaören II, Dam Lake	Samancı (2011)
Carassius carassius		Karacaören II, Dam Lake	Samancı (2011)
Cyrinus carpio	skin, fin	Tahtalı Dam Lake	Karakişi and Demir (2012)
Oncorhynchus mykiss	skin	Sücüllü Dam Lake	Akçimen et al. (2012)
Oncorhynchus mykiss	skin	Sücüllü Dam Lake	Tokşen et al. (2015)
***Lamproglena pulchella* Nordmann, 1832**			
Scardinius erythrophthalmus	gill	Sapanca Lake	Soylu (1990)
Capoeta trutta	gill	Keban Lake	Sağlam (1992)
Chondrostoma regium	gill	Keban Lake	Sağlam (1992)
Cyprinus carpio	gill	Halil-ür Lake	Öktener et al. (2008a)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
Capoeta trutta	gill	Halil-ür Lake	Öktener et al. (2008a)
Order Poecilostomatoida			
Family Chondracanthidae			
Chondracanthus lophii **Johnston, 1836**			
Lophius piscatorius	gill	Marmara Sea	Öktener and Trilles (2004a)
Family Ergasilidae			
Ergasilus briani **Markevich, 1932**			
Alburnus mossulensis	gill	Keban Dam Lake	Sağlam (1992)
Ergasilus fryeri **Paperna, 1964**			
Anguilla anguilla	gill	Bafa Lake	Altunel (1979)
Ergasilus gibbus **Nordmann, 1832**			
Anguilla anguilla	gill	Aegean Sea	Altunel (1980)
Anguilla anguilla	gill	Karacabey Lagoon Lake	Altunel (1990)
Anguilla anguilla	gill	Köyceğiz Lake	Soylu et al. (2013)
Ergasilus lizae **Krøyer, 1863**			
Mugil cephalus	gill	Aegean Sea	Tareen (1982)
Mugil cephalus	gill	Aegean Sea	Altunel (1983)
Liza saliens	gill	Aegean Sea	Altunel (1983)
Liza ramada	gill	Aegean Sea	Altunel (1983)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
Chelon labrosus	gill	Aegean Sea	Altunel (1983)
Oedalechilus labeo	gill	Aegean Sea	Altunel (1983)
Mugil soiuy	gill	Black Sea	Öktener and Trilles (2004a)
Anguilla anguilla	gill	Köyceğiz Lake	Soylu et al. (2013)
***Ergasilus mosulensis* Rahemo, 1982**			
Liza abu	gill	Atatürk Dam Lake	Öktener et al. (2007)
Alburnus mossulensis	gill	Atatürk Dam Lake	Öktener et al. (2008c)
***Ergasilus sieboldi* Nordmann, 1832**			
Cyprinus carpio	gill		Geldiay and Balık (1974)
Abramis brama	gill		Geldiay and Balık (1974)
Squalius cephalus	gill		Geldiay and Balık (1974)
Alburnus mossulensis	gill		Geldiay and Balık (1974)
Scardinius erythrophthalmus	gill		Geldiay and Balık (1974)
Esox lucius	fins		Geldiay and Balık (1974)
Capoeta trutta	dorsal, caudal fins	Keban Dam Lake	Sarıeyyüboğlu and Sağlam (1991)
Chondrostoma regium	gill	Keban Dam Lake	Sağlam (1992)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
Capoeta trutta	gill	Keban Dam Lake	Sağlam (1992)
Alburnus orontis	gill	Balıklıag Stream	Cengizler and Goksu (1994)
Capoeta capoeta	gill	Balıklıag Stream	Cengizler and Goksu (1994)
Cyprinus carpio	gill	Karacabey Lagoon Lake	Aydoğdu et al. (2001)
Tinca tinca	gill	Uluabat Lake	Öztürk (2002)
Esox lucius	gill	Karacabey Lagoon Lake	Öztürk et al. (2002)
Mugil cephalus	gill	Karacabey Lagoon Lake	Öztürk and Aydoğdu (2003)
Aphanius chantrei	gill	Sarıkum Lagoon Lake	Öztürk (2005)
Platichthys flesus	gill	Sarıkum Lagoon Lake	Öztürk (2005)
Tinca tinca	gill	Sapanca Lake	Akbeniz (2006)
Cyprinus carpio	gill	Sapanca Lake	Uzunay (2006)
Vimba vimba	gill	Sapanca Lake	Uzunay (2006)
Neogobius melanostomus	gill	Sırakaraağaçlar Stream	Özer (2007)
Aphanius danfordii	gill	Sarıkum Lagoon	Öztürk and Özer (2008)
***Paraergasilus longidigitus* Yin, 1954**			
Alburnus alburnus	gill	Enne Dam Lake	Koyun et al. (2007)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
***Nipergasilus bora* Yamaguti, 1939**			
Mugil cephalus		Aegean Sea	Ben Hassine (1983)
Chelon labrosus		Aegean Sea	Ben Hassine (1983)
***Neoergasilus japonicus* (Harada, 1930)**			
Scardinius erythrophthalmus	fins, gill	Sapanca Lake	Soylu and Soylu (2012)
Family Taeniacanthidae			
***Taeniacanthus lagocephali* Pearse, 1952**			
Lagocephalus spadiceus	gill, operculum	Mediterranean Sea	Özak et al. (2012)
***Anchistrotos laqueus* (Leigh-Sharpe, 1935)**			
Serranus hepatus	gill	Marmara Sea	Öktener and Trilles (2009)
Family Bomolochidae			
***Bomolochus bellones* Burmeister, 1833**			
Belone belone	gill	Aegean Sea	Alaş et al. (2015b)
***Bomolochus unicirrus* (Brian, 1906)**			
Sphyraena sphyraena	gill	Mediterranean Sea	Demirkale et al. (2015b)
Order Siphonostomatoida			
Family Caligidae			
***Caligus apodus* (Brian, 1924)**			
Mugil cephalus	gill	Aegean Sea	Altunel (1983)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
Liza saliens	gill	Aegean Sea	Altunel (1983)
Liza ramada	gill	Aegean Sea	Altunel (1983)
Chelon labrosus	gill	Aegean Sea	Altunel (1983)
Solea solea	body surface	Mediterranean Sea	Özak et al. (2013)
Caligus bonito **Wilson C. B., 1905**			
Coryphaena hippurus	gill, inner surface of operculum	Aegean Sea	Öktener and Trilles (2009)
Caligus brevicaudatus **Scott, 1901**			
Solea solea	body surface	Mediterranean Sea	Özak et al. (2013)
Caligus diaphanus **Nordmann, 1832**			
Chelidonichthys lucerna	gill, inner face of operculum	Aegean Sea	Alaş et al. (2015b)
Caligus lagocephali **Pillai, 1961**			
Lagocephalus suezensis	mouth cavity	Mediterranean Sea	Özak et al. (2012)
Lagocephalus spadiceus	mouth cavity	Mediterranean Sea	Özak et al. (2012)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
***Caligus ligusticus* Brian, 1906**			
Lithognathus mormyrus	inner opercular surface	Mediterranean Sea	Demirkale et al. (2015a)
***Caligus minimus* Otto, 1821**			
Dicentrarchus labrax		Aegean Sea	Tareen (1982)
Dicentrarchus labrax	mouth, operculum, gill	Farm – Aegean Sea	Tokşen (1999)
Dicentrarchus labrax	mouth, gill	Farm – Aegean Sea	Uluköy and Kubilay (2007)
Dicentrarchus labrax	mouth, operculum, gill	Çamlık Lagoon Lake, Çukurova University Station	Özak (2007)
Dicentrarchus labrax	body surface, fins	Hurmaboğazı Lagoon Lake	Canlı (2010)
Dicentrarchus labrax		Farm – Black Sea	Özer and Öztürk (2011)
Labrus merula	gill, external surfaces	Aegean Sea	Tanrikul and Perçin (2012)
***Caligus pageti* Russel, 1925**			
Mugil cephalus	gill	Aegean Sea	Altunel (1983)
Liza saliens	gill	Aegean Sea	Altunel (1983)
Liza ramada	gill	Aegean Sea	Altunel (1983)
Chelon labrosus	gill	Aegean Sea	Altunel (1983)
***Caligus solea* Demirkale, Özak, Yanar and Boxshall, 2014**			
Solea solea		Mediterranean Sea	Demirkale et al. (2014)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
***Caligus pelamydis* Krøyer, 1863**			
Scomber scombrus		Aegean Sea	Tareen (1982)
***Caligus temnodontis* Brian, 1924**			
Pomatomus saltatrix	operculum inner surface, buccal cavity	Mediterranean Sea	Özak et al. (2010)
***Lepeophtheirus europaensis* Zeddam, Berrebi, Renaud, Raibaut, Gabrion, 1988**			
Platichtys flesus	gill	Ekinli Lagoon	Oğuz and Öktener (2007)
Family Hatschekiidae			
***Hatschekia mulli* (Van Beneden, 1851)**			
Mullus surmuletus	gill	Aegean Sea	Akmirza (2000a)
***Hatschekia pagellibogneravei* (Hesse, 1878)**			
Diplodus annularis		Aegean Sea	Akmirza (2000b)
Family Lernaeopodidae			
***Clavellotis fallax* (Heller, 1865)**			
Diplodus sargus	gill	Aegean Sea	Akmirza (2000b)
Spondyliosoma cantharus	gill	Aegean Sea	Akmirza (2000b)
Pagellus erythrinus	gill	Aegean Sea	Akmirza (2000b)
Sarpa salpa	gill	Aegean Sea	Akmirza (2000b)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
***Clavellotis briani* Benmansour, Hassine, Diebakate, Raibaut, 2001**			
Lithognathus mormyrus	gill	Mediterranean Sea	Koyuncu et al. (2015)
***Clavellotis strumosa* (Brian, 1906)**			
Pagellus erythrinus	gill	Marmara Sea	Öktener et al. (2008b)
***Clavella alata* Brian, 1909**			
Phycis phycis	gill	Aegean Sea	Öktener et al. (2010)
Clavellisa scombri (Kurz, 1877)			
Scomber scombrus	gill	Marmara Sea	Öktener and Trilles (2009)
***Lernaeopoda galei* Kroyer, 1837**			
Mustelus mustelus	cloacal region	Aegean Sea	Karaytuğ et al. (2004)
***Thysanote impudica* (Nordmann, 1832)**			
Chelidonichthys lucerna	gill	Marmara Sea	Öktener and Trilles (2004a)
***Parabrachiella bispinosa* (Nordmann, 1832)**			
Chelidonichthys lucerna	gill	Mediterranean Sea	Öktener and Trilles (2004b)
***Parabrachiella exigua* (Brian, 1906)**			
Pagellus erythrinus	gill	Mediterranean Sea	Öktener and Trilles (2004b)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
***Parabrachiella merluccii* (Bassett-Smith, 1896)**			
Merluccius merluccius	gill	Aegean Sea	Alaş et al. (2015d)
***Parabrachiella insidiosa* (Heller, 1865)**			
Merluccius merluccius	gill	Aegean Sea	Alaş et al. (2015d)
***Parabrachiella hostilis* (Heller, 1868)**			
Umbrina cirrosa	gill	Aegean Sea	Alaş et al. (2015a)
***Tracheliastes polycolpus* Nordmann, 1832**			
Capoeta trutta	fins	Keban Dam Lake	Sağlam (1992)
Capoeta umbla	fins	Murat River	Koyun (2011)
***Naobranchia cygniformis* Hesse, 1863**			
Spicara maena	gill	Aegean Sea	Alaş et al. (2015c)
***Pseudotracheliastes stellifer* (Kollar, 1835)**	gill	Uluabat Lake, Kocadere Lake	Geldiay and Balık (1974)
Silurus glanis	gill	Uluabat Lake, Kocadere Lake	Geldiay and Balık (1974)
Family Lernanthropidae			
***Lernanthropus brevis* Richiardi, 1879**			
Dicentrarchus labrax	gill	Aegean Sea	Akmirza (2003)
***Lernanthropus callionymicola* El-Rashidy and Boxshall, 2012**			
Callionymus filamentosus		Mediterranean Sea	Özak et al. (2014)
***Lernanthropus gisleri* Van Beneden, 1852**			
Umbrina cirrosa	gill	Mediterranean Sea	Özak et al. (2014)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
***Lernanthropus kroyeri* Van Beneden, 1851**			
Dicentrarchus labrax	gill	Farm – Aegean Sea	Tokşen (1999)
Dicentrarchus labrax	gill	Farm – Aegean Sea	Özel et al. (2004)
Dicentrarchus labrax	gill	Farm – Black Sea	Öktener et al. (2010b)
***Lernanthropus nordmanni* Wilson C. B., 1922**			
Dicentrarchus labrax	gill	Aegean Sea	Tareen (1982)
***Lernanthropsis mugilis* (Brian, 1898)**			
Liza aurata	gill	Aegean Sea	Altunel (1983)
***Lernanthropinus trachuri* (Brian, 1903)**			
Trachurus mediterraneus	gill	Sea of Marmara	Öktener and Trilles (2004a)
***Lernanthropus indefinitus* Koyuncu, Romero, Karaytuğ, 2012**			
Argyrosomus regius	gill	Mediterranean Sea	Koyuncu et al. (2012)
***Mitrapus oblongus* (Pillai, 1964)**			
Sardinella aurita	gills	Mediterranean Sea	Romero and Öktener (2010)
***Sagum posteli* Delamare – Deboutteville and Nunes-Ruivo, 1954**			
Epinephelus aeneus	gill	Aegean Sea	Tokşen et al. (2012)
Family Pandaridae			
***Pandarus bicolor* Leach, 1816**			
Mustelus mustelus	ventral surface, fins	Aegean Sea	Öktener and Trilles (2009)

Table 3 (continued): Parasitic Copepods – Host species list.

Parasites and hosts	Sampled from	Location of the host fish capture	Authors
Family Pennellidae			
***Pennella instructa* Wilson, 1917**			
Xiphias gladius	base of anal, pectoral fins, abdominal tissue	Aegean Sea	Öktener et al. (2007)
Seriola dumerili	skin	Farm – Mediterranean Sea	Öktener (2009)
Xiphias gladius	eye	Aegean Sea	Öktener et al. (2010c)
***Pennella filosa* (Linnaeus, 1758)**			
Xiphias gladius	fins, body, operculum	Aegean Sea	Tuncer et al. (2010)
Xiphias gladius	operculum	Aegean Sea	Tanrıkul and Akyol (2011)
***Lernaeenicus neglectus* Richiardi, 1877**			
Mugil cephalus		Aegean Sea	Tareen (1982)
***Lernaeolophus sultanus* Nordmann, 1839**			
Diplodus vulgaris	Mouth base	Mediterranean Sea	Öktener and Trilles (2004b)
***Peniculus fistula* von Nordmann, 1832**			
Coryphaena hippurus	ventral fin	Aegean Sea	Öktener (2008)
***Lernaeocera branchialis* (Linnaeus, 1767)**			
Trisopterus minutus	upper and base of mouth	Aegean Sea	Alaş et al. (2015c)

CONCLUSIONS

The parasitic copepods are one of the most important enemies of fish. There were done several studies about parasitic copepods in Turkey. This review is aimed to update the species list of the parasitic copepods reported from host fish in aquarium and farm conditions, marine and freshwater habitats of Turkey. It includes new parasitic copepod species records with host according to changes in classification.

Several studies on diversity of parasitic copepods in fish from freshwater and marine water habitats have been studied in the world (Dippenaar, 2005; Benmansour and Ben Hassine, 1997; Avenant-Oldewage and Oldewage, 1993; Barzegar and Jalali, 2009; Holland and Kennedy, 1997; Radujkovic and Raibaut, 1989; Ramdane and Trilles, 2010; Bakır et al., 2014; Khamees et al., 2015; Luque et al., 2013; Morales-Serena et al., 2012; Raibaut et al., 1998).

Fish-parasite checklist studies are important taxonomic documents obtaining the fish-parasite relationships, host selectivity and geographic distribution of fish parasites. They may contribute as baseline data in the disciplines of parasitology, zoology, medicine, environmental science in terms of determining biological diversity, treatment and control of parasites, identification of parasite, determining host selectivity and geographic distribution of fish zoonoses, compare of fish parasite fauna of local, regional and worldwide (Alaş and Öktener, 2015).

Online databases about flora and fauna were created by both civil society organizations and international science centres in a virtual environment developing with the information age. Online database such as ITIS; Fishbase, WoRMS, shark-references.com, etc., can contribute to the demonstration of biodiversity, taxonomy of the species of the existing flora and fauna and their geographic, the provision of bio-ecological characteristics, also fulfils a really important task by revising and updating the addition of new species presented to the scientific world (Alaş and Öktener, 2015).

Checklist studies about fish parasites can give information of host specificity, geographic distribution, bio-ecological characteristics between parasite and host. They may constitute a source for scientists as zoologists, parasitologists, ecologists, etc., working about fish parasites and also useful in minimizing of doubtful, error reports and notifications of both the parasite-host. Checklists are important in achieving all of data about parasite and hosts among the countries at a glance. But, you know that valid names and synonymies of parasite and host species may be changed. Reports of parasite findings may be published at different/same dates and regions by different researchers. Some information can not be reached. Although checklist studies are important, they need to revise and update and it must be delivered to many readers. In this sense, checklist studies may contain little restrictive and not current information, hence these constitute disadvantages. Therefore, we want to specify the examples that the opinion that the more efficient the database (Alaş and Öktener, 2015).

Ecological conditions, habitat properties and fish diversity can be different in each country. For these reasons, data obtained from various countries cannot be compared with each other. Our aim is to reveal the parasitic copepod diversity for fishes in Turkey.

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ALGAL BIO-INDICATION IN ASSESSMENT OF HYDROLOGICAL IMPACT ON ECOSYSTEM IN WETLANDS OF “SLAVYANSKY RESORT”

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ABSTRACT

Algal bio-indication is commonly used in water quality assessment but can also help in assessing the impact of hydrology on freshwater wetland ecosystems. We identified 350 species and infraspecific taxa of algae from nine taxonomic divisions (Cyanoprokaryota, Chrysophyta, Euglenophyta, Dinophyta, Xanthophyta, Cryptophyta, Bacillariophyta, Chlorophyta, Charophyta) in 121 phytoplankton samples collected between 2007-2013 from seven lakes in the wetlands of the Regional Landscape Park “Slavyansky Resort”, Ukraine. The algal species richness and phytoplankton biomass decreased as water salinity increased. In turn the water salinity was influenced by the inflow of groundwater, karst fracture and by the alluvial water tributaries of a paleoriver that affects the formation processes of lake-spring sulphide mud from the resort, which is often used for therapeutic purposes.

ZUSAMMENFASSUNG: Die Algen-Bioindikation in der Bewertung hydrologischer Einflüsse auf Feuchtgebietsökosysteme im Landschaftspark “Slavyansky Resort”.

Die Bioindikation mittels Algen wird häufig für die Bewertung der Wasserqualität verwendet, sie kann jedoch auch in der Einschätzung der Auswirkungen hydrologischer Ereignisse in Feuchtgebieten von Süßwasserökosystemen von Nutzen sein. Es wurden 350 Arten und infraspezifische Taxa von Algen aus neun taxonomischen Einheiten (Cyanoprokaryota, Chrysophyta, Euglenophyta, Dinophyta, Xanthophyta, Cryptophyta, Bacillariophyta, Chlorophyta, Charophyta) in 121 zwischen 2007-2013 entnommenen Phytoplanktonproben identifiziert und zwar aus sieben Seen der Feuchtgebiete im Landschaftspark “Slavyansky Resort”. Der Reichtum an Algenarten und Phytoplankton Biomasse verringerte sich mit dem steigenden Salzgehalt des Wassers. Dieser wird seinerseits durch den Zufluss von Grundwasser aus dem Karstbereich und aus Gewässerzuflüssen beeinflusst, die Entstehungsprozesse der Quell-Seen Sulphide des therapeutischen Schlamms im Resort beeinträchtigen.

REZUMAT: Evaluarea bio-indicaţiei algale a impactului hidrologic asupra ecosistemului acvatic din „Staţiunea Slavyansky”.

Algele bio-indicatoare sunt frecvent utilizate în evaluarea calității apei, dar, de asemenea, pot ajuta la evaluarea impactului asupra ecosistemului bazinelor hidrografice de apă dulce. Am întâlnit 350 de specii și taxoni infraspecifici de alge din nouă încrengături (Cyanoprokaryota, Chrysophyta, Euglenophyta, Dinophyta, Xanthophyta, Cryptophyta, Bacillariophyta, Chlorophyta, Charophyta) în 121 de probe de fitoplancton colectate între 2007-2013 din șapte lacuri din zonele umede ale Parcului Regional Peisagistic „Stațiunea Slavyansky”. Bogăția și biomasa fitoplanctonului scad odată cu creșterea salinității apei. Salinitatea apei este influențată de afluxul de apă subterană, fracturi carstice, și afluenții care afectează procesele de formare a nămolului terapeutic sulfuric de lac-izvor din stațiune.

INTRODUCTION

Salinity plays an important role in the formation of communities of aquatic organisms such as microalgae. Its influence is reflected both in the species composition, abundance and biomass of phytoplankton and subsequent decomposition of plant residues in water bodies in general and of wetlands in hot dry climate in particular. The species composition of algae and mineralized lakes relation is well-known (Hammer, 1986).

The presence of mud with therapeutic properties was an important factor in the creation of the Slayansky Resort, because of its value.

The formation of mud with therapeutic properties is a complex, multy-year process that takes place in waters with high salt content. For lake-spring sulphide muds, for example those found in the Slayansky Resort, Ukraine, factors such as composition and salinity of water entering the pond are much more important than climatic factors (Holopov et al., 2002). The composition of the water entering the wetlands park is influenced by salt-infused sediments of Permian age (from karst fracture under lakes Ripne, Veysove and Garache), and it should be noted that there are also two types of topographic relief in the study area – watershed plateaus with altitudes from 90 to 180 m a.s.l., and accumulative plains with I-II river terraces, known as Kazenyi Toretz and Sukhoy Toretz (Popkov et al., 2005).

The chemical composition of water generates the necessary conditions for the specific processes of decomposition of organic residues in different groups of bacteria. These bacteria enrich the biogenic components of mud, giving many of them high therapeutic activity levels. The organic residues often encourage the formation of microalgae, which are the primary producer in the ecosystem, although in some water bodies it can be zooplankton. It should be noted that the more massively developed the microalgae are, the more potential material is generated for the formation of therapeutic mud.

The algal diversity in the Regional Landscape Park “Slavyansky Resort” was formed through periodic desiccation as well as being influenced by various anthropogenic impacts, and has been studied sporadically since the second half of the 17th century and more regularly since 2007 by the current research team (Klymiuk and Barinova, in press; Lyalyuk and Klymiuk, 2011; Barinova et al., in press; Klymiuk et al., 2014). The aim of the present study is to determine the relationships of salinity levels in the wetlands of “Slavyansky Resort” with the microalgae species richness and biomass as a basis for understanding the formation of therapeutic mud.

MATERIAL AND METHODS

Study area

The regional landscape park “Slavyansky Resort”, Ukraine, was created in 2006. Its purpose was for the preservation and thoughtful use of unique natural complexes and artificial plantations of parkland, and the development of recreational areas. The park is located in the northeastern part of the city Slaviansk in Ukraine. It covers 431 hectares and includes three resorts, an extensive park, a seasonal ornithological reserve “Priozerny”, and natural “monuments” of national importance such as lakes Ripne and Slipne, which are sources of unique therapeutic mud and brine. It was given the Belgium Grand Prix award in 1907 for quality (Kurulenko and Tretyakov, 2008) (Fig. 1).

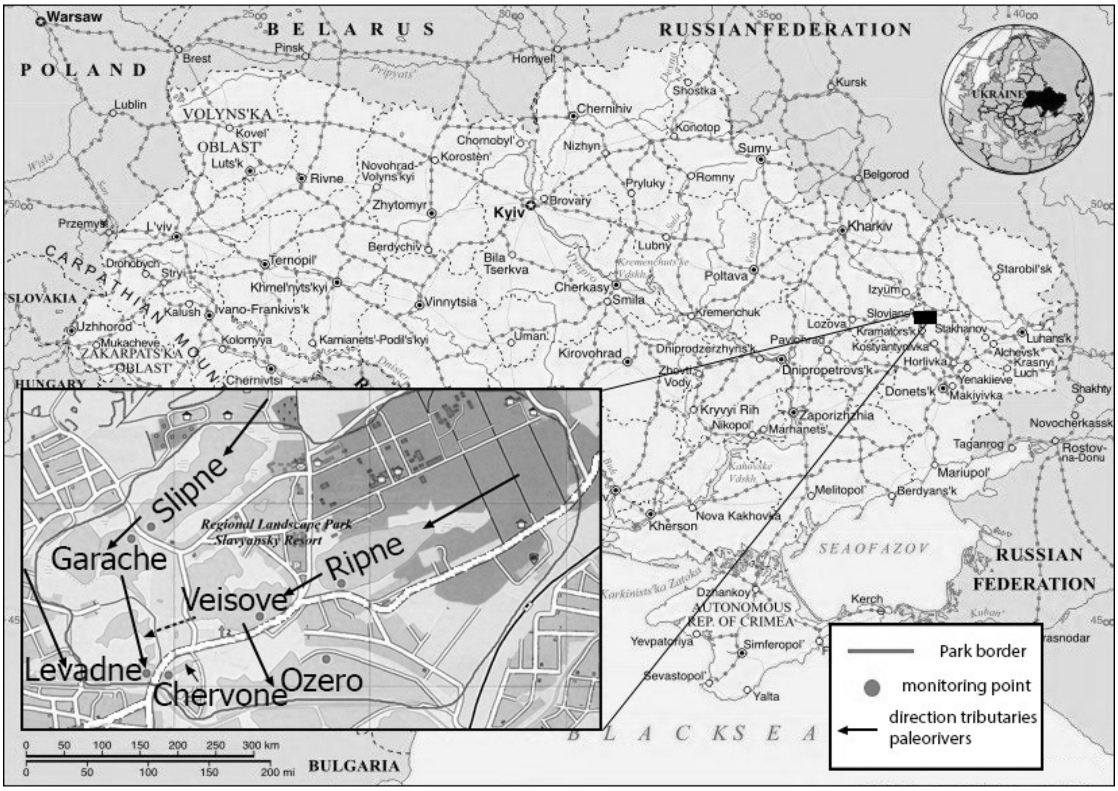

Figure 1: Map of the study site in the RLP "Slavyansky resort".

Just inside the park are seven perennial lakes (Ripne, Veisove, Garache, Slipne, Levadne, Chervone, and an untitled lake informally named Ozero) and many temporary pools. The lakes are mostly of thermokarst origin, small, and shallow. The lakes are generally unconnected to each other, periodically dry up but can become briefly interconnected in spring following (heavy rainfall/snowmelt). It is impossible to trace the palaeoriver and its tributaries from the topographic profile. Sediments from the lakes are diverse, varying from sand to mud. Lake water color tends to be slightly yellow or colorless with a pH range of 6.3-8.0, and a conductivity range of 1.31-11.26 mSm/cm. Depth of the lakes is generally shallow (about 0.5-2.5 m) with lake Ripne being the deepest at 8.5 m. The lakes contain a unique community of organisms, including algae, which are the basis of the formation of therapeutic mud. In lake Ripne there is industrial fishing for mud and brine mud baths for the Slavyansky Resort – one of the oldest mud-bath resorts in Ukraine.

Sampling and laboratory study

The studied material comes from samples collected monthly during 2007-2013 from lakes Ripne, Veisove, Garache, Slipne, Levadne, Chervone, and Ozero. Phytoplankton was collected in the littoral and profundal zones. A sample volume was of 2 l was collected and concentrated by accumulation on membrane filters "Vladipor" no. 7, or via a 10-20 l sample which was concentrated using a plankton net number 77. Algae were studied alive and in fixed (using 4% formaldehyde solution) states, using light microscopes MBI-3 and Micros MC 50 (Austria) with a magnification of 40X-90X (with immersion). Identification of algal species was performed using an international series of determinants of marine and freshwater algae species. Conductivity was analyzed with ionometric methods following Globan (1987).

RESULTS

Altogether 334 species of algae (350 species and infraspecific taxa) from nine taxonomic Divisions (Cyanoprokaryota, Euglenophyta, Chrysophyta, Dinophyta, Xanthophyta, Cryptophyta, Bacillariophyta, Chlorophyta, and Charophyta) were recorded by our sampling (238 species and infraspecies), a finding supported by existing literature on the resort (Klymiuk et al., 2014; Tsarenko et al., 2006, 2009).

Changes in the measured chemical and biological variables in different lakes downstream of the tributaries of the paleoriver were plotted against water conductivity, the number of species, and the biomass of phytoplankton (Figs. 2 and 3). These figures demonstrate that conductivity increases from lake Ripne across lake Veisove to lake Ozero, indicating the course of the left tributary of the palaeoriver underneath these three lakes. The central and right tributaries of the paleoriver can be mapped in the changes in conductivity from lake Slipne, across lake Garache to lake Levadne.

The lakes Ripne, Veisove, Garache, Slipne, Levadne and Ozero have a gradient of conductivity. On average in each lake the conductivity varied between 6.6 mSm/cm and 11 mSm/cm (Figs. 2 and 3). The number of algal species detected in the same time period (January 2013 to May 2013) in the lake communities ranged from 30 to 75 (Figs. 2a and 2b).

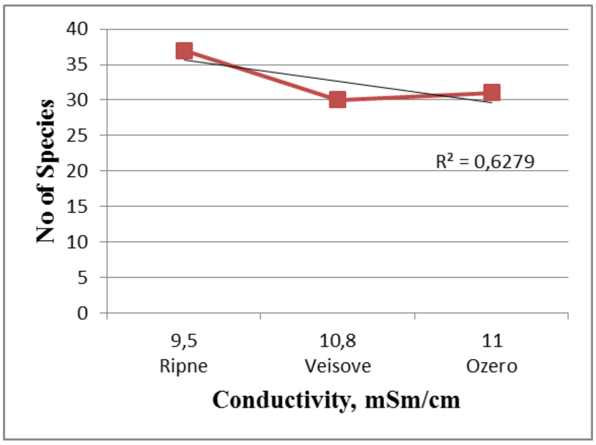

Figure 2a: Relationships between species numbers and water conductivity in the lakes: A – Ripne, Veisove, Ozero.

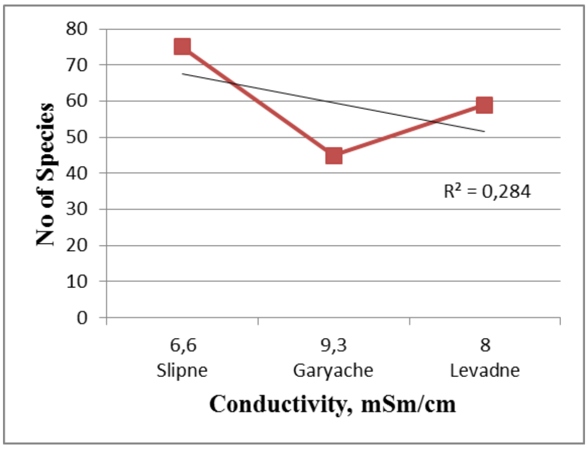

Figure 2b: Relationships between species numbers and water conductivity in the lakes: B – Slipne, Garyache, Levadne.

The highest average biomass of phytoplankton is registered in lake Slipne (3.86 g/l), the lowest in lake Ozero (1.11 g/l) (Figs. 3a and 3b).

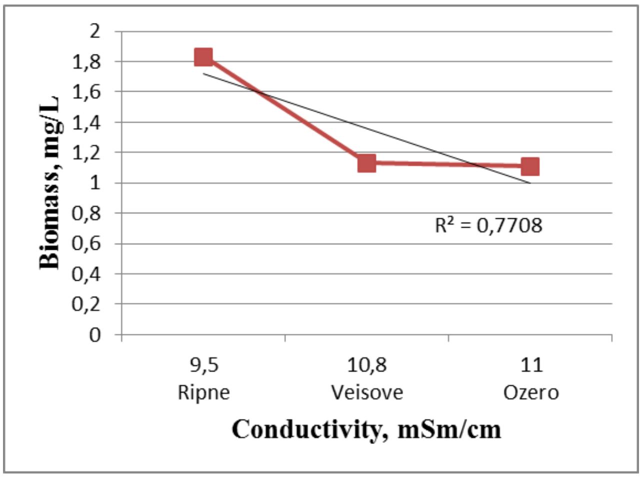

Figure 3a: Relationships between phytoplankton biomass and water conductivity in the lakes: A – Ripne, Veisove, Ozero.

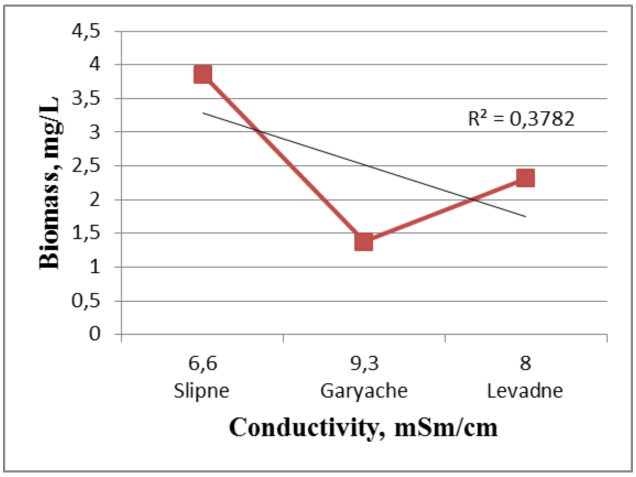

Figure 3b: Relationships between phytoplankton biomass and water conductivity in the lakes: B – Slipne, Garyache, Levadne.

DISCUSSION

In the course of our analysis we found an inverse relationship between conductivity, species richness and phytoplankton biomass across two gradients that divide the lakes of the "Slavyansky Resort" into two: the first gradient groups lakes Ripne, Veisove and Ozero, whilst the second gradient groups lakes Slipne, Garyache and Levadne.

The species number is proportional to taxonomic diversity, because more saline waters have fewer taxa than freshwater (Figs. 2a and 2b). Salinity is the major regulating factor, in relation to the total number of species in algal communities (Naumenko and Makeeva, 2011; Barinova et al., 2010a, 2011; Klymiuk et al., 2014), in the abundance and biomass of phytoplankton (Krupa et al., 2014), and in the composition of the dominant species (Naumenko and Makeeva, 2011; Barinova et al., 2010b, 2011).

Biomass characterizes the activity of creation of organic matter in the ecosystem, so hence an increase in salinity within an ecosystem results in not only reduced diversity, but also reduces the productive capacity (Figs. 3a and 3b).

The influence of the right tributary of the paleoriver in the landscape is visible only in lake Ripne, with further movement of water masses through the alluvial layers in lake Veisove and lake Ozero only being detected by a consistent increase in the conductivity from lake Ripne, via lake Veisove to lake Ozero (Fig. 1). The intermediate tributary has its origin above lake Slipne (identified with the help of bio-indication from planktonic algae (Klymiuk et al., 2014), with ground flows into lake Garyache, and then lake Levadne. Among the lakes in the line Slipne – Garyache – Levadne there is no clear increase in water conductivity, suggesting that the intermediate tributary is not an important one in the regulation of water conductivity. In contrast, the left tributary of the paleoriver is visible in the modern landscape in spring, during which period it is also likely to have superficial connections to lake Veisove. As a result, all tributaries that join lake Levadne originate the river Kalantaevka. It should be noted that a significant complication in assessing the impact of inflows on the chemical composition of the lakes is the presence of a fault under the karst lakes Garyache, Veisove, and Ripne (Popkov et al., 2005) and as a result the presence of additional brine-rich waters. It is also important to understand that during the underground exchange between lakes, water passes through non-uniform layers of alluvium and becomes enriched with minerals to varying degrees (mineralization of alluvial waters range from one to 150 g/l (Popkov et al., 2005)). Thus, in the current landscape most of the movement of water is not visible, except through measuring the activities of these lakes ecosystems.

The park Authorities are trying to improve the mineralization and production of therapeutic mud through the addition of salt to lake Slipne. These attempts may be successful in the case of short-term necessity, especially in the absence of seasonal surface runoff. However, this study indicates that this this effect is likely to be short-lived, because of the regular inflow of freshwater into the lake from the palaeobasin. The influence of groundwater flow can be so significant, even during low-water periods, that the addition of salt to the water body is likely to make little difference. Instead, it may be better to increase salinity via a reclamation work which aims to reduce at least part of the groundwater flow (by gutters and ditches) above the lake, whilst at the same time increasing the inflow of salty water. Although the application of this technique is also seasonal, compared with the first method it will achieve a more lasting effect on therapeutic mud production. In any case, because the production of medical mud is a long-term process, any effects such as those described above are likely only to be of short duration, so the effect of the impact from the purpose of increasing the quantity of medical mud will be scarcely noticeable.

CONCLUSIONS

A decrease in species richness and biomass of planktonic algae has been found with increasing water salinity of the wetlands in the RLP “Slavyansky Resort”. The ecosystem productivity is reduced with a significant increase in mineralization, which in turn affects the speed of formation of therapeutic mud. When there is insufficient salinization, the formation of medical mud is impossible due to the nature of the process’ chemistry. Mineralization of the lakes depends on the presence or absence of underlying karst fracture, and on the flow direction of underground paleoriver tributaries, which are often invisible in the landscape, but which can be identified either via bio-indicators from the algal communities, or via the chemical composition of the water. Any activities in relation to transforming the water quality of these lakes should take into account the peculiarities of their groundwater supply if they are to be successful.

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FOOD AND FEEDING OF FISHES. WHAT DO WE NEED TO KNOW?

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KEYWORDS: feeding ecology, ecomorphology, chemoecology, food selection.

ABSTRACT

Unrevealing food and feeding habits of fishes is the centre of research in aquatic biology, ecology, conservation biology and fisheries. The current practice in feeding ecology of fish accredits it as descriptive ecology, relying primarily on the information of their diet, directly through gut analysis or indirectly by computing some diet based indices. Such methods often mislead in the understanding of the true feeding behaviour of organisms need for more reliable and functional approach. The main objective of feeding ecology is to evaluate feeding behaviour of fish. Recent developments in tools and techniques of analytical research is an opportunity to take up more reliable details by formulating affordable methodical design for recording, modulating and designing suitable approaches for better explanation of the feeding biology in fish.

ZUSAMMENFASSUNG: Nahrung und Ernährungsart der Fische. Was müssen wir wissen?

Das Auffinden der Nahrung und die Ernährungsart der Fische steht im Mittelpunkt der Forschungen zur aquatischen Biologie, Ökologie und Erhaltung der biologischen Vielfalt sowie der Fischereibetriebe. Gegenwärtig ist die Ernährungsökologie der Fische Teil der deskriptiven Ökologie, die sich unmittelbar auf Informationen der Nahrungsanalyse des Mageninhaltes oder indirekt auf die Berechnung einiger Nahrungsindikatoren stützt. Derartige Methoden erzeugen Verwechslungen hinsichtlich des Ernährungsverhaltens und erfordern eine umfassende Neubearbeitung für eine sichere und funktionelle Herangehensweise. Das Hauptziel der Ernährungsökologie ist die Auswertung des Verhaltens der Fische während der Nahrungsaufnahme. Die Verbesserung der Apparatur und der analytischen Untersuchungstechniken ermöglicht eine genauere Analyse mittels einer zugänglichen Formulierung eines Designs für die Registrierung, Vorbereitung und entsprechende Herangehensweise zur genaueren Erklärung der Ernährungsbiologie der Fische.

REZUMAT: Hrana și modul de hrănire al peștilor. Ce trebuie să știm?

Descoperirea hranei și a modului de hrănire al peștilor este centrul cercetării pentru biologia acvatică, ecologie, biologia conservării și pentru fermele piscicole. La momentul actual ecologia hrănirii peștilor este parte a ecologiei descriptive, bazându-se în principal pe informația dietei primită direct din analiza conținutului stomacal sau indirect prin calcularea unor indici de dietă. Astfel de metode creează confuzie în înțelegerea exactă a comportamentului de hrănire și necesită o revizie extensivă pentru o abordare sigură și funcțională. Obiectivul principal al ecologiei hrănirii este evaluarea comportamentului de hrănire al peștilor. Perfecționarea instrumentelor și tehnicilor de cercetare analitică permite o analiză mai precisă prin formularea accesibilă a unui design pentru înregistrarea, ajustarea și conceperea unor abordări adecvate pentru explicarea mai exactă a biologiei hrănirii peștilor.

INTRODUCTION

Examining the food and feeding habits of a species is important for evaluating the ecological role and position of the species in the food web of ecosystems (Allan and Castillo, 2007). Information on their diet provides further support on practices of aquatic management, especially agriculture, aquaculture and conservation. Among many animals in aquatic ecosystem, fish are a major top predator and occupy a deterministic status in the trophic cascade of the aquatic ecosystem. Several species of fishes play an important role in economies in many countries around the world. However, what determines the success in commercialization of fish is the food it receives for growth and nutrition. There are several types of formulated and commercially available feed for fish. However, the basis of formulation of such artificial feed mainly targets protein supplementation and hardly fulfils all nutritional requirements including micro-nutrients, thereby, replacing other essential nutrients from fish food. Similarly, introducing non-native fish species for higher economic gain is common among developed and developing countries. These practices often threaten native fish species towards extinction. A crucial factor to the native fish species encountering the introduction of a non-native fish is the overlapping of trophic niches (Olden et al., 2006). Avoidance of competition for food or management of niche partitioning may lead to successful co-habitation of the species (Curtean-Bănăduc A. and Bănăduc D., 2008).

The question is: could it be possible to gather accurate and real scientific information on the food and feeding habits of fish? There are several challenges that need to be addressed. A few of them are:

1. Fish explore high habitat diversity expanding from marine to freshwater; morphological diversity from the smallest to the largest in body size; behavioural diversity of the inhabitant to migratory in nature, etc.

2. It passes through several ontogenic stages during its development and each stage may prefer different types of food and exhibit variable feeding habits.

3. Several fishes exhibit opportunistic feeding behaviour, i.e. they may shift their feeding habit between two isomorphic food habitats. For example, the omnivorous fish *Cyprinus carpio* and herbivorous fish *Labeo rohita*, and hybrid *Oreochromis aureus x Oreochromis niloticus*, may shift to periphytophagus mode of feeding when substrates are available in the environment (Milstein et al., 2013; Saikia and Das, 2009; Saikia et al., 2013).

The subject has been discussed over time with different approaches to obtain meaningful conclusions on the feeding habit of fish. For all these reasons, the generalization of food and feeding habits in fish, in reality, is a very arduous task. The main purposes of this paper, on the above background, is: (a) to highlight gaps in current knowledge on their feeding biology and demonstration of possible approaches to overcome those gaps; (b) to summarize different approaches to describe and enumerate food and feeding habits in fish effectively.

The bottlenecks

There are two broad topics traditionally addressed while discussing feeding habits of animals. These are: (i) diet that comprises of the food habitually eaten by the animal; (ii) the mode of feeding or ingesting diet in a particular spatio-temporal dimension.

In fishes, two methods are available to find the above criteria. First, the assessment of stomach content using various descriptive mathematical techniques. Stomach content has long been used for preliminary assessment of diet in aquatic animals (Cortés, 1997; Ellis et al., 1996). In fish with a stomach, the stomach is dissected and undigested food or food particles are recorded qualitatively and quantitatively (Baker et al., 2014; Pelicice and Agostinho, 2006). There exists a handful tools of which can be used to estimate the stomach contents in the fish (Tab. 1). When a true stomach is not available, food from the first few portions of the gut is collected for analyzing. Second, all data recorded is subjected to mathematical models proposed by different authors (Tab. 2). Some of these models, for example Levin's diet breadth, Ivlev's electivity index, Hulberts index, etc., are popularly used irrespective of fish species. Figure 1 describes how the feeding habits of fish are being studied by different authors following these models. Two key words, "feeding habit" and "feeding ecology" were used to gather random web-based information through "Google" for collection of data (N = 70) in figure 1. Large numbers of studies are performed using percentage abundance data.

Table 1: Different measures used to estimate stomach content of fish. Examples are stated randomly.

Crt. no.	Description of index	Author for reference
1.	(Prey item recorded/total wet weight of food) × 100	e.g. Pothoven and Nalepa, 2006
2.	Visual inspection (0.25, 0.50, 0.75 and 100)	e.g. Pelicice and Agostinho, 2006
3.	Vacuity coefficient	e.g. Figueiredo et al., 2005
4.	Frequency of occurrences	e.g. Hajisamae et al., 2003
5.	Volumetric contribution	e.g. Hajisamae et al., 2003
6.	(Total stomach content weight/fish weight) × 100	e.g. Hyslop, 1980
7.	Weighted resultant index	Mohan and Sankaran, 1988
8.	Index of Relative Importance	Pinkas et al., 1971
9.	Index of Preponderance	Marshall and Elliot, 1997
10.	Feeding index	Kawakami and Vazzoler, 1980

Table 2: Mathematical models for diet analysis in fish.

Crt. no.	Description of index	Author for reference
1.	Pianka's overlap index	Pianka, 1973
2.	Pelicice feeding activity index	Pelicice et al., 2005
3.	Shannon index	Marshall and Elliot, 1997
4.	Repletion index	e.g. Figueiredo et al., 2005
5.	Electivity index	Ivlev, 1961
6.	Levin's standardized index	Krebs, 1989
7.	Schoener's overlap index	Schoener, 1970
8.	Pearre's selectivity index	Pearre jr., 1982
9.	Manly's α	Chesson, 1978
10.	Saikia's diet breadth index	Saikia, 2012
11.	Hurlbert's diet breadth	Hulbert, 1978
12.	Moritia's index	Krebs, 1989

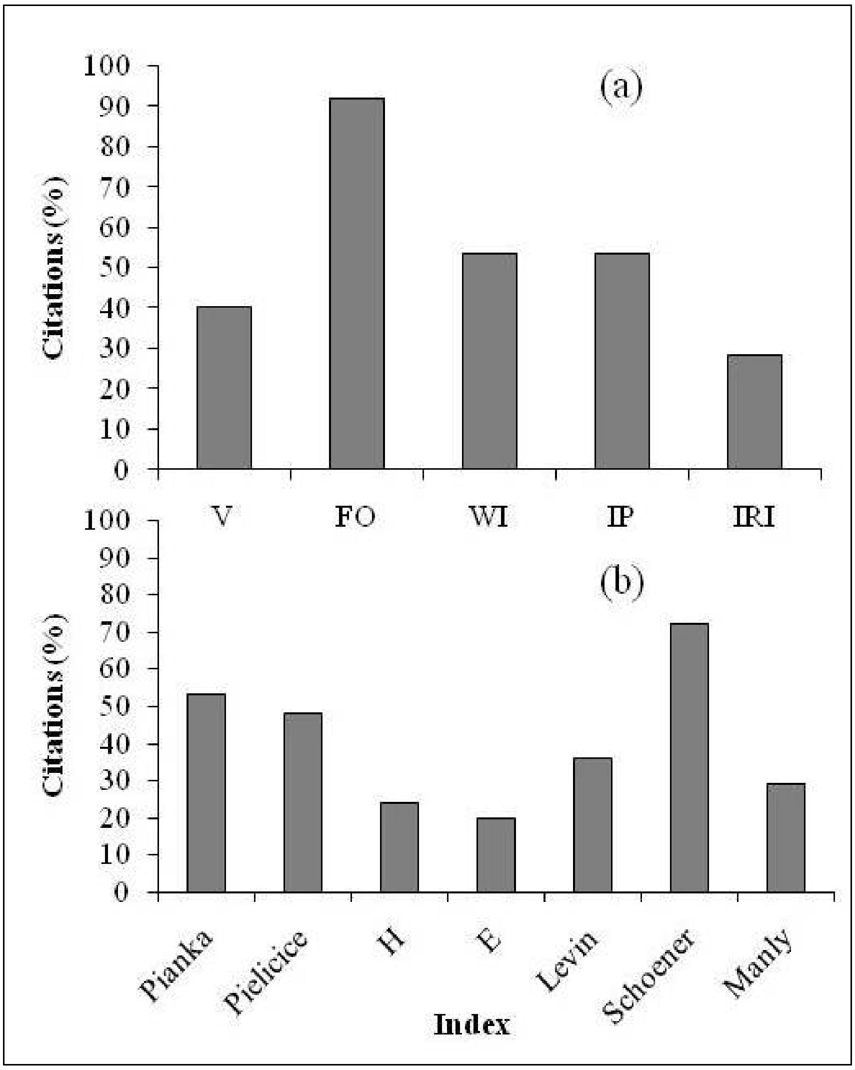

Figure 1: Frequency of citations of some (a) indices to study gut content and (b) models for preference/rejection analysis in fish (N = 70). H, Sahnnon index; E, Electivity index; V, Vacuity index; FO, Frequency of Occurrence; WI, Weighted resultant index; IP, Index of preponderance; IRI, Index of relative importance.

Although, stomach/gut content analysis fulfils the primary objective to enlisting the common foods that find passage to the alimentary canal of the fish, their computation using defined models may often have biased results and erroneous outcomes. The following observations are generally ignored: (i) Stomach/gut content analysis solely depends on the available undigested food present in the stomach/gut of the fish at the time of sampling. It gives just a “snapshot” to the food content in the gut at a particular time. An empty gut, however, does not always indicate that the fish avoids the food available in its surroundings. The cause of such avoidance of food in a particular moment by fish may be environmental e.g. insufficient temperature to support metabolic rates in the gut of the fish. In Sockeye Salmon *Oncorhynchus ranka*, rate of digestion is reported to be highly dependent on temperature (Brett and Higgs, 2011). There may be several other external factors (e.g. pH, salinity, turbidity, conductivity, etc.), influencing the acceptance and rejection of a particular diet by fish.

(ii) The general practice of identification and quantification of gut content in fishes mostly addresses undigested parts of the ingested diet. In the case of plankton feeders, soft bodied zooplankton (e.g. protozoa, some rotifers) are often skipped off the counting procedure for their rapid digestibility. There is a clear differentiation of the enzymatic activity among fishes from different trophic status as well as food habits. For example, herbivorous and omnivorous species have been reported to have more amylase activity than carnivorous species (Fish, 1960; Sabapathy and Teo, 1993; Vonk and Western, 1984). Thus, it is obvious that some food items from the gut in those fishes would be missed resulting in variation of their quantitative data on food. Another physiological factor is the gut retention time that may, directly or indirectly, influence enzyme activity on the digestion of the food. Information from the gut contents is, therefore, biased and never gives reliable basis for generalization on the feeding habit of fish.
(iii) Subsequently to gut content analysis, different normalized models are used to enumerate a clearer picture of the feeding habit of fish. Table 2 gives the summary of some of such mathematical models. The feature that is uniform to all these models is that these are based on the presence/absence matrix of food in the gut content. Although these models give enough statistical background on the feeding habit of fish, it is not possible to draw a conclusion on feeding the biology of fish because of highly biased presence/absence matrix. Cellular counts like colonial algae (e.g. *Secenedesmus* sp, *Navicula* sp., etc.) often dominate biomass counts like zooplankton (e.g. *Daphnia* sp., rotifers, etc.). Moreover, biomass counts are less prevalent and more erroneous. In addition, a precision to sample size is not available to describe what amount of sample is to be collected to precisely document the diet in fish. Lack of uniformity while using these models for diet analysis is another limitation to draw a comparative conclusion on the diet of different fish. Figure 1 shows how variably these models are used in 70 research articles to describe the food habits of fish.
(iv) The lack of expediency in the currently practiced methods becomes clear when biological features of fish are correlated with food habits. Studies on fishes where diatoms were found to be highly preferred among planktonic food lack information on the respective biological features favouring such food (e.g. Magana, 2009; Sherwood and Nishimoto, 2005). In some cases, change in the feeding habit with ontogeny (juvenile to adult) is not discussed in relation to the change in the biology of the fish (e.g. Brandão-Gonçalves and Sebastien, 2013; Ofori-Danson and Grace, 2006). The important part is the feeding habit without any true interpretation to biological features of the organism is always incomplete.

All the above problems are very basic studies in the feeding biology of fish and need attention in order to understand the realistic mechanisms involved in food preference and biology of the fish. The following part of this article makes an effort to underline some methodical approach to overcome these problems.

Feeding Ecology

The overall study on the food and feeding habits of animals can be discussed under the term "Feeding Ecology". It defines a relationship where the animal adopts a strategy for optimum foraging of predation on its preferred food. The broad domains of feeding ecology are described below (Fig. 2): an **informative account** of food organisms naturally ingested by the fish; **quantification** of gut content; **morphological adjustment** in the mouth or any other body morphs of the fish in relation to the food it ingests; **organic environment** in the gut; **olfaction** for reception and rejection of food; **molecular signalling** of food reception.

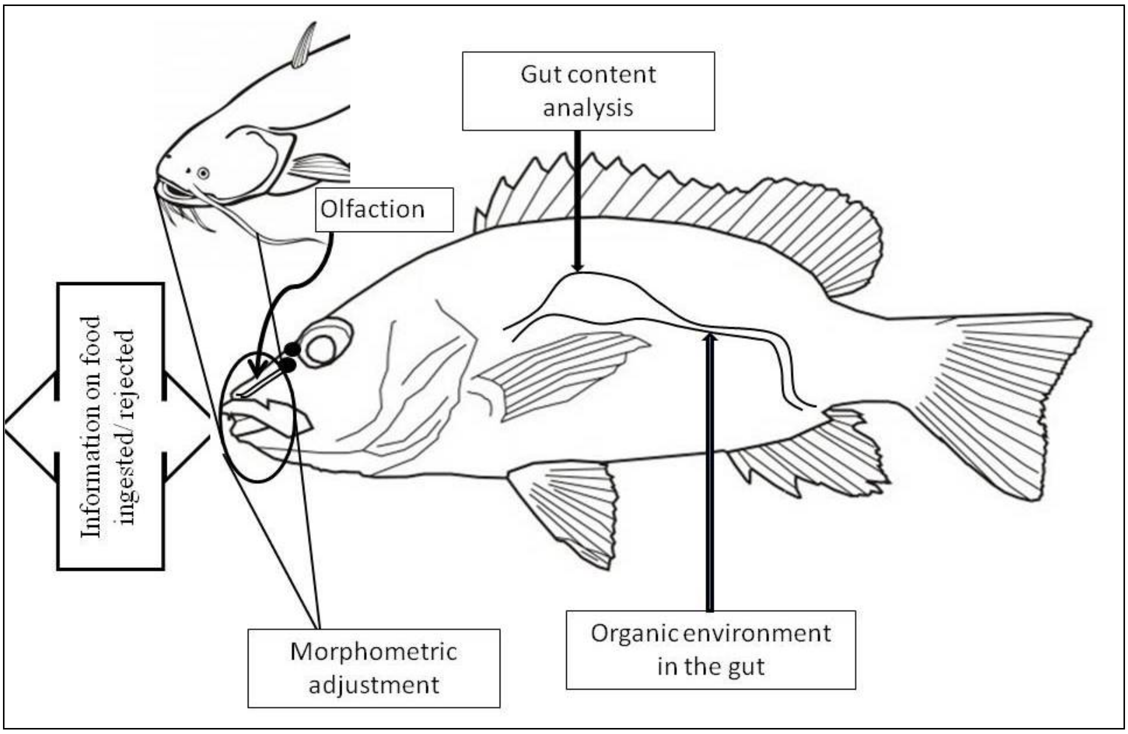

Figure 2: Domains needed to describe feeding ecology in fish.

Methods to Study Feeding Ecology in fish

Stomach or gut content

Stomach or gut content analysis is indeed the first part of feeding ecology, and could be met sufficiently by following the methods described in Hyslop (1980). From the stomach of bearing fishes, food may be collected from both oesophagus and stomach, as in most cases, soft bodied food remained intact in oesophageal part. However, in the case of stomachless fishes, a good practice comprises of dissecting the whole stomach since some hard bodied food may occur in the distal part of the fish.

Quantification of food and feeding ability

Frequency data (relative abundance or relative occurrence) from gut samples are used to analyse food selection, and weight or volumetric data (gut fullness) are used to estimate feeding intensity relationships. Although, there are good numbers of methods to quantify food availability and food selection in fish (Tab. 2), all these, more or less, rely on the frequency of the occurrence of food in gut or between gut and environment. For food selection, frequency data can be used only if food resources are sampled from the environment when fish are collected. This leads to difficulty in analysis since sampling of fish and resources are not uniform and obtaining unbiased samples of food resources available for fish is, therefore, a challenge. It becomes more difficult for carnivorous fishes which feed on active preys that eventually skip during sampling. These methods, therefore, can be used to generate preliminary information on the food preference of fish. A conservative approach would be to sample in large quantities to avoid a sampling error. With some limitations, radiotracer methods are often used as more descriptive methods to enhance accuracy in results. Aihara et al. (2008) used fluorescent dye to label food using $DilC_{12}$, in order to trace the food in the gastrointestinal tract.

Ecomorphology

As seen in the above sections, relying on only gut content data using mathematical models could lead to erroneous outcomes. According to the hypothesis in ecomorphology, diet should be predictable from the morphology of the fish, particularly from morphological traits related to feeding such as mouth size, jaw shape and dentition (Ogunlaru et al., 1997). Thereby, it aims to establish a correlation between one or several morphological features, which would indicate a potential adaptation of a particular species to a certain ecological niche (Costa and Cataudella, 2007; Teixeira and Bennemann, 2007). Thus, one may determine which environmental or biological factors are influencing individual forms within an ecosystem, thereby increasing their success in the exploitation of the available resources (Cunico and Agostinho, 2006; Motta and Kotrschal, 1992). Fish explore almost all ecological zones of aquatic ecosystem and shows high degree of variations in their mouth morphometry. Depth wise, the change in their morphometry has been outlined in figure 3. Such morphometry directly influences their feeding, especially the size-dependent selection of prey in the environment. Ecomorphology, therefore, is an appropriate term for describing the feeding ecology of a species, including food preferences, diet overlap, and habitat use.

There are different ways to study the morphology of fish. The traditional practice is to measure morphometric characters on a "longitudinal scale", recording the depth and breath. Although it is a highly prevalent practice, repeated measures on such longitudinal scale could be biased and may leave high rate of instrumental errors. Besides, the head surface of a fish is very uneven, and orientation of some parts (e.g. eyes, operculum, etc.) may vary immensly. An approach to a geometric morphometry could be more reliable over such a "meristic" approach. An easily approachable geometric technique is the TRUSS analysis. It is one of the highest recommendable techniques for morphometric characterization in fish (Strauss and Bookstein, 1982). The TRUSS allows us to take uniform landmarks for all comparable morphs of organisms on a geometric plane.

The external morphology could be further extended to internal mouth morphology of the fish. This is often seen more informative than external morphology to demonstrate feeding habit since a direct correlation exists between gustation and ability to detect chemicals through different extra- and intra-oral structures in the mouth of vertebrates. Cave dwelling fishes, with a habit to feed in the dark can be best differentiated from open water fishes feeding under light by the presence of their abundant taste buds in the mouth (Ohkubo et al., 2005). The presence of diversified taste buds on their mouth region indicates the strength of gustatory sensuality in detecting food or feeding areas by fish (Fig. 4). For example, from fishes, three types of taste buds are reported. These are Taste bud I, Taste bud II and Taste bud III. Morphologically, Type I taste buds are generally sunk in somewhat relative to the level of the neighbouring epithelial cells and mostly located near the entrance of the mouth. Type II taste buds are slightly elevated from the epithelium and not surrounded by a rill into which the base is sunk. Type III taste buds never raise above the normal level of the surface epithelium. They may be useful for ensuring full utilization of the gustatory ability of the fish, detection and analysing the quality and palatability of food, during its retention in the mouth (Elsheikh et al., 2012). In some cases, taste buds in gill rakers also supply information on the feeding habit of fish (Elsheikh, 2012). Besides, it is possible to classify fish on the basis of the gustatory reception to some specified chemical substances.

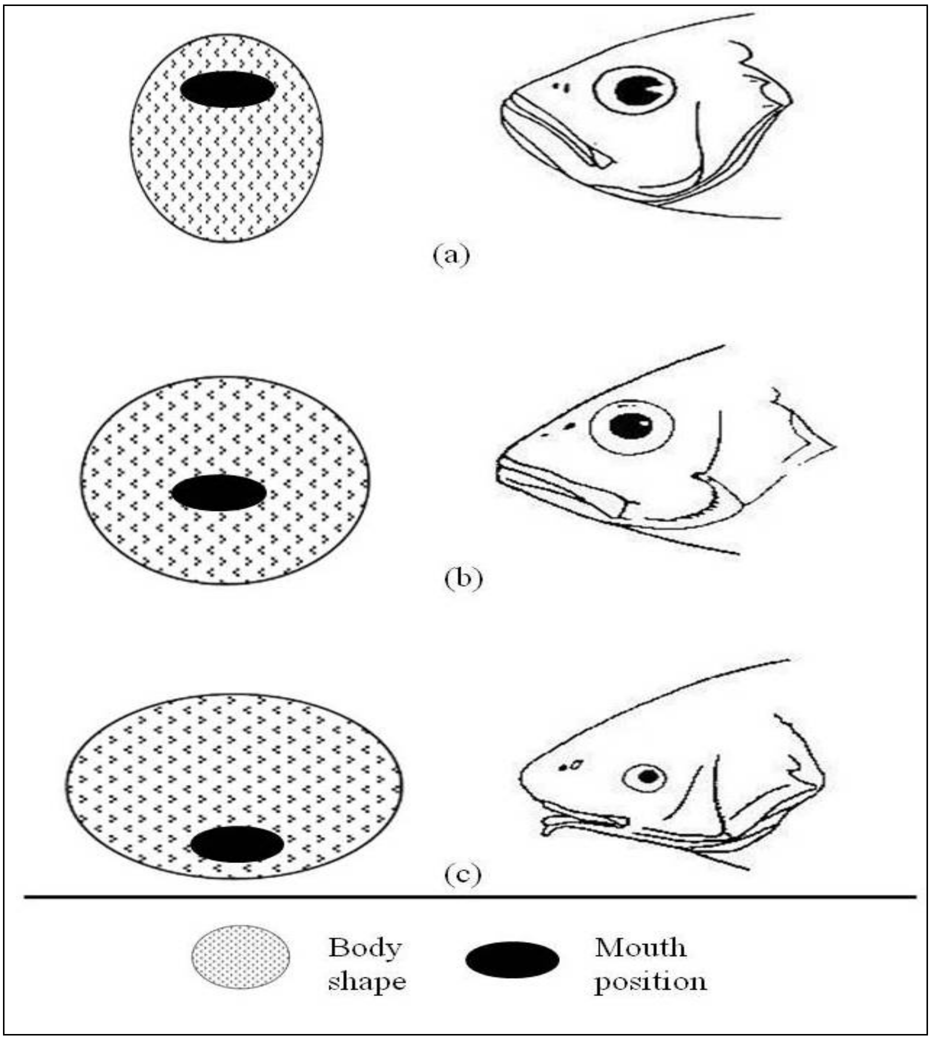

Figure 3: A general representation of ecomorphology where changes in the mouth position and body shape in fish is shown according to different depths.
(a) Surface dwellers, (b) mid-column dwellers and (c) bottom dwellers.

Microbial gut flora and food

Probiotics has become a new addition in the aquaculture research to reveal possible resident gut microflora of fish respective to the food supplement. However, studies on feeding habits still need to link food and gut microflora in their methods. Separate studies have shown that these microflora respond to digestive physiology (Cahill, 1990) and feeding strategy of fish. Ringø et al. (1995) suggested that *Bacteroides* sps. and *Clostridium* sps. enhance nutrition by providing essential fatty acids and vitamins. Some gut bacteria (e.g. phytase producing bacteria) have a high presence in carps that feed on plant or products (Khan and Ghosh, 2013; Roy et al., 2009). Their observation suggested that microbial community in the gut changes along with the ontogeny of fish (Luczkovich and Stellwag, 1993). Thus, in studies of feeding habits, a correlative analysis must be conducted to support how gut microflora assist in the digestion of ingested food. Such attempts will validate the physiology of the food digestion and absorption and help in tracing the transient foods that the fish ingests.

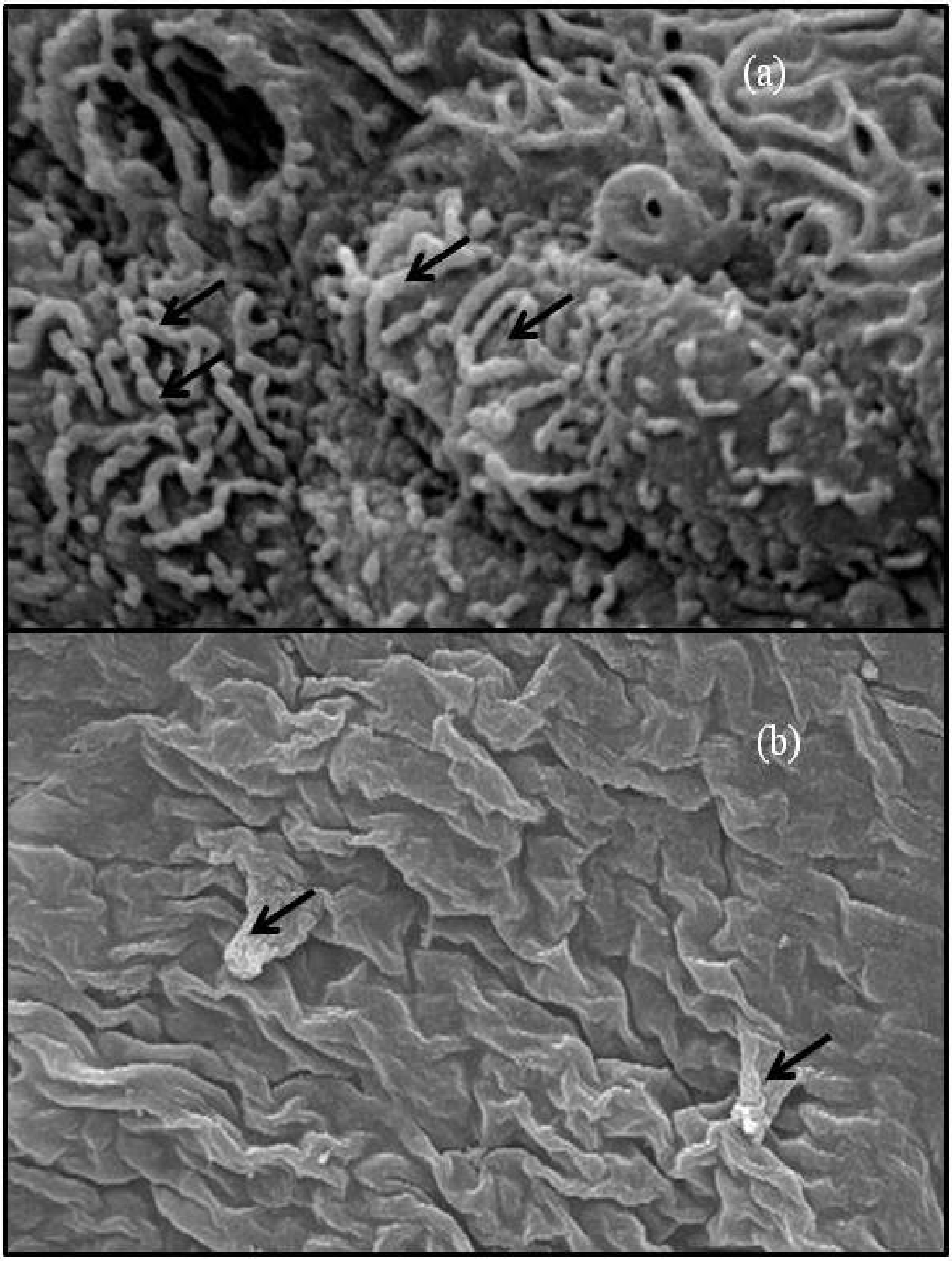

Figure 4: Scanning Electron Micrographs (SEM) on (a) bacterial association and (b) taste buds (black arrow) in the mouth region (intra-oral) of a small freshwater fish *Amblypharyngodon mola*.

Olfaction

Olfaction is directly correlated to the odorant nature of substances. Food selection in fish is highly regulated by the biochemical quality of the food (Kasumyan and Morsi, 1996; Kasumyan and Sidorov, 2010; Mikhailova and Kasumyan, 2010). Primarily, a classification of fishes into three broad trophic groups as herbivorous, carnivorous and omnivorous does not indicate any precise food preferences with specific biochemical nature. There may be different amino acids or other biochemical substances stimulating olfactory receptors in fish and qualify as better food. The larvae and adults in fishes always have different choices for food based on chemical signals (Kasumyan, 2011). Fishes are often attracted towards certain chemicals available in their food and characterizing these chemicals is necessary to understand their response to desired food. It was reported that fishes are attracted towards L-Lysine and L-Arginine if available in their surroundings. The free amino acids as extracts of food odour result in high sensitivity in selecting particular type of food by fish. This is necessary to identify to which group of biochemical composites the fish may have desired attractability. The behavioural testing of fish employing the food pellet with and without the chosen chemical is the commonly adopted technique to study preferences of food based on the biochemical nature of food. There are two suggestive approaches for such behavioural tests. First, studying the frequency of touching and grasping of pellets made of taste substances computing "index of taste attractiveness" (Kasumyan and Morsi, 1996). Second, use of radiolabelled dye with taste substances and observations under a microscope (Aihara et al., 2008). However, the second approach may be followed as a confirmatory test to the first approach.

Molecular Signalling

It is obvious that reception of food through olfaction is mediated by some chemical pathways in the body. The molecular science of taste had its beginning in the late 20th century. Today great efforts have been forwarded to understand molecular biology of taste science in accordance to modern advances of tools and techniques in molecular and cell biology. For the first time, Buck and Axel (1991) identified G-protein coupled receptors as odorant receptors with seven-membrane topology and for this discovery they received the Nobel Prize of Medicine and Physiology in 2004. Since then, series of research have been initiated to study taste science in relation to food science and agriculture.

For taste reception, vertebrates in general express two families of G-protein coupled receptors (GPCRs), viz. T1Rs and T2Rs, residing on the surface of sensory cells of each taste bud (Adler et al., 2000; Hoon et al., 1999). In mammals, heteromeric T1R1/3 receptors respond to umami tastants such as amino acids (Zhao et al., 2003) whereas, T1R2/3 responds to sweet tastants like sugars or sweet proteins, etc. (Nakajima et al., 2006; Nelson et al., 2001) and T2R series of taste receptors respond to bitterness (Chandrasekhar et al., 2000). Keiko Abe and his group initiated several experiments on zebra fish (*Danio rerio*) and Medeka (*Oryzias latipes*). They observed that T1Rs and T2Rs of mammals and fish have a high degree of similarities (Abe, 2008). However, in fish, T1R2/3 heteromeric receptors form responds to amino acid rather than to sugar.

Thus, a detail on the molecular biology of taste receptors and their signalling cascade to neurosensory system has to be addressed to understand the true feeding biology of fish.

CONCLUSIONS

Food scientists and technologists have long paid great attention for better management of food industry. Although limited, fishery industry may also participate in such efforts by developing precisely designed target oriented fish feeding module. From a habitat management point of view, there are possibilities that a change in environmental quality from protein rich sources to sugar rich sources or vice versa, or any other aversive tastes, may directly affect natural fish population in an aquatic ecosystem.

A "food based conservation" approach is highly preferred when eco-restoration deals with fish communities. It seems extremely obvious now not to rely on abstract sampling procedures for merely descriptive assessment of food and feeding biology in fish. Food science is an applied science and the detailed feeding biology of fish can contribute to formulate feeding design for better management and growth of fish. Along with animal biologists, especially those working with fish, aquatic ecologists and molecular biologists may form an integrative approach for better outlining such feeding studies.

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A STATISTICAL MODEL FOR ESTIMATION OF ICHTHYOFAUNA QUALITY BASED ON WATER PARAMETERS IN OITUZ BAZIN

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KEYWORDS: Romanian Carpathians, lotic system, ichtyofauna, estimation model.

ABSTRACT

Fish represents an important food source for people worldwide. Moreover, although considered a very old occupation, fishing continues to provide jobs, especially for the people living in the coastal countries. The quality of surface waters affects the quality of fish as a food source. For this reason, the present study aims to assess the quality of the ichthyofauna in the Oituz River and some of its tributaries using several parameters that have been computed based on the biometric data of the biological material gathered during 2004-2008, in correlation with the water pH and water temperature. The present paper also highlights some observations regarding the changes of the analyzed ecosystems, as well as some recommendations regarding the fish consumption in the studied basin, considered as a food source for humans.

RÉSUMÉ: Modèle statistique basée sur les paramètres de l'eau, pour estimer la qualité de l'ichtyofaune, dans le bassin de la rivière Oituz.

Le poisson est une source importante de nourriture pour les humains. En outre, bien qu'il s'agit d'une très vieille activité, la pêche continue à fournir des emplois, en particulier pour la population des pays riverains. La qualité de l'eau de surface détermine aussi la qualité du poisson comme source de nourriture. Pour cette raison, cette étude envisage l'estimation de la qualité d'ihtyofaune dans la rivière Oituz et quelques affluents, faisant usage des paramètres qui ont été calculées sur la base de données biométriques du matériel biologique pris dans la période de 2004-2008, en corrélation avec le pH et la température de l'eau. Ce travail fait aussi des observations sur les changements dans les écosystèmes analysées, ainsi que des recommandations sur la consommation de poisson du bassin étudié, aperçu comme nourriture pour l'homme.

REZUMAT: Model statistic bazat pe parametrii apei, pentru estimarea stării ihtiofaunei din bazinul râului Oituz.

Peştele reprezintă o importantă sursă de hrană pentru om. În plus, pescuitul, deși este o îndeletnicire foarte veche, continuă să furnizeze locuri de muncă, mai ales pentru populația din țările riverane. Calitatea apelor de suprafață determină și calitatea peștelui ca sursă de hrană. De aceea, prezentul studiu vizează estimarea calității ihtiofaunei din râul Oituz și câțiva afluenți, utilizând parametri care au fost calculați pe baza datelor biometrice ale materialului biologic capturat în perioada 2004-2008, în corelație cu pH-ul și temperatura apei. Lucrarea evidențiază și observații privind modificări ale ecosistemelor analizate, precum și recomandări privind consumul peștelui din bazinul analizat ca hrană pentru om.

INTRODUCTION

Certain environmental problems are embedded in social-ecological systems (Schlüter et al., 2012), which are systems with a high degree of complexity. The complexity derives from multiple interactions (both on spatial and on temporal scales) between the social communities and the ecological systems that are supporting them, as well as from profound uncertainties (Berkes, 2007; Fulton et al., 2011). Modelling is a traditional tool in natural resource management to study such complex systems (Bousquet and Le Page, 2004; Carpenter et al., 1999; Schmolke et al., 2010), benefiting of results from different areas such as numerical optimization, visualisation, graph theory, agent-based and network approaches, and statistics.

Waters and fisheries count among the systems which have to be studied in order to improve the understanding of the processes and factors that could lead to sustainable outcomes. There are numerous numerical models for fish life: transit of fish eggs, larvae, and nursery areas (Hilborn and Walters, 1987). The best suited mathematical models are based on the direct extraction of information from existing data sets (i.e., empirical approaches), but the modelling tools depend on the objectives of the modelling (North, 2009). The model formulations are situation-specific (Ibarra et al., 2005; Milner-Gulland, 2011).

Since 1900, fish populations have been used as environmental indicators. Researchers have proved (Simon, 1999) that the relative health and condition of an aquatic community is a sensitive measure of the site-specific condition. On the other side, environmental factors (such as water temperature, salinity, depth and mud percentages, metals concentration, etc.) are frequently selected as predictor variables of the models. In line with this course, the present paper offers an estimation model for the quality of waters of the Romanian river Trotuş, based on the data gathered for two years related to the fish populating the river.

Trotuş is an important river of the largest hydrographic basin of Romania, in Siret Basin. Its origin is in the Trotuş Mountains, at 1,380 m altitude. Although it is a river with medium length (162 km), Trotuş River crosses an extremely varied landscape, with a difference level of (from spring to inflow) more than 1,000 m. Variations of the air temperature in Trotuş Basin display alpine climate conditions on the highest peaks, while being mild or with thermal inversions in depressions and valleys. Near the city Oneşti, Trotuş is collected by Oituz River. (Ujváry, 1972; ***, 1992)

As far as the pollution in the Oituz River basin area is concerned, we mention some aspects which can influence the quality of the ichtyofauna. In this area, there is a sawmill at Oituzul Ardelenesc and two sawmills at the exit from Oituz, at Bâtca point.

The forest exploitations in Breţcu and Oituz Forest Districts and in Mereni and Oituz Private Forest Districts cause a series of negative phenomena on the riverbed. During 2008, in the settlements of Oituz River basin there were about 100 circular saws producing sawdust which can reach the riverbed in some areas, thus altering the habitat conditions. Another consequence of deforestation is the increase of water temperature due to the lack of shading which limits the survival of the salmonids and the benthic invertebrates in the river water.

Other sources of pollution are the sump salvages of Halos and Ferastrău areas, as well as the fecal-domestic pollution from the coastal villages. There is no industrial pollution there.

Fish – as poikilothermic species – do not need energy for the body temperature adjustment. The body temperature of the fish is 0.5-1 degrees higher or lower than the temperature of the water in which they live. The intensity of their metabolism is closely related to the fish size, water temperature and water pH (among others) so our analysis is based on this correlation. For example, trout grows well at temperatures of 12-18 degrees, while at higher temperatures their metabolic rate decreases. Generally, the climate changes have a major influence on fish, both regarding the survival of the individuals and of species. (Moyle, 2002)

The water temperature is an important factor to consider, due to its influence on every other of its quality parameters: conductivity, salinity, oxidation reduction potential, pH, CO_2, compound toxicity, dissolved oxygen (Moyle, 2002). The temperature can alter the physical and chemical properties of water. In this regard, water temperature should be accounted for when determining the metabolic rates and photosynthesis production. Temperature fluctuations can also affect the behaviour choices of the aquatic organisms. (Wetzel, 2001)

The pH of pure water varies with temperature. Pure water only has a pH of 7.0 at 25 degrees Celsius. The pH value is influenced by the dissolved organic matter, the melting snow and rainfall, and the sewage discharges. For example, the optimum pH value for the salmonids must range between 7 (neutral) and 8 (alkaline), while the values below 5.5 or above 8.5 are unsuitable for their development. (Baldisserotto, 2011)

MATERIAL AND METHODS

Our statistical modelling is based on the regression technique which illustrates the correlation between the dependent variables *fish weight* and *fish length* with the *temperature* and pH of water as predictors. Moreover, the analysis compares the statistical results from two different periods of time, 2004 and 2008, in order to observe if important changes came up. In social and natural sciences, multiple regression procedures are widely used in research, as these allow researchers to answer questions that consider the role(s) that multiple independent variables play in accounting for variance in a single dependent variable. Our implementation of regression model uses functions from Matlab toolboxes.

A rigorous substantiation of the existence of a correlation and, afterwards, the design of the model which describes the correlation (the regression model) is based on the calculation and interpretation of several statistical indicators. The following stages have been run through: verification of the existence of a correlation, analysis of the empirical regression curve, determination of the mathematical equation of the model and of its parameters, and use of the model for prognosis.

Our statistical analysis was based on data from Oituz River, on certain species that were found in most of the collection points: *Phoxinus phoxinus* (L = 8-14 cm, G = 10-14 g), *Squalius cephalus* (L = 25-30 cm, G = 0.3-1.5 kg), *Salmo trutta fario* (L = 25-30 cm, G = 0.8-1.6 kg) and *Barbus meridionalis* (L = 20 cm, G = 300-400 g).

The figures between parentheses indicate the average length and weight for the individuals of that species. The metabolism intensity depends more on the size of the fish than on the age and it is inversely proportional to the size of the fish.

The data were collected in two years, in the sampling sites indicated in figure 1 for the year 2004 and in figure 2 for the year 2008. The biological material was sampled through electrofishing, using the "catch and release" method. Every collection point is associated with one value for weight and one for length, representing the average values of these characteristics for the individuals captured in that location. We also mention that the measure units for the two variables, weight and length, were grams and centimetres, respectively.

The above mentioned species differ in their capacity to adapt to the climate and environmental conditions. *Salmo trutta fario* prefers low temperatures: 12-19 degrees Celsius (Raleigh et al., 1986), and even less in the reproductive period, around 6-8 degrees Celsius (Bănărescu, 1964). There are studies showing that, if possible, the trout avoids temperatures above 13 degrees Celsius (Moyle, 2002), and tolerates a pH between five and 9.5, the optimum values being 6.8-7.8 (Raleigh et al., 1986).

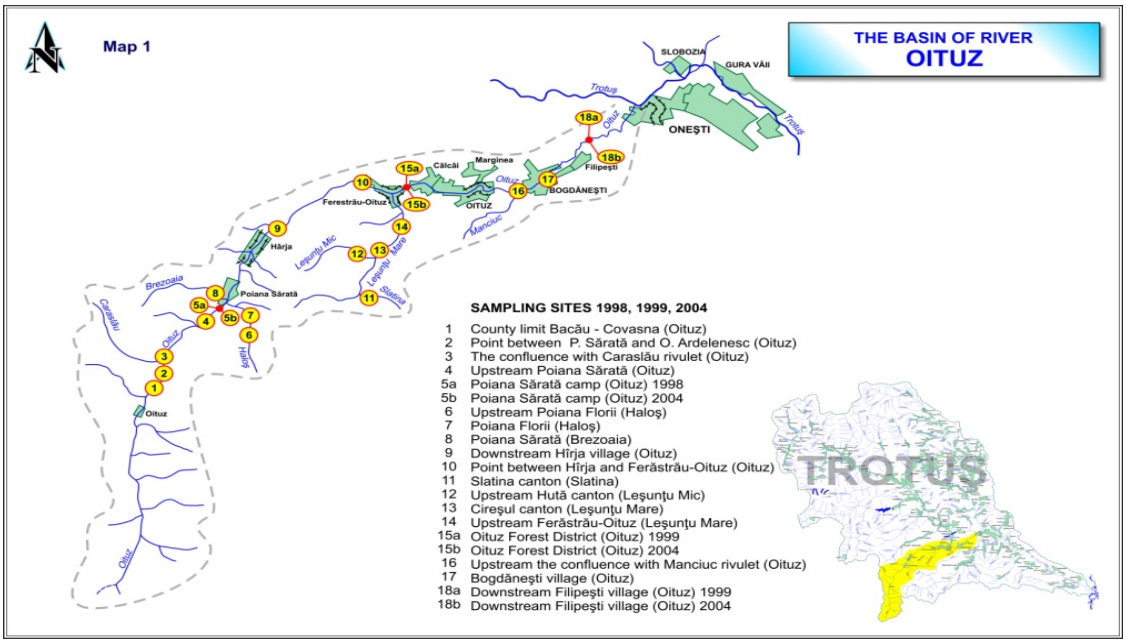


Figure 1: Sampling sites used in 2004 in the basin of river Oituz.

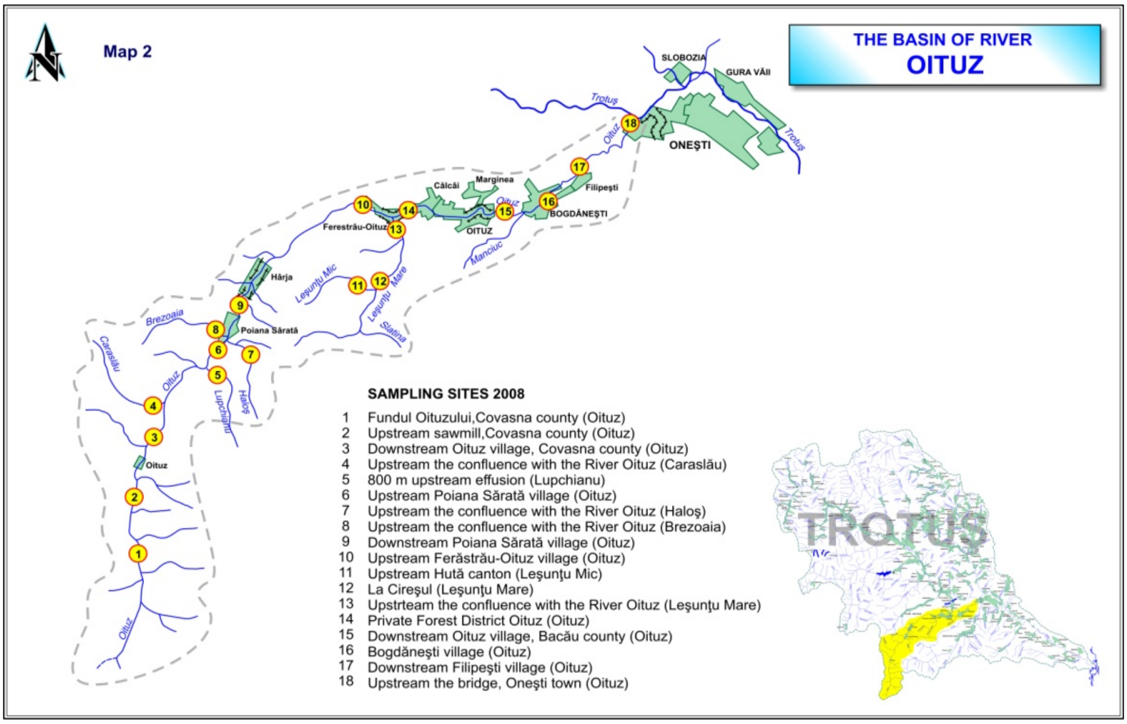


Figure 2: Sampling sites used in 2008 in the basin of river Oituz.

For the other species, the optimum conditions are defined by: pH 7-7.5 and temperature between two and 20 degrees Celsius for *Phoxinus phoxinus*; pH 6-7.8 and 4-20 degrees Celsius for *Squalius cephalus*; 5-25 degrees Celsius for *Barbus meridionalis* (Froese and Pauly, 2014).

RESULTS AND DISCUSSION

Related to 2008, in the case of *Phoxinus phoxinus* species, we have obtained a model which covers 87% of the measured data (Fig. 3) for the fish length and about 80% of the collected data in the case of fish weight (Fig. 4) The equations which describe the multiple regression models are given below:

$$L_{med} = 68.0473 - 3.2472 \cdot T - 6.3250 \cdot Ph + 0.3284 \cdot T \cdot Ph$$
$$R^2 = 0.87, \qquad p = 0.005$$
$$G_{med} = 88.0833 - 4.7570 \cdot T - 8.5523 \cdot Ph + 0.4810 \cdot T \cdot Ph$$
$$R^2 = 0.8059, \quad p = 0.003$$

In statistics, it is well known that the greater the slope (or regression coefficient) the more influence the independent variable has on the dependent variable; if the regression coefficient is negative, the variables are negatively correlated, (one variable increases and the other one decreases).

For L_{med} and G_{med}, the coefficient of the above regressions are negative, which involves a negative dependence of the dependent variables on the considered predictors.

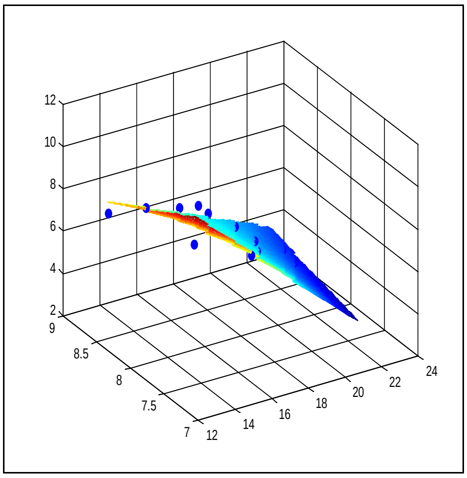


Figure 3: Length, temperature and pH correlation for *Phoxinus phoxinus*.

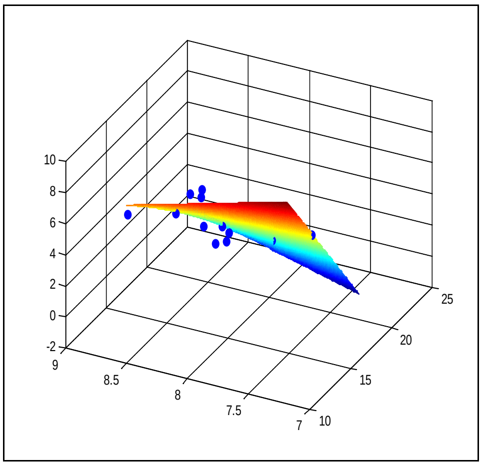


Figure 4: Weight, temperature and pH correlation for *Phoxinus phoxinus*.

For *Salmo trutta fario* species, taking into account the same variables of the model, we have obtained the following results for 2008:

- for length, the statistical model covers 87% from the collected data (Fig. 5)

$$L_{med} = 919.69 - 21.7525 \cdot T - 104.6385 \cdot Ph + 0.3284 \cdot T \cdot Ph^3,$$
$$R^2 = 0.8735, \qquad p = 0.0016$$

- for weight, the statistical model covers 76% from the collected data (Fig. 6)

$$G_{med} = 5489.9 - 131.8 \cdot T - 626.8 \cdot Ph + 0.2 \cdot T \cdot Ph^3$$
$$R^2 = 0.7651, \qquad p = 0.01$$

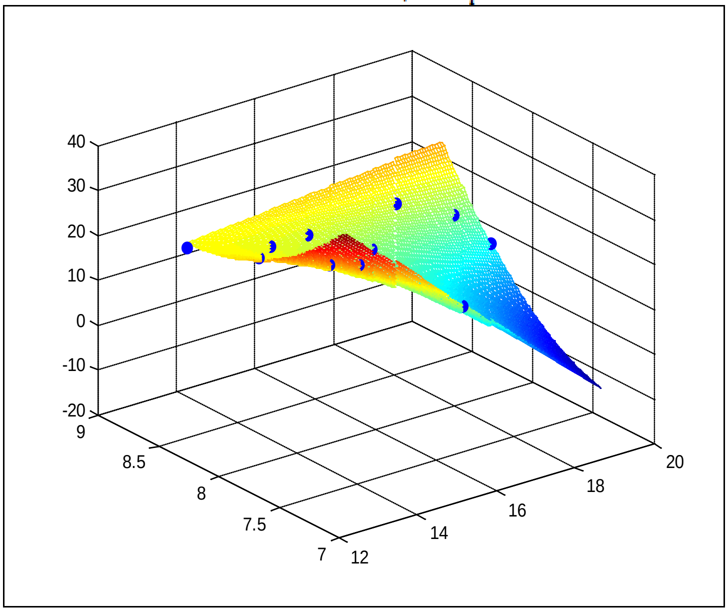


Figure 5: Length, temperature and pH correlation for *Salmo trutta fario*.

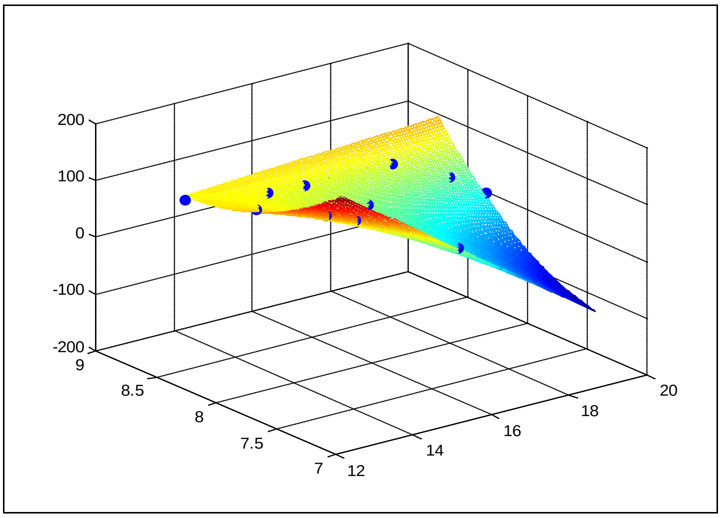


Figure 6: Weight, temperature and pH correlation for *Salmo trutta fario*.

The following analysis reveals a species that is not very sensible at the variation of the water temperature and pH. *Barbus meridionalis* species has a relatively high prevalence in Romania; it manifests a process of territorial expansion and is considered as having low vulnerability.

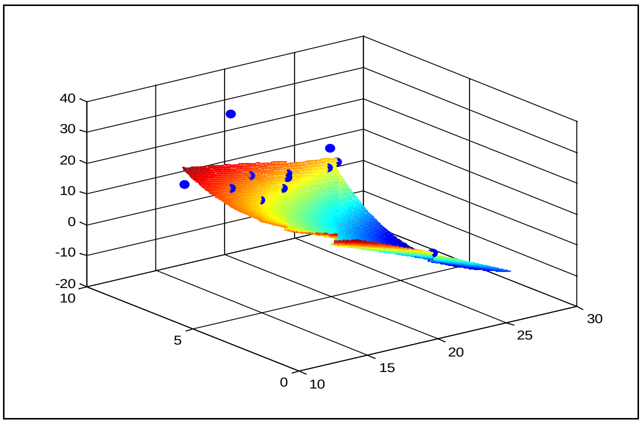


Figure 7: Length, temperature and pH correlation for *Barbus meridionalis*.

We noticed (Fig. 7) that the estimation model covers only 25% of the collected data for the weight as dependent variable and about 23% for the length as dependent variable.

In the case of *Squalius cephalus* species:

- for the dependent variable *length*, the statistical model covers 72% of the collected data (Fig. 8)

$$L_{med} = -1196.3 + 53.3 \cdot T + 143.4 \cdot Ph - 0.6 \cdot T \cdot Ph,$$
$$R^2 = 0.7269, \qquad p = 0.07$$

- for the dependent variable *weight*, the statistical model covers 95% of the collected data (Fig. 9)

$$G_{med} = -2531.4 + 224.9 \cdot 35.8 \cdot Ph^2 - 26.7 \cdot T \cdot Ph$$
$$R^2 = 0.6931, \quad p = 0.09$$

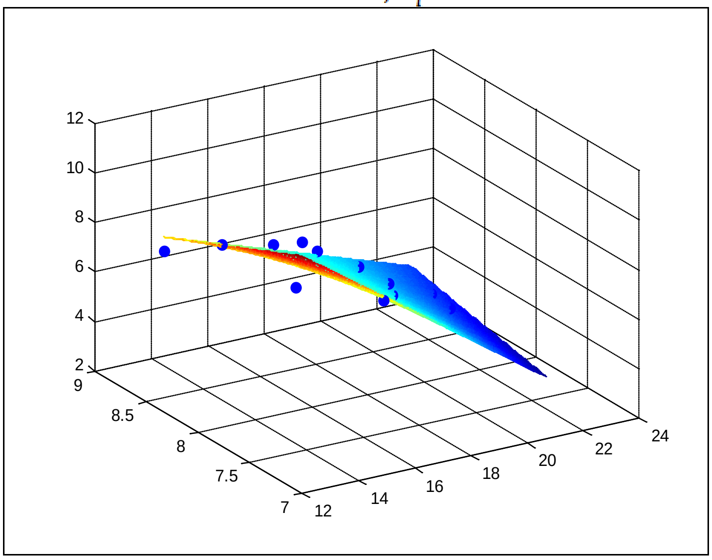


Figure 8: Length, temperature and pH correlation for *Squalius cephalus*.

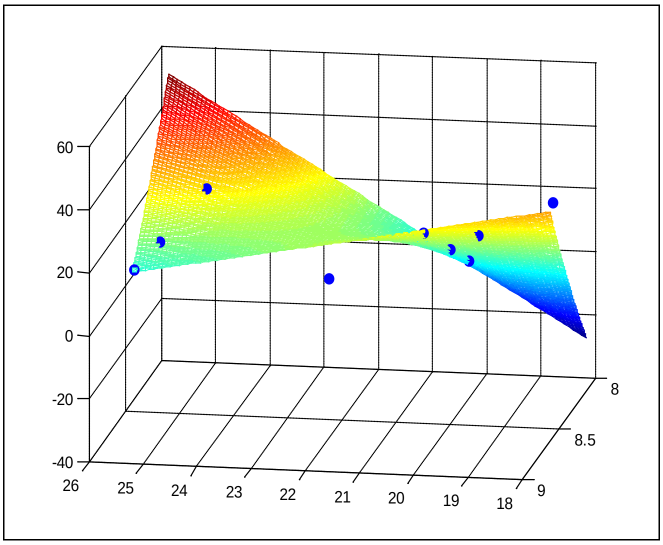
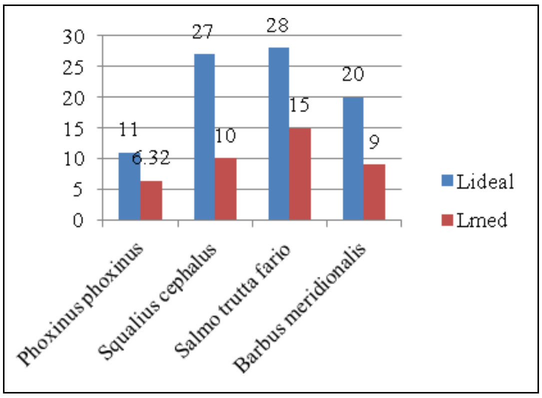


Figure 9: Weight, temperature and pH correlation for *Squalius cephalus*.

For the year 2004, the same analysis has been performed for the considered species and the estimated models are slightly different from those for 2008.



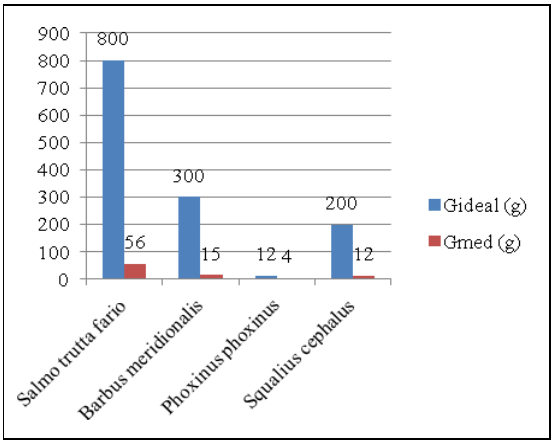


Figure 10: The ideal values of fish length and weight versus the real values.

CONCLUSIONS

For the considered species, the statistical analysis on the available data reveals that there are several species of fish that are more sensitive to the environmental changes, while others are not. In the case of *Salmo trutta fario*, the rate of growth varies widely, depending on the thermal and trophic conditions. For most of the species in our study (except for *Squalius cephalus*) because they are cold water fish, both length and weight increase at low temperatures. A major reason for the change in pH, which can greatly affect the fish metabolism, is given by the presence of houses in the area. *Squalius cephalus* species grows better in environments with temperatures which are not typical for a mountain water (see the positive coefficients of water temperature and pH). Because there are no major sources of industrial pollution, the water quality in Oituz River basin has normal parameters, so the ichthyofauna is not significantly affected. For the considered species we can conclude that *Squalius cephalus* and *Barbus meridionalis* species are more adaptable to the climate and environmental changes than the other two species (*Phoxinus phoxinus* and *Salmo trutta fario*).

However, the data analysis reveals that the individuals do not reach maturity, either due to the domestic pollution caused by the towns bordering the river, or due to the anthropic influence (such as overfishing) (Fig. 10).

ACKNOWLEDGEMENTS

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ILLEGAL FISHING ACTIVITY – A NEW THREAT IN MANNAR ISLAND COASTAL AREA (SRI LANKA)

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KEYWORDS: Northern Sri Lanka, fishing industry, fishing community.

ABSTRACT

Illegal fishing net use is one of the most serious threats to the health of the world's fisheries and for the secure employment of fishers. Illegal modes of fishing adversely affect the fishing industry according to the Fisheries and Aquatic Resource Ministry of Sri Lanka which is the regulatory body of the fisheries industry. In Sri Lanka, usage of illegal fishing methods has increased in recent years. There is an urgent need to identify prohibited or illegal fishing activities and the use of dangerous or harmful substances in fishing. The present study was carried out in the Mannar coastal area from June 2013 until the latter part of June 2014, to identify illegal, prohibited and dangerous fishing activities, and to understand the major threats and impacts on the fishing community and the socio, economic, biological and ecological impacts through field surveys and library methods. The study aims to outline appropriate planning and solutions to minimize illegal fishing and to save the coastal biodiversity and fishing community.

RESUMEN: La pesca ilegal, una nueva amenaza en el área costera de la isla Mannar.

De acuerdo al Departamento de Pesquerías y Recurso Acuáticos de Sri Lanka, que representa la entidad reguladora de la industria pesquera en esta república, las distintas formas de pesca ilegal afectan negativamente la industria pesquera y se sabe que han aumentado en los últimos años. Existe una urgente necesidad de identificar las actividades ilegales de pesca y el uso de sustancias peligrosas y nocivas utilizadas para la pesca. Este estudio fue llevado a cabo en el área costera de Mannar de junio de 2013 a junio de 2014. Se realizó una identificación de las principales amenazas e impactos de la pesca ilegal sobre las comunidades pesqueras y en los sistemas socioeconómicos, biológicos y ecológicos mediante encuestas en campos y revisión bibliográfica. El objetivo de este estudio es encontrar una planeación apropiada para minimizar y remediar la pesca ilegal así como salvar la biodiversidad costera y las comunidades pesqueras.

REZUMAT: Pescuitul ilegal, o nouă amenințare în zona de coastă a insulei Mannar.

Plasele de pescuit ilegal folosite în ocean sunt una dintre cele mai serioase amenințări asupra crescătoriilor de pește la nivel mondial, dar și asupra siguranței pescarilor. Potrivit *Pescăriilor și resurselor acvatice* din Sri Lanka care acționează ca un mecanism regulator asupra industriei crescătoriilor de pește, metodele ilegale de pescuit afectează industria crescătoriilor de pește. În Sri Lanka, incidența metodelor ilegale de pescuit a crescut în ultimii ani. Există o nevoie imediată în ceea ce privește identificarea activităților ilegale de pescuit și folosirea substanțelor periculoase sau dăunătoare pentru pescuit. Studiul de față s-a desfășurat în zona de coastă a insulei Mannar în perioada Iunie 2013 – sfârșitul lui Iunie 2014. Această abordare pune accentul pe amenințările majore și pe impactul pe care îl au asupra comunității de pescari, dar și pe impactul social, economic, biologic și ecologic al acestor studii, studii de teren și cercetări din literatură. Studiul urmărește găsirea unui plan și a unor metode de reducere a pescuitului ilegal și speră la salvarea biodiversității de pe coastă și a pescarilor.

INTRODUCTION

Illegal fishing net use is one of the most serious threats to the health of the world's fisheries and for the secure employment of fishers. Other illegal fishing methods include the use of dynamite, stupefying substances, other noxious, harmful materials or substances and bottom trawling methods. All of these methods are common throughout the coastal areas of Sri Lanka, especially in the Palk Bay region and Gulf of Mannar, both in northern Sri Lanka.

The Fisheries Act (1996), implemented by the Sri Lanka Ministry of Fisheries and Aquatic Resources, strongly prohibits the above mentioned illegal fishing methods. Further, since 2010, the Department of Fisheries and Aquatic Resources in Mannar District, Sri Lanka, has also taken action to prohibit illegal fishing methods, including methods such as artificial fishing devices constructed from mangrove tree logs, concrete pillars, stones, and old car bodies, as well as monofilament nets, dynamiting and tree branches for squid fishing.

The use of these illegal fishing methods threatens many marine resources, especially coral reefs, mangroves, mammals, and endangered species such as turtles. One particular social issue is the effect of such methods on the numerous small-scale fishing communities in the study region. The affected fishers have, on several occasions, made complaints to relevant authorities on this issue, but the authorities have failed to take action against them due to political interference in this region.

The fisheries sector is an important economic element for people of the Mannar district in the Northern of Sri Lanka (encompassing industries, employment and livelihood). This sector has been affected for the last three decades by an ethnic civil war. The local economy had been badly affected, with internal and international displacement, loss of property including fishing gear and infrastructure, and loss of life. With the lifting of a ban on fishing after the Tamil war (which ended May 2009), the Mannar fishing communities appreciated this move by the Government of Sri Lanka. As a result, large numbers of fishermen ventured into coastal fishing and a considerable improvement in income can be observed in this sector, and this is regarded as a major turning point for the fishing sector in the post-war scenario. However, while there is hope of restoration of normalcy in their daily lives, fishers have also had to deal with the threat of illegal fishing activities in their fishing grounds.

In order to lead to prosperity, the Sri Lankan fishing industry needs proper management. The mission gets harder to achieve with the present, very permissive restrictions within Sri Lankan territorial waters.

Illegal fishing is increasing with every day and it represents a threat to the country's fishing resources. According to the National Aquatic Resource Agency of the Fisheries Ministry (NARA), poaching will have a long-term negative impact on the fishing industry in Sri Lanka, affecting its sustainability in the future.

Sri Lanka has a vast sea area and rich marine resources, and requires the protection of fish and other valuable aquatic organisms for future generations without losing the need for short-term profits to support communities recovering from the war. The Fisheries Department noticed that illegal fishing methods have increased in the fishery industry of Sri Lanka.

According to Kumara Withana, Legal Officer of the Fisheries Department in 2010, 211 cases of illegal fishing were recorded. Along with the methods outlined above, operating as a fisher without a license is also illegal.

The Fisheries Aquatic Resource Act No. 2 (1996) as amended by the Fisheries and Aquatic resource (Amendment) Act No. 4 (2004) and the Fauna and Flora Ordinance (DATE) have prohibited five fishing methods in Sri Lankan waters: 1) use of push nets for fishing, 2) harpooning of marine mammals, like dolphins, dugong and whales, 3) fishing with moxi and trammel nets, 4) fishing with gill nets in coral reefs or rocky areas, 5) monofilament nets use.

Not only does the Fisheries Act define prohibited fishing modes, but it also very clearly states that "no person shall use or attempt to use any poisonous explosives like dynamite or stupefying substance or other noxious or harmful material or substance in Sri Lankan waters for the purpose of poisoning, killing, stunning, disabling any fish or other aquatic resources".

The Fisheries and Aquatic Resources Department of the Fisheries Ministry, as the regulatory and implementing agency of the Fisheries Act, has empowered the Fisheries Inspectors (operating under Fisheries Directors in 14 Districts) to take action against illegal fishing methods.

MATERIAL AND METHODS

This study took a mixed-methods approach to data collection. Primary data was gathered using direct observation, focus group discussions and interviews amongst the affected fishers and their communities. Some data was recorded using a video camera. Secondary data were collected from the relevant institutions, such as DFEO's office and Fishermen co-operative societies', reports from January 2012 to December 2013. The primary and secondary data were analyzed using descriptive statistical analysis (mention any software used, or that it was coded and analyzed by hand).

Description of the project area

The study area is located in the Mannar District, and encompassed Mannar Island. It is an area surrounded by rich fishing areas. Most of the productive fishing grounds lie in Palk Bay and the Gulf of Mannar. When compared with other parts of Sri Lanka, the sea of Mannar has a remarkable marine environment suitable for fishing, with a marine coast line stretching 163 km, from Thevanpiddy in the north to Mullikulam in the south. Encircling Mannar Island is a shallow continental shelf with rich fishing banks, pearl banks and prawn banks as well as an extensive area (3,828 ha) of brackish water and mangroves.

Fishing is a major contributor to the economy of Mannar District with 38% of its population involved in fishery. As of August 2010, 28,852 people in the Mannar District, belonging to 7,813 families, are dependent on the marine fishery sector. Of these 7,547 are listed as active fishers. Mannar District is comprised of six Fisheries Inspector Divisions (FID) covering 38 fishing villages (Fig. 1).

Palk Bay and the Gulf of Mannar coastal waters (including the continental shelf) contain a variety of species of fin-fish, shell fish and holothurians.

The total catch of fin-fish, crustaceans, echinoderms and molluscs (including chanks and cephalopods) in Mannar district for 2008 and 2009 was 5,735 MT and 6,528 MT, respectively. Shallow water species include silver bellies, bream, prawns, rabbit fish, mullet fish and squid. Large pelagic fish such as seer, rock fish, mackerel and sardine are also caught in addition to prawns and crabs.

The coastal lagoon is a shallow, tidal flat area between Mannar Island and the mainland, which holds various pelagic and demersal shore species. This diversity of marine environment with rich fish resources has been the basis for a long and strong tradition of lagoon, coastal and offshore fishing as well as collecting of marine products such as sea cucumber and chank by diving.

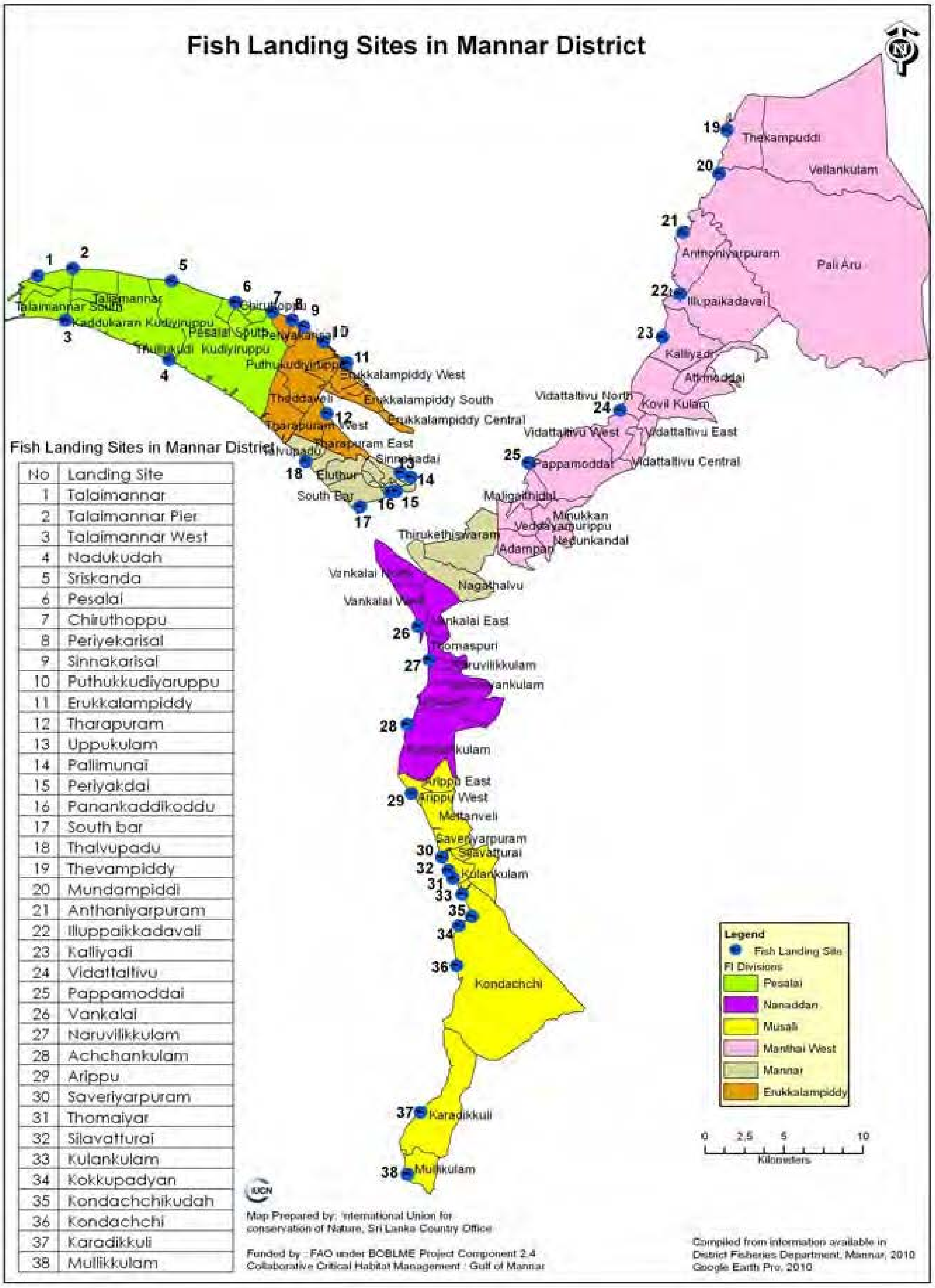

Figure 1: Fish landing sites in Mannar District.

The landing site survey revealed that trawling is practiced exclusively in Pesalai, while gill nets, drift nets, crab nets and bottom set nets are used in all areas. Multi-hook lines targeting cuttlefish are used in Pallimunai and Vankalai, and beach seine fishery is mostly carried out in three centres at Vankalai, Thalaimannar Pier, and Nadukudah, and two centres at Pallimunai and Panankaddikoodu. More than 200 stake nets (Ja-kotu) were observed in Pappamoddai while 100-200 are operated from the Erukkalampiddy, Pallimunai and Panankaddikoodu. In addition to the above, brush piles targeting squids and cuttlefish are used in Silavatturai, Vankalai, Thalvupadu and Pesalai. Sea cucumber, oysters and gastropods (e.g. conch) are caught by skin diving/hand picking. Encircling nets (Surukku nets and Laila nets), Moxi nets and push nets and other harmful fishing methods such as dynamiting and harpooning were banned island-wide long ago, but the ban has not been enforced in the Mannar District.

Objectives of the Research

This study has three objectives: first, to identify the areas in which illegal fishing methods are used; second, to identify the major threats and their social, economic and ecological impacts on the fishing industry; and finally, to devise appropriate solutions to these threats.

RESULTS AND DISCUSSION

Destructive fishing practices

As a precautionary measure, the Department Fisheries, Mannar, has, since 2010, strictly prohibited the aforementioned illegal fishing methods, including improvised fishing gear such as tree logs, concrete logs, stones, car bodies, monofilament nets and tree branches for cuttlefish (squid) fishing in the district (ADF-Mannar).

The following destructive fishing practices which are known to have an impact on the fishery resources were observed during the study:

- Dynamiting – legally banned, but still taking place between Pallimunai to Thavulpadu.
- Large stake net – is being used from South bar to Vankalai covering 10 km^2 area. The Mannar court strictly ordered in 2013 that it cannot be used in this area.
- Trawling – This is presently limited to Pesalai.
- Monofilament nets (Thangus) – were being used in almost every landing site, but reinforcement of the ban from third October 2010 is in place.
- Brush piles and multi-hook artificial bait for cuttlefish were being used in two of the 14 landing sites surveyed: Pallimunai and Vankalai.
- Surukku nets (Purse seine or ring nets) – banned from third October 2010, but still being used in some areas (e.g. Thalvupadu Pappamoddai).
- SCUBA diving to collect sea cucumber and conch – banned in GoM, but fishermen from Kalpitiya still collect them in this way from Silavatturai.
- Uncontrolled exploitation collection of holothurians (sea cucumber), gastropods (conch) and bivalves (oysters) without permission or without conforming to the conditions of the permit, especially on recommended sizes.

Methods of fishing and their impacts

1. Dynamite fishing:

Using dynamite requires dynamite paste (ball shaped), a cap and a cord which is used for lighting the explosive. A stick of dynamite including a detonator (aluminium cap cord) costs Rs. 1,000.

Usually three to four sticks are pasted together for one blast and kills fish within an area of six m^3. The length of the cord is changed according to the distance and the depth of the blast, and the volume of the dynamite (two, three or four sticks) is determined by the size of the school of fish.

The man who ignites the fuse smokes a cigar or beedi. When a shoal of fish is sighted, he lights the fuse rod with the cigar or beedi, and throws it from the boat. The dynamite explodes violently, splashing the water more than 10 meters high. Soon after the explosion, dead fish can be seen floating and the fishermen jump into the water to collect them.

The use of explosives for blast fishing has been around for centuries and it is increasing. Explosions can produce very large craters, devastating between 10 and 20 square meters of the sea floor. They kill not only the target fish, but all the other surrounding fauna and flora. In coral reefs, reconstruction of the damaged habitats can take decades. Explosives are easily and cheaply purchased and often come from the mining or building industries. In many regions, explosives are extracted from old munitions from past wars or current conflicts. Elsewhere, fishermen buy them through the illegal arms trade.

Adverse effects due to the use of dynamite are witnessed in the southern part of the Gulf of Mannar. One novel illicit fishing method that developed from traditional dynamite fishing have been devised and carried out for the last fifty years by some fishermen from the neighbouring areas such as Panankattikottu and Pallimunai. Locally available cost-free discarded materials like concrete pillars, car bodies, parts of damaged boats, wooden logs, etc., are built into a structure, which is then dropped onto the sea bed. The location of the structure is marked and targeted with dynamite. Through this indigenously invented method fishing is carried out.

Once a fisherman throws dynamite in the sea there is a great probability that it might hit a coral reef. Coral reefs serve as a breeding place and gives protection to the juvenile fish. So, if the remaining coral reefs are destroyed there is a strong likelihood that fishing opportunities will be reduced, and that long-term, fishers are likely to have reduced catches and thus lose their livelihood. Within the study area, coral reefs that were historically visible above the sea surface (including Arippu, Vankalai and Silavaturai reefs) have been destroyed recently due to the use of dynamite.

In addition to these direct effects on the sea bottom, dynamite fishing, and the associated building activities to replace coral reefs, also causes a detrimental impact on the coastal and littoral environment, by driving the destruction of mangrove forest in the coastal area of Vankalai. Lots of mangrove tree logs were removed in July 2014 at Vankalai Sea (Fig. 2).

Figure 2: Mangrove tree logs removed in 2014 in the coastal area of Vankalai.

As a result of their intricate entangled above-ground root systems, mangrove communities protect shorelines during storm events by absorbing wave energy and reducing the velocity of water passing through the root barrier. Mangrove-covered shorelines are less likely to erode, or will erode significantly more slowly, than unvegetated shorelines during periods of high wave energy. Protecting mangroves sustains natural protection, and is less expensive than seawalls and similar erosion control structures, which can increase erosion in front of the structure and at adjacent properties.

Another impact of dynamite fishing is that drift nets used by small scale fishermen are also destroyed. Yet another negative consequence of dynamite fishing is the direct personal risk to the user – within the study area, several local fishermen have been maimed by explosions of dynamite, losing their livelihood (Fig. 3).

Figure 3: Injured fishermen by dynamiting.

In terms of impact on the larger animals in the area, dynamite fishing can affect endangered marine species such as the dolphin and dugong, which have been killed in the study area. Dugongs aged between 20 to 30 years old and weighing around 545 kg have been killed in Mannar, indicating a serious loss to the population. The corpses were confiscated by the NARA National Aquatic Resources and Development Agency, and displayed them on public at the Sri Lankan national museum on 31st December (Fig. 4).

From the above information, it is clear that dynamite fishing is both widely used in the study area despite legal obligations to stop, and that it causes significant ecological, marine, coastal and social damage.

Figure 4: Dugong killed by the dynamite in Mannar Sea (Chamikara, 2010).

Large Stake nets

The second illegal fishing method that I shall discuss in this paper is the Large Stake net or pound net. Before describing the net, I would like to note that, in my opinion, the modern type of stake net or wing net demands serious and immediate attention of the government.

A stake net is a fixed fishing device that consists of poles or stakes secured into the sea bed, with the sides covered with netting. The structure includes a pound or chamber with a netting floor, a heart, or wing and a straight wall or leader or fencing net (Figs. 5 and 6). Large Stake nets are generally set close to shore and the leader is set perpendicular to the shore to guide migrating fish into the pound.

The stake net has a long tradition in the Northern Province, but its use has always been limited to the lagoon side, its size has been limited, and only wooden poles were used.

The modern type of stake net has developed only following the recent civil war, and is significantly different (Figs. 5 and 6). Set stake nets nets are large stationary fishing gear which is set in one to 15 m depth in the migratory path of the target species in order to guide them in to trapping enclosures.

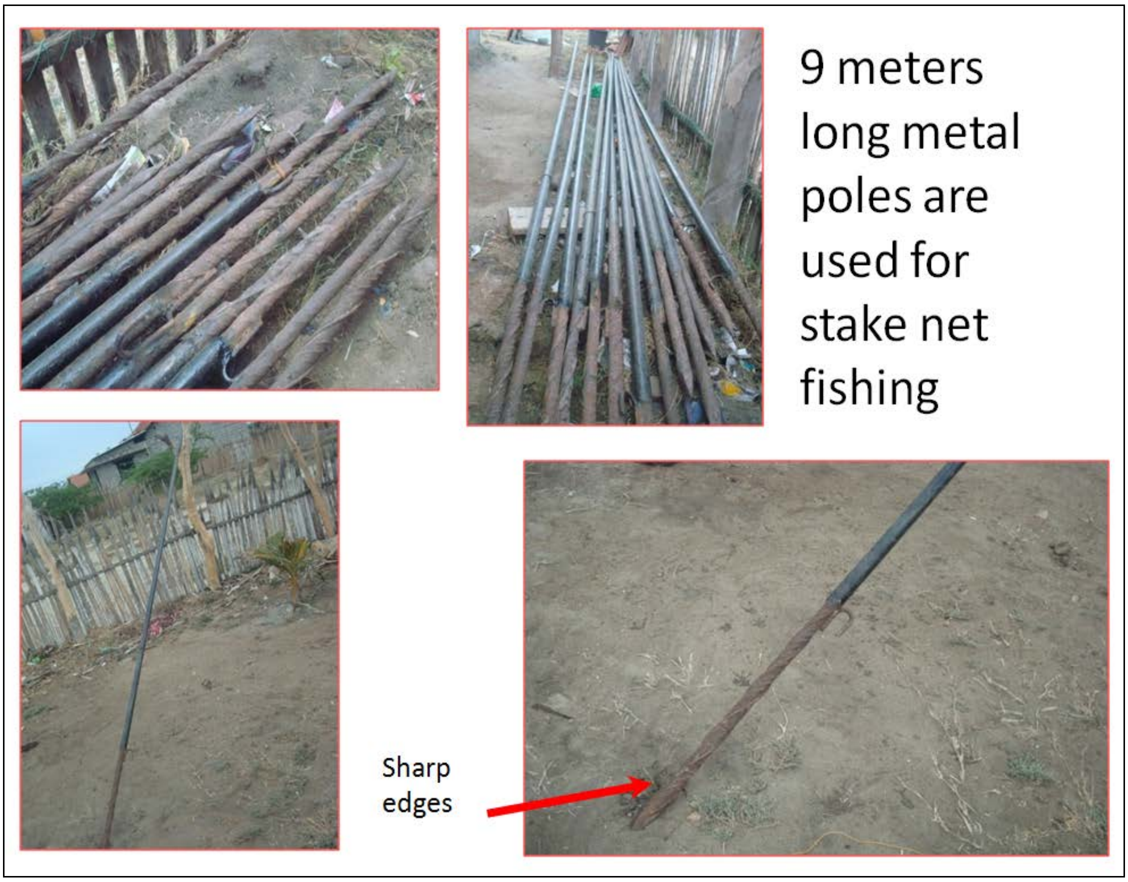

Figure 5: Stake net fishing construction.

Figure 6: Stake net fishing in ocean.

This stake net is like a large fence in the sea, consisting of 20 to 50 pieces of nine m galvanised iron poles (very sharp), to which the enormous nets are fixed in a stretch of about 50 m. Disappointingly, in Southern Mannar, this modern net is increasingly popular. Hundreds of these nets have been placed recently, as a whole about ten kilometres of sea is fenced in this fashion from the South Bar beach up to Vankalai Coral Reefs, with small scale fishermen and beach seiners becoming increasingly obstructed by this new illegal and dangerous fishing method.

This new netting method has the following implications:

Ecological Impact

- Marine resources, including the Vankalai and Arippu coral reefs and other marine organisms of the sea bed, have been destroyed by the use of heavy metal poles;
- Practically all schools of fish coming from the north of Talaimannar get caught in these nets, significantly restricting the movement of fish towards the shore;
- Fishermen using fibreglass boats find it very difficult to observe and avoid the protruding metal poles, especially in the dark, an issue because the poles will readily make a hole in the boats should they come into contact. A number of boats have already been damaged this way, threatening the fisher’s livelihood;
- Beach seining is an important mean of livelihood for thousands of people in Southern Mannar. Due to the current presence of the wing nets, however, around 100 fishing families depend on beach seine production and 1,000 fishermen have been affected as all fish are fenced off by these wing nets.

The use of this method provides a few people with enormous yields, while leaving others without fish, triggering a serious increase in clashes within and between communities.

As this type of nets are highly capital intensive, the fishermen involved (Pallimunai and Panamkattikottu) will not be happy to see their activities restricted and their large interests being at stake. Of course, the fishermen from these areas have only succeeded in the instalment and operation of these wing nets with the use of powerful political supporters.

Nevertheless, for the benefit of the Mannar fishing community at large, the use of this wing net should be stopped and prohibited as soon as possible. In 2013, the government announced a list of dangerous and banned fishing methods (Notice board in ADF office Mannar, by Ministry of Fisheries). Considering the above, it may be considered that the wing net is an unacceptable type of gear, against which measures need to be taken urgently to avoid further destructions and communal clashes.

Some of the victims affected by the use of metal nets have complained to the police about it. The police brought the issue to the Mannar magistrate court, through ADF/Mannar. Subsequent to investigations, the Magistrate court, Mannar issued orders for the restriction of the use of metal nets in such areas. Unfortunately the court order has not been honoured.

Bottom Trawling

This method has been banned by the ADF in Mannar since 2010, however this study has found that in Pesalai and Pallimunai fishermen are still using this method, and also that over 2,500 Indian trawlers have been observed in the Gulf of Mannar and Palk Bay region.

Trawlers destroy the sea bed in the north and south of Mannar three days a week, sweeping the bottom of the sea. Aquatic creatures are swept away by this kind of trawl net fishing, affecting the catch of non-trawl fishing methods. In addition, trawlers destroy the drift nets of local fishermen and can serious damage small boats and nets. This mostly occurs at night, when trawl boats fail to observe the long, and invisible gillnets most commonly deployed by local fishers. This results in an annual missed income of approximately six million LKR (Sri Lankan Rupees), or 40,000 LKR per fisherman, which constitutes in general about 20% of a fishermen's annual revenue (Scholtens et al., 2012).

Other measurable impacts include: local fishermen lose their valuable fishing gear, restricting them to fewer days of fishing and a much reduced income as a result; the shrimps that are the main target of bottom trawling are sourced from Sri Lankan waters but caught and processed by international boats, losing Sri Lanka Rs. 4-7 billion annually in lost prawn sales. Sri Lanka loses an estimated US$ 750 million annually to Indian poachers, affecting around 50,000 Sri Lankan fisher families.

Figure 7: Gill Nets which were damaged by Tree Logs.

By-catch is also an issue with the very unselective bottom-trawling method: many species, including those at risk of extinction, are accidentally caught and then thrown back into the sea, often already dead. These collateral losses, known as discards, can reach up to 56-60% of the total catch. (Kayalvili, 2014)

In an interview with the author, the Minister of Fisheries and Aquatic Resources Development, Dr. Rajitha Senaratne, said “The fishermen of the Northern Province of our country have started their fishing activities again after the war. They never cross the Indian borders for fishing. They do their fishing within their limits in the North. But when Tamil Nadu fishermen come in thousands of huge crafts and carry on fishing according to bottom trawling method, Northern Fishermen have no place left for their fishing. This bottom trawling method of fishing they are using is banned in our country. This method of fishing has also been banned by the world food and Agriculture Organization and by the Indian Ocean Tuna Commission (IOTC). Because of this method of fishing the bottom of our northern sea and the marine environment get completely destroyed. In future it is possible there will be no fish left in the North”.

Why the law is not being implemented

According to the Sunday Times, officials are not yet aware of the economic losses that occur when blast fishing is carried out and there are many loopholes in the existing law. As a conservationist observed in an interview, the police are expected to catch the culprits with the goods and that is difficult because the blast fishermen are in a boat out at a sea, so even if the police do get a tip-off it is difficult to reach and apprehend the culprits. The interviewee went on to say that there is also no coastguard equipped to support any police action with necessary facilities (boats, binoculars, blast detecting equipment) and no police or coastguard officials with necessary qualifications such as swimming, diving and battle training.

Another conservationist commented during an interview that the cost of enforcing the law is high and enforcement officers do not have a proper knowledge on existing rules and regulations. They also noted that political influence has played a part in the non-implementation of such enforcing units.

"Like in other fields what we need are experts who have mandate to give an authoritative report on blast-fishing that courts can use. Like judicial Medical officers (JMOs), these experts, of course with knowledge of the internal anatomy of a fish, such as fisheries biologists from NARA and the universities should be given that mandate".

Figure 8: Damaged gills net by trawling.

CONCLUSIONS

This study has reinforced our understanding of the detrimental impacts of certain, illegal fishing methods in Sri Lanka. When fishing techniques have been universally recognized as destructive, the only solution is to ban them. Anyone continuing to use these techniques must be severely punished.

The Fisheries and Aquatic Resource Department of the Fisheries Ministry as the regulatory and implementing agency of the Fisheries Act No. 2 (1996) and the Amendment No. 4 (2004), has empowered the Fisheries Inspectors in 14 districts to take action against such illegal fishing net. Regulations are in place, but are yet to be implemented.

According to Kumari Withana, Legal Officer of the Fisheries Department, Chapter IV of the Fisheries Act very clearly deals with the conservation of aquatic resource. The section 27 of the Fisheries Act says that “no explosive or poisonous device can be used or kept in the Sri Lankan waters. The Act has permitted the magistrate courts to impose Rs. 100,000 fine or three years to five years prison term for those who are using explosives for fishing purposes”. The interviews and observations presented here support this comment, and note in particular that a lack of knowledge about, and support for, the enforcement of the low, is probably the major factor in a lack of implementation of the Fisheries Act, and the ongoing damage to fishery resources.

The cost of enforcing the law is high and enforcement officers do not have proper knowledge on existing rules and regulations, said another conservationist adding that political influence has played a part in the non-implementation of such enforcing units.

It is recommended that an awareness program should be organized to enlighten the net users of the negative consequences of the use of such nets. Regulations should be enforced, as a joint effort between the Fisheries Department, security forces and fisheries societies, for example by organizing an awareness program among the different users of marine resources in the affected area.

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EFFECT OF INDUSTRIAL WASTEWATER ON FISH IN KAROON RIVER

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KEYWORDS: Industrial wastewater, fish, Karoon River.

ABSTRACT

In 2009, 36 fish were sampled from two stations in the Karoon River near an industrial site. Two species of fish, *Barbus grypus* and *Hypophthalmichthys molitrix* were analyzed for total mercury (Hg) concentration in liver and muscle tissues. The average concentrations of total Hg in liver of *B. grypus* were 18.92 and 10.19 $\mu g.g^{-1}$ in stations 1 and 2 respectively. The corresponding values for total Hg in edible muscle of *Barbus grypus* were 8.47 and 0.08 $\mu g.g^{-1}$. The average concentrations of Hg in the liver of *H. molitrix* were 25.49 and 12.52 $\mu g.g^{-1}$ in stations 1 and 2 respectively. The values for *H. molitrix* were 11.88 and 3.2 $\mu g.g^{-1}$ in station 1 and station 2 respectively. The results showed that the bioavailability of Hg has increased considerably after industrialization and that these values were higher than the standard values as a result of anthropogenic activities in the region.

ZUSAMMENFASSUNG: Auswirkungen von Industrie-Abwässern auf die Fische im Karoon-Fluss.

Während des Jahres 2009 wurden 36 Fischarten von zwei Standorten im Karoon-Fluss nahe der Industrieanlage erfasst. Zwei Arten *Barbus grypus* und *Hypophthalmichthys molitrix* wurden im Hinblick auf die Gesamtkonzentration von Quecksilber in Leber und Muskeln untersucht. Die durchschnittliche Konzentration des Gesamt-Quecksilbers in der Leber von *B. grypus*betrug 18.92 $\mu g.g^{-1}$ an Probestelle 1, beziehungsweise 10.19 $\mu g.g^{-1}$ an Probestelle 2. Die entsprechenden Werte für das Gesamtquecksilber in essbaren Muskeln von *Barbus grypus* waren 8.47 and 0.08 $\mu g.g^{-1}$. Die durchschnittliche Konzentration von Quecksilber in der Leber von *H. molitrix* betrug 25.49 $\mu g.g^{-1}$ am Porbestandort 1 und 12.52 $\mu g.g^{-1}$ am Probestandort 2, während die Werte in essbaren Muskeln der Art 11.88 $\mu g.g^{-1}$ an Probestelle 1 und 3.2 $\mu g.g^{-1}$ an Probestelle 2 betrugen. Die Ergebnisse zeigen, dass die biologische Verfügbarkeit nach der Industrialisierung beachtlich angestiegen ist und dass diese Werte bedingt durch die anthropogenen Tätigkeiten in der Region höher liegen als die Standardwerte.

REZUMAT: Efectul apelor industriale uzate asupra peştilor din râul Karoon.

În 2009, 36 de probe de pești au fost recoltate din două stații ale râului Karoon în apropierea zonei industriale. Două specii de *Barbus grypus* și *Hypophthalmichthys molitrix* au fost analizate în ceea ce privește concentrația totală de Hg din ficat și mușchi. Concentrația medie de Hg în ficatul speciei *B. grypus* a fost 18,92 și 10,19 $\mu g.g^{-1}$ în stația 1 și respectiv 2. Valorile corespondente de Hg, pentru această specie, în mușchi au fost 8,47 și 0,08 $\mu g.g^{-1}$. Concentrația medie de Hg în ficatul speciei *H. molitrix* a fost 25,49 și 12,52 $\mu g.g^{-}$ în stația 1 și respectiv 2. În ceea ce privește specia *H. molitrix* valorile înregistrate au fost de 11,88 $\mu g.g^{-1}$ în stația 1 și 3,2 $\mu g.g^{-1}$ în stația 2. Rezultatele au arătat că biodisponibilitatea elementului Hg a crescut considerabil după industrializare, aceste valori fiind mai ridicate decât valorile standard datorită nivelului ridicat de activitate antropică din zonă.

INTRODUCTION

Heavy metals such as mercury (Hg) are natural trace components of the aquatic environment. They cause serious alterations in metabolic, physiological and structural systems of living organisms when present in high concentration (Iliopoulou and Kotsanis, 2001), and induced health risks in sea food (Khoshnood and Khoshnood, 2013). Coastal fish species such as flat fish have been proposed as sentinel species to assess the possible effect of anthropogenic activities on a coastal area and for monitoring marine environment pollution (Eastwood and Couture, 2002), because fish are often at the top of the aquatic food chain and may concentrate large amounts of some metals from water (Mansour and Sidky, 2002). Tissues such as liver, kidney, muscles, viscera and whole organisms are typically analyzed to determine the concentration of the metals (Olifa et al., 2004).

In some cases, fish catches have been banned for human consumption because their total mercury content exceeded the maximum limits recommended by the Food and Agriculture/World Health Organization (Emami Khansari et al., 2005; FAO/WHO, 1972). Human sources of mercury include industrial wastewater, use of fossil fuels, fungicides and burning of waste (Hernandez et al., 1999).

Pollution studies in the Persian Gulf area collectively known as ROPME Sea Area (RSA) are extremely important. The Persian Gulf is relatively shallow, semi-enclosed with very high evaporation rates and is characterised by low flushing of waters (Mora et al., 2004a). Thus, any pollution discharge into the sea has limited opportunity for dilution and disperses more slowly than in other, more open marine systems (Shepperd, 1993). Moreover, the region relies heavily upon the seawater itself as a source of freshwater through desalination processes (Mora et al., 2004a).

Ongoing industrial development in the region, albeit geographically variable, continues to cause concern with respect to marine environmental quality. Unfortunately, regional information on heavy metal presence is not uniformly available. Agriculture, mostly located in the northern zone, is expanding in the region, bringing a threatened increase of emissions of pesticides and other agrochemicals, including heavy metal-based formulations (Fowler et al., 2002).

This study is a response to the to the lack of any comprehensive data on the Hg content of fish from this part of the Persian Gulf, and the considerable global concern about mercury contamination of commercial and subsistence fisheries products. In this paper, we will describe a new mercury analytical method that is a rapid and reliable technique, requiring minimum analysis time, and which is suitable for the routine analysis of large numbers of fish samples. The proposed method offers a fast and simple approach to sample digestion, dilution, and mercury determination for low concentrations in fish. In this study, the technique is applied for the first time in this region.

The aim of this study is to develop a rapid method for bio-monitoring studies of heavy metal pollution in the marine environment, in particular, to determine the total content of Hg in fish collected from various sampling points of the Persian Gulf, since these fish are an important component of the human diet in these regions.

It is hoped that the results of this study will help scientists generate data needed for the assessment of mercury intake from fish. Such data will be needed for the development of public health advisory guidelines on consumption.

MATERIAL AND METHODS

Selection of the study area and sample collection

Fish samples were collected along two stretches of the Karoon River, in the southwest of Iran. Thirty-six fish specimens including *Barbus grypus* and *Hypophthalmichthys molitrix* were caught from April to June 2009. These two species were collected from two sample sites, one a wastewater discharge location (station 1) and the other about two kilometres upstream of a wastewater discharge location along the Karoon River (station 2).

Analysis Procedure

Immediately after the collection, fish samples were stored on ice in an isolated box (Eaton et al., 1995) and transferred to the Environmental Laboratory. Body weight and length of the fish were measured and the sex was determined. Male fish were then selected and a part of the dorsal muscle from each was dissected as a sample. The fish liver tissue was also removed and prepared for processing. All of the samples were dried at 600°C for 48 h in an oven (Gregory et al., 2005).

Total mercury was measured using an LECO AMA254 Advanced Mercury Analyzer (USA) according to ASTM, standard no. D-6722. Each sample was analyzed three times. The LECO AMA 254 is a unique Atomic Absorption Spectrometer (AAS) that is specifically designed to determine total mercury content in various solids and certain liquids without sample pre-treatment. Designed with a front-end combustion tube that is ideal for the decomposition of matrices, the instrument's operation may be divided into three phases during any given analysis: decomposition, collection, and detection.

To assess the analytical capability of the proposed methodology, accuracy of total Hg analysis was tested with reference matrices of dogfish liver tissue (DOLT 3), and muscle tissues (DORM 2). The results confirmed that the observed and reference values were not statistically different ($P < 0.05$) (Tab. 1).

Table 1: Obtained and certified concentration ($\mu g.g^{-1}$ dry weight) in certified reference materials.

CRM		HG
DORM-1	Certified	0.789 ± 0.074
	Obtained	0.0791 ± 0.027
DORM-2	Certified	4.64 ± 0.26
	Obtained	4.60 ± 0.22

Statistical analysis:

The statistical analyses were done using SPSS software (Version 11.5). The data were tested to check the normality using the Kolmogorov-Smirnov test, which showed that they are normally distributed. Pearson's correlation test was used to assess any significant relationship of concentration in tissue with fish length and weight in the two regions studied (level of significance, ($p < 0.05$)). In addition, paired sample t-tests were used to compare mercury concentration between stations.

RESULTS AND DISCUSSION

Weight, Length and Sex

The length of *Barbus grypus* individuals caught from station 1 were within the interval range of 24.5-36.5 cm; and from station 2 were between 24-41 cm. Results for *Hypophthalmichthys molitrix,* in station 1 showed a range length of 39 to 58 cm and in station 2 lengths ranged between 31.5-51 cm.

All of the fish sampled in this study were male. The average measured size and weight of each sample are given below (Tab. 2).

Table 2: Fish sample biometry measurements; * 1 = below discharge point, ** ST2 = above discharge point.

Species	Station	No. of samples	Length (cm)		Weight (g)	
			Range	Mean ± Std	Range	Mean ± Std
B. grypus	1*	6	24.5-36.5	32.3 ± 4.2	240-710	585 ± 186
	2**	6	24-41	32.1 ± 6.3	209-1,010	604 ± 302
H. molitrix	1	6	39-58	48.1 ± 7.5	754-2,650	1,672 ± 760
	2	6	31.5-51	43.0 ± 6.9	497-2,286	1,309 ± 649

Total mercury concentration in Muscle and Liver

Table 3 presents the concentration range, mean and standard deviation of mercury based on dry weight (µg.g^{-1}) in muscle and liver of tissues from *Barbus grypus* and *Hypophthalmichthys molitrix* from the two sampling areas. The maximum mercury concentration was measured in station 1 (i.e. below the waste-water discharge point) in liver samples of *Hypophthalmichthys molitrix* (25.48 µg.g^{-1}), and the minimum concentration of mercury was noted in the muscle of *Barbus grypus* in station 2 (i.e. above discharge point) (0.08 µg.g^{-1}).

Table 3: Hg concentration of *Barbus grypus* and *Hypophthalmichthys molitrix* tissues; * St1 = Station 1, ** St2 = Station 2.

Species	tissues	Range		Mean ± std	
		St1*	St2**	St1*	St2**
B. grypus	liver	8.8-15.25	0.77-5.77	11.88 ± 2.46	3.2 ± 1.75
	muscle	5.28-14.15	0.04-2.75	8.47 ± 4.31	0.081 ± 1.02
H. molitrix	liver	16.57-31.26	4.26-19.56	25.49 ± 5.82	12.52 ± 5.41
	muscle	10.24-25.25	1.53-16.64	18.92 ± 5.99	10.19 ± 5.26

Various studies of coastal environments have shown that accumulation of Hg in several organisms varies along a concentration gradient of anthropogenic Hg (Coelho et al., 2005).

Hg concentration in samples of muscle and liver of *Barbus grypus* in the two stations were shown to be significantly different ($p < 0.05$). The same results were founded in *Hypophthalmichthys molitrix*, maybe because station 1 is an industrial region, with many large factories dealing with petrochemical, oil and gas extraction and transportation, agriculture, production and pesticides.

A significant positive correlation between body weight and length was found in all fish samples ($p < 0.01$ or $p < 0.05$) (Figs. 2-4). These relationship are in line with various studies (Branco et al., 2004; Pinho et al., 2002) that demonstrate an increase of Hg levels in muscular tissues of aquatic organisms with age, to which length is assumed to be directly related (Branco et al., 2004). For instance in figure 1 (station 1), concentration of Hg in muscle and liver shows very positive correlation at R2 0.764 for liver and R2 0.815 for muscle in *Barbus grypus*. The same relation can be seen for station 2 (Fig. 2).

Significant positive correlations were observed between body weight and Hg concentration in liver and muscle ($p < 0.05$) in the two fish species, at both stations. A significant positive correlation with body length was likewise found for Hg in liver tissues of the two species ($p < 0.01$) at both stations, and similarly, muscle also demonstrated a positive correlation for both species at both stations ($p < 0.05$).

Generally, the growth-dependent variation of trace element level (and Hg level) is known to be influenced by various factors such as metabolic rate and growth dilution of the element (Langston and Spence, 1995). The increased fish Hg concentrations demonstrated here suggest that the bioavailability of Hg has increased considerably after industrialization. This is probably the result of increased Hg methylation due to the increased concentration of dissolved organic carbon and reduced concentration of dissolved oxygen, and the discharge of Hg from petrochemical activities in these regions. Alternatively, Hg could have been released into the water, attached to suspended or dissolved organic matter, as a result of increased decomposition of organic material from flooded land. Increased decomposition in combination with a deeper water column creates anoxic conditions favouring Hg methylation. Increased methyl-Hg accumulation and biomagnifications in food webs occurs particularly in fish, as these species are often at the top of the food chain. These species are also popular for human consumption, and therefore may pose a threat to the health of populations dependent on fishing in the actual coastal zone for sustenance. It is important to create awareness of Hg health effects linked to consumption of different fish species by improving the information available to the local population.

For comparison, within this region, Hg levels have been observed to vary between 0.19 and 2.34 $\mu g.gr^{-1}$ in coastal sediments from Doha, Qatar (Al-madfa et al., 1994). The highest concentration of Hg (2,035 $\mu g.gr^{-1}$ dry or 0.49 $\mu g.gr^{-1}$ wet) in muscle was measured in a grouper from Al-Madfa in UAE, and only just approached 0.5 $\mu g.gr^{-1}$ wet weight, a level considered by many countries to be the upper acceptable limit for consumable fish, including for instance Saudi Arabia. Studies from the Persian Gulf and the Gulf of Oman in 2004 found mercury concentrations in the muscle and liver of grouper varied in the ranges 0.50-2.35 and 0.287-4.65 $\mu g.gr^{-1}$ respectively – comparable with the results presented here. Mercury is recognized as one of the most important bioaccumulated metals in fish (Mora et al., 2004b).

On the other hand, the Gulf of Trieste in Italy is exceedingly polluted due to historic cinnabar mining in the catchment region, with total Hg ranging from 0.064 to 30.38 $\mu g.g^{-1}$ and averaging 5.04 $\mu g.gr^{-1}$ (Covelli et al., 2001).

When the data from this study are compared with findings from Gaspic et al. (2002) and Kucuksezgin et al. (2002), it is notable that the present results show higher Hg concentrations in the liver compared with other body regions. Liver tissues are often recommended as the best environmental indicator of water pollution over any other fish organs. This is possibly attributed to the tendency of liver to accumulate pollutants of various kinds at higher levels from their environment.

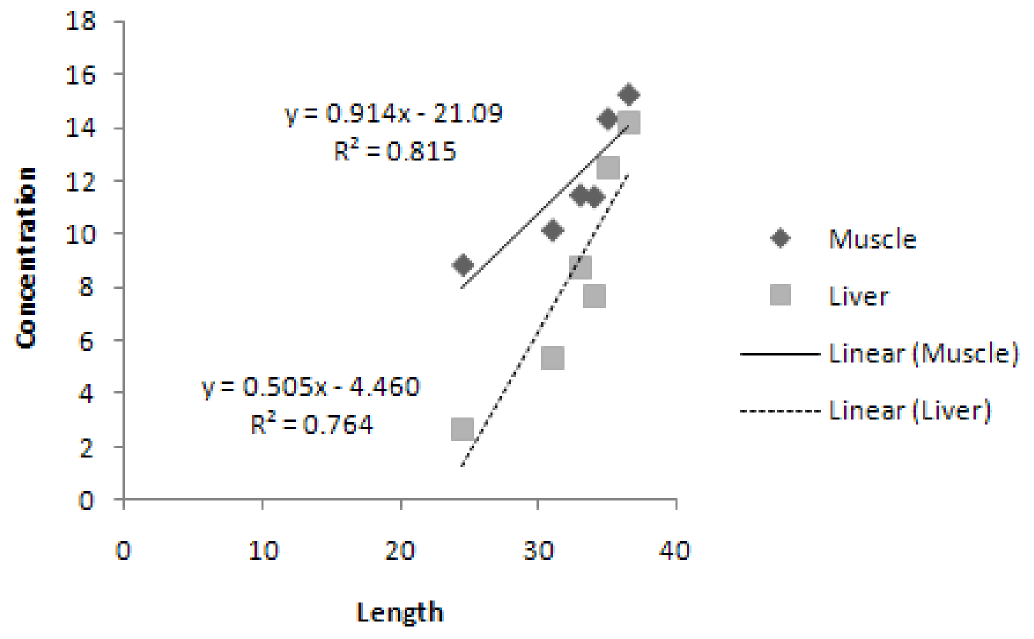

Figure 1a: Relationship between Hg concentration, length and weight on *Barbus grypus* in station 1.

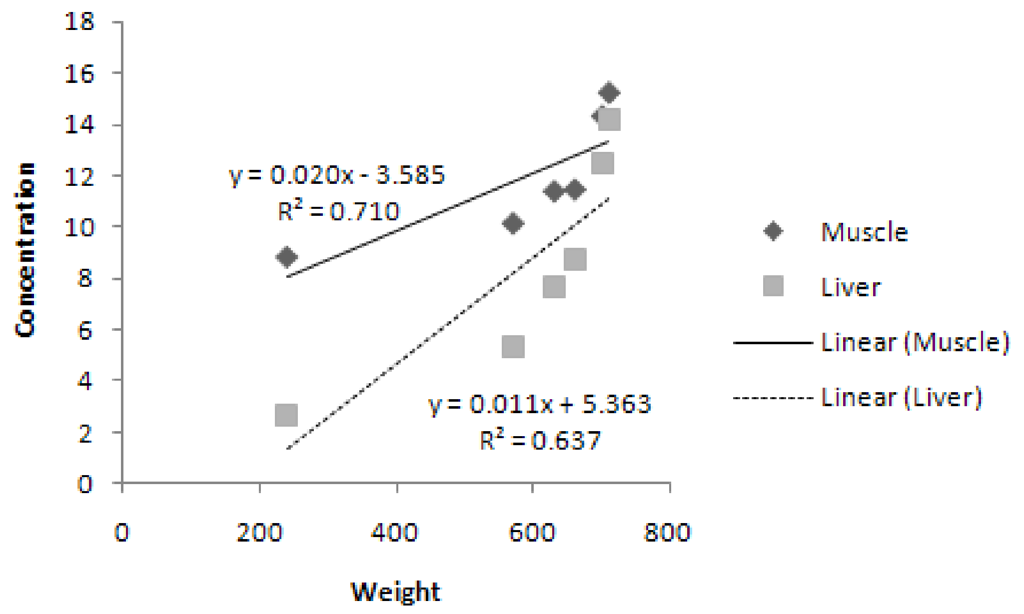

Figure 1b: Relationship between Hg concentration, length and weight on *Barbus grypus* in station 1.

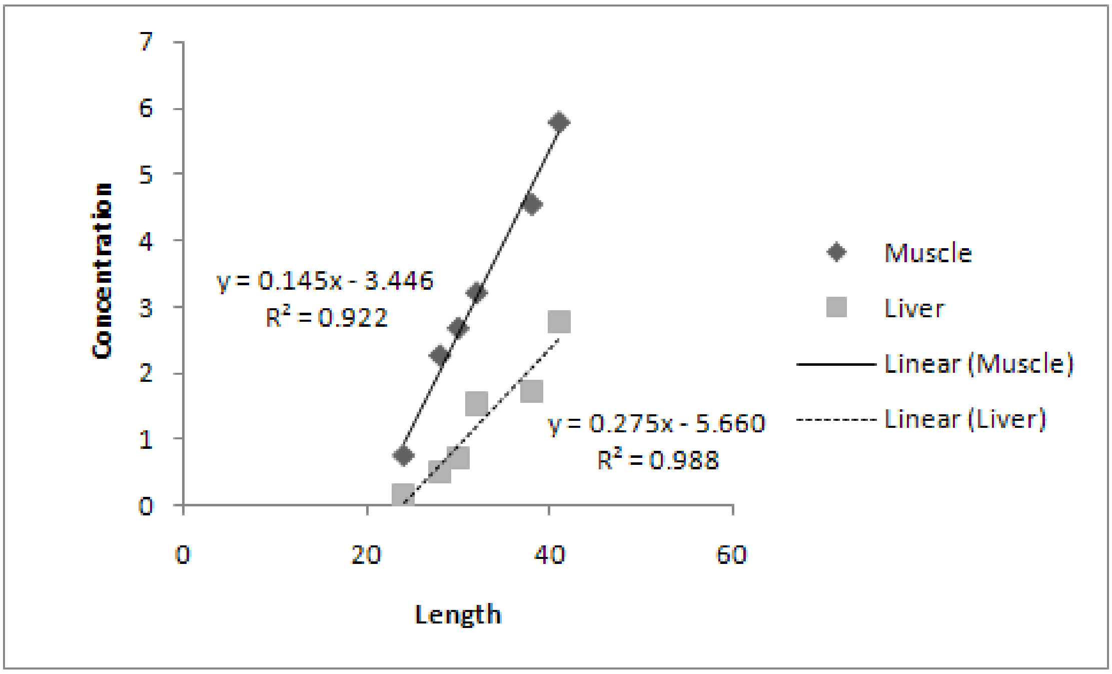

Figure 2a: Relationship between Hg concentration, length and weight in *Barbus grypus* in station 2.

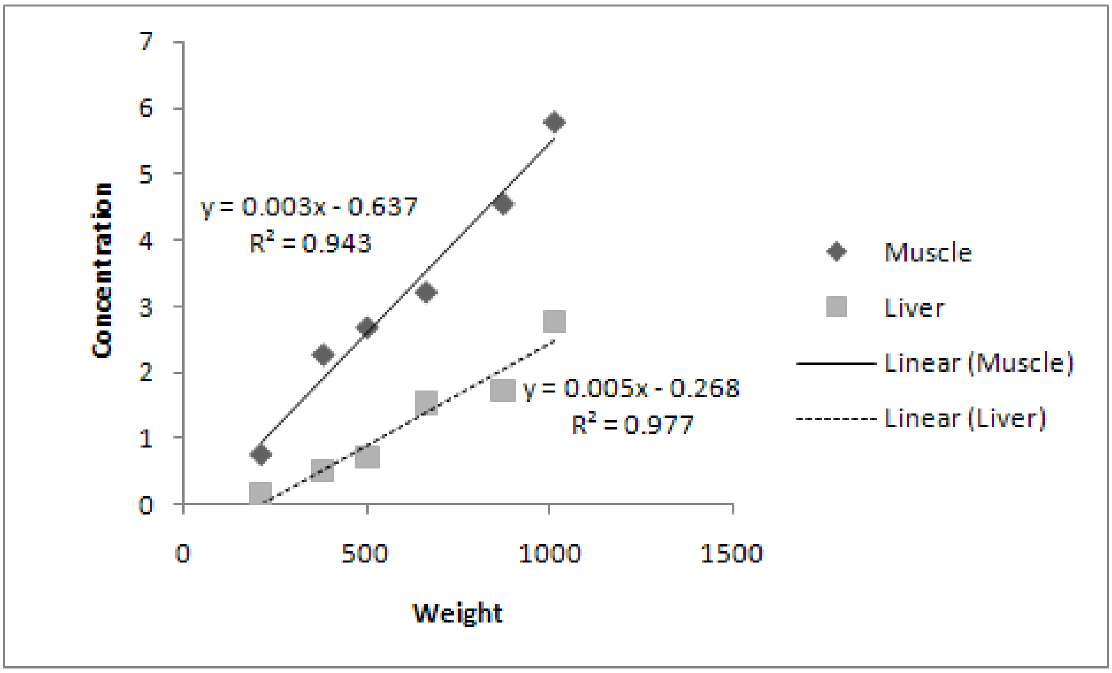

Figure 2b: Relationship between Hg concentration, length and weight in *Barbus grypus* in station 2.

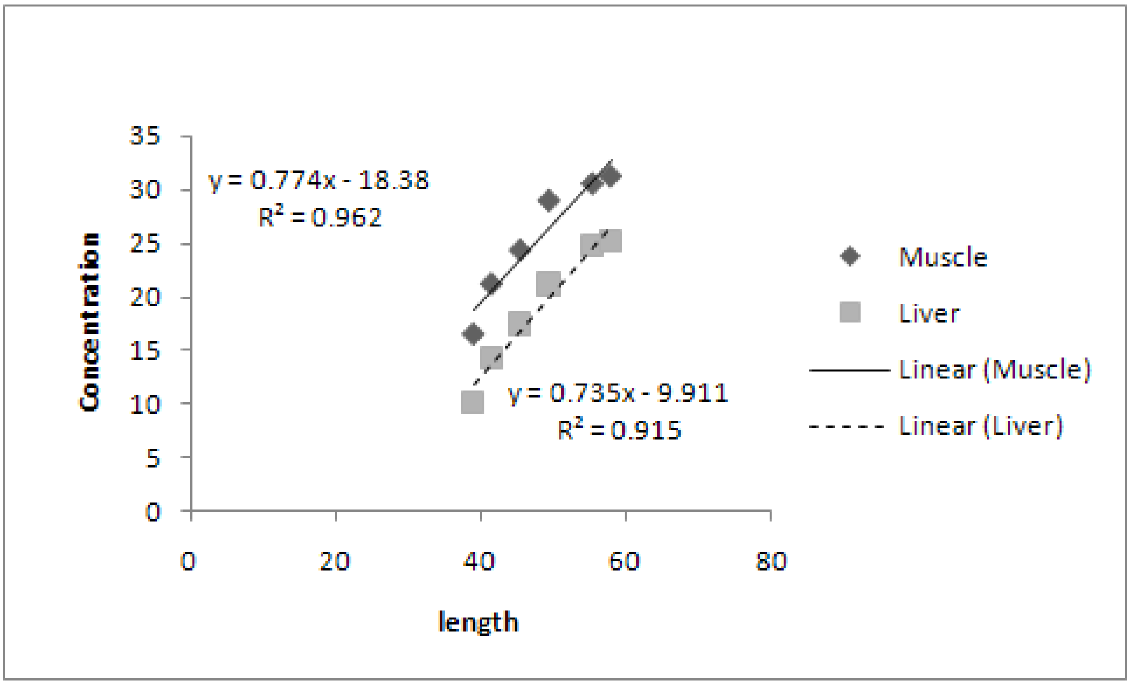

Figure 3a: relationship between Hg concentration, length and weight in *Hypophthalmichthys molitrix* in station 1.

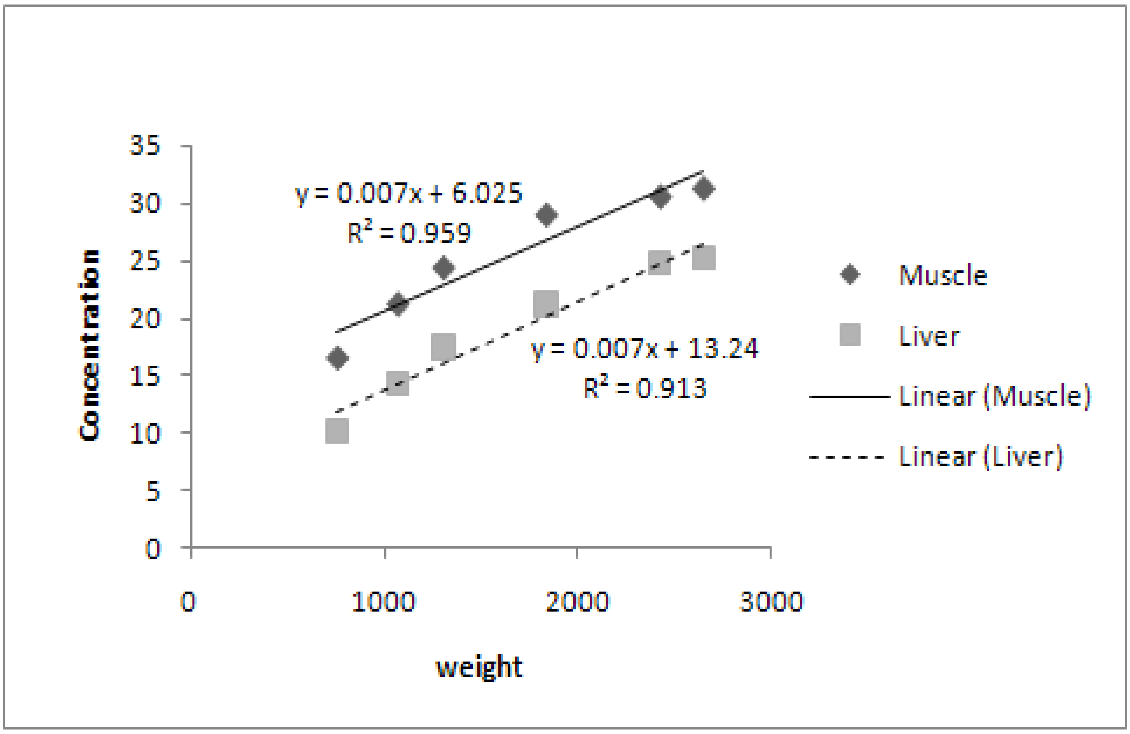

Figure 3b: relationship between Hg concentration, length and weight in *Hypophthalmichthys molitrix* in station 1.

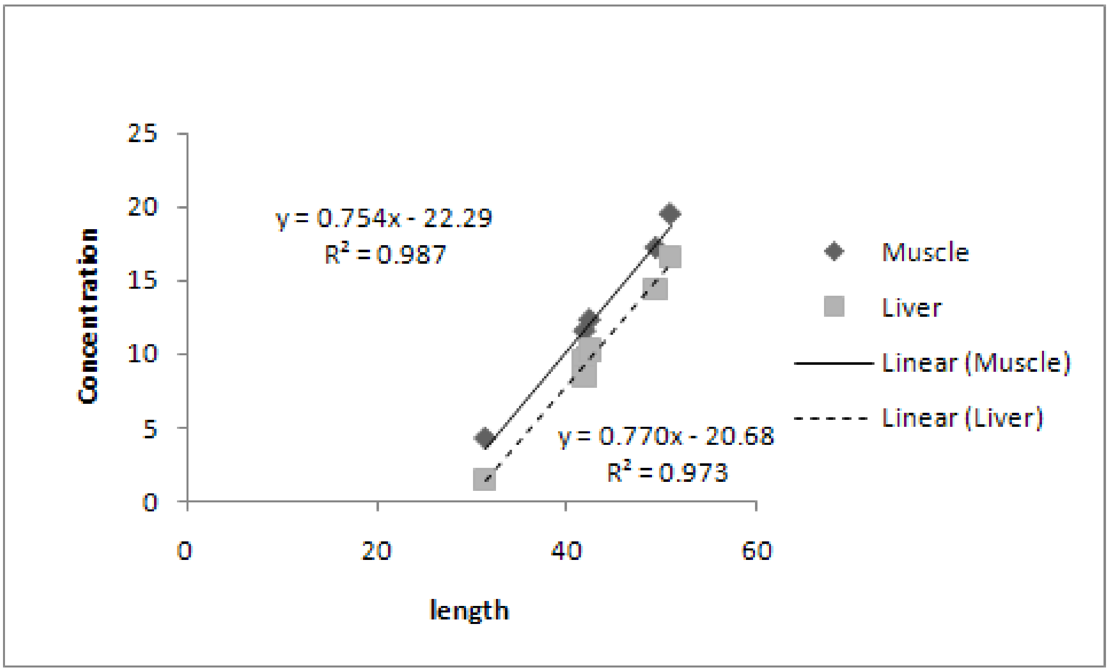

Figure 4a: Relationship between Hg concentration,
length and weight in *Hypophthalmichthys molitrix* in station 2.

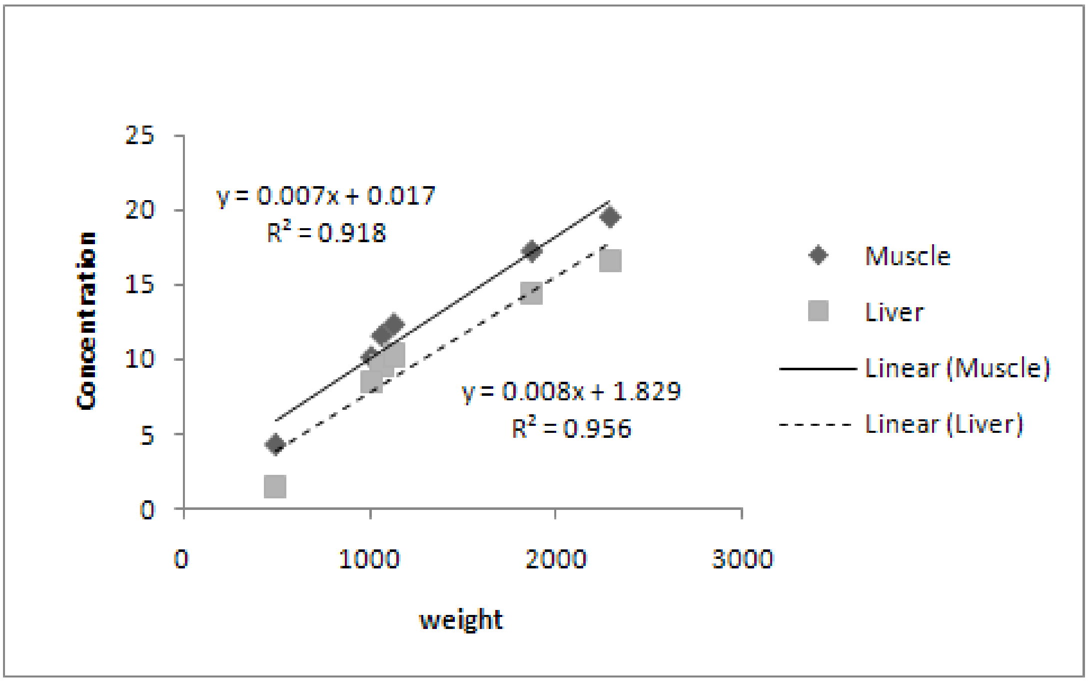

Figure 4b: Relationship between Hg concentration,
length and weight in *Hypophthalmichthys molitrix* in station 2.

Other studies on heavy metal content investigated different organ tissues of Red Pandora (*Pagellus erythrinus*) from the eastern Aegean Sea between May 1996 and July 1998, demonstrating that concentrations of mercury in muscle tissues ranged from 16 to 716 $g.kg^{-1}$, in the liver between 125-5,451 $g.kg^{-1}$, and in the gonad 2.0-1,858 $g.kg^{-1}$ (Uluturhan and Kucuksezgin, 2007).

Therefore, diets relying heavily on fish could be the main source of exposure to mercury in the general population. More have to be done on public advisory advice on fish consumption and government control of pollutants in the area.

CONCLUSIONS

The results of this study provide a basis for the assessment of human exposure to mercury from fish collected from the Kaloon River, Iran. The concentration of mercury in the fish samples observed in this study is high when compared to some other areas of the world, especially when compared to non-polluted areas of the world. The pollution observed here is the result of anthropogenic activities such as petrochemical industries, agricultural pesticides, oil extraction and transportation, and sunken ships, amongst other causes.

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THE DEMOGRAPHIC SUCCESS OF *MARSILEA QUADRIFOLIA* L. IN A MAN-MADE WATER BODY FROM DANUBE DELTA BIOSPHERE RESERVATION

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KEYWORDS: *Marsilea quadrifolia* L., Danube Delta Biosphere Reserve, demographic success, anthropogenic habitat, micro-reserve.

ABSTRACT

Marsilea quadrifolia L. (water clover) is a unique species from Romanian flora that belongs to the Marsileaceae family and is one of the most vulnerable plants in Europe due to the loss of its habitats. In this paper, the demographic evolution of a new *M. quadrifolia* population in the Danube Delta Biosphere Reserve and its natural and anthropic threats are reported. The aquatic fern, *M. quadrifolia,* has colonized a suitable man-made water body. After a decade of monitoring, the demographic trend is positive but the support capacity of habitat for the water clover remains limited in the long term. The population is vulnerable due to succession of vegetation and its vicinity with a human settlement. The establishment of a micro-reserve represents a suitable method to protect and maintain this threatened *M. quadrifolia* population.

ZUSAMMENFASSUNG: Der Ansiedlungs- und Ausbreitungserfolg von *Marsilea quadrifolia* L. in einem anthropogenen Lebensraum des Biosphärenreservats Donaudelta.

Marsilea quadrifolia L. ist die einzige Art der Familie Marsileaceae, die in der Flora Rumäniens vorkommt und aufgrund der Zerstörung ihrer natürlichen, charakteristischen Lebensräume zu den europaweit am stärksten gefährdeten Pflanzenarten gehört. In der vorliegenden Arbeit wird über den demografischen Erfolg einer Population von *M. quadrifolia* berichet, im Biosphärenreservat Donaudelta identifiziert wurde. Obwohl die demografische Entwicklung positiv ist, der langfristige Bestand des Lebensraumes begrenzt ist. Die Dauerhaftigkeit dieser Population wird sowohl von natürlichen Faktoren und anthropogenen Faktoren gefährdet. Die Einrichtung eines Mikroreservates ist eine mögliche praktische Lösung, die für den Schutz dieser Population von *M. quadrifolia* vorgeschlagen wurde.

REZUMAT: Succesul demografic al speciei *Marsilea quadrifolia* L. într-un habitat antropic din Rezervaţia Biosferei Delta Dunării.

Marsilea quadrifolia L. (trifoi cu patru foi) este singura specie de ferigă din familia Marsileacea care este prezentă în flora României și una dintre speciile de plante vulnerabile. În această lucrare este raportat succesul demografic al unei populații de *M. quadrifolia* care a colonizat un habitat acvatic antropic din Rezervația Biosferei Delta Dunării. După un deceniu de monitorizare, trendul demografic este pozitiv, dar capacitatea de suport a habitatului pe termen lung este limitată. Persistența populației este amenințată deopotrivă de factorii naturali şi de cei antropici. Crearea unei micro-rezervaţii poate fi soluţia practică pentru protecţia şi conservarea acestei populaţii vulnerabile de *M. quadrifolia*.

INTRODUCTION

Marsilea quadrifolia L. (known by the vernacular names “four-leaf clovers”, “water clover”, or “water shamrock”) is an aquatic and amphibious pteridophyte which occurs especially in standing shallow waters. This heterosporous and floating-leaved fern is considered the lectotype of the generic name (Grolle, 1988; Johnson, 1988; Iamonico, 2012). The oldest genus of Marsileaceae family (Lupia et al., 2000), has about 52 extant species worldwide, and is prevalent in intertropical regions (Lin and Johnson, 2013).

In Europe, only four species of *Marsilea* genus occur: *M. quadrifolia* L., *M. strigosa* Willd., *M. batardae* Launert, and *M. aegyptica* Willd., the latter is only found in the Lower Volga region (Crabbe and Akeroyd, 1993). Due to the habitat destruction as a consequence of increased human activities, all the other *Marsilea* species have become rare, vulnerable, endangered or extinct in the wild. Therefore, in the European Union they all are protected and are being nominated as species of community interest whose conservation requires the designation of special areas of conservation.

According to the map of European distribution of *M. quadrifolia* species (Jalas and Suominen, 1972), this specific fern is prevalent between 45º and 50º north latitude. Consequently, the native range corresponds to the lowlands and flood plains of the main rivers, and hygrophilous grasslands of Europe. In the past, this plant has been quite common in the area of its distribution from Western Europe; the historical floras called it a “pig pasture weed” (Poschlod et al., 2005).

At the end of the twentieth century, the studied species became a rare taxa in its natural European range (Bruni et al., 2013; Estrelles et al., 2001; Godreau et al., 1999; Lozano et al., 1996). The declining trend related to the significant loss of natural habitats, especially due to river courses affected by human induced changes such as: channelization and embankment, drainage of floodplains and others wetlands, high fertilization of the agricultural lands, and changes of agricultural practice (Schneider-Binder, 2014; Godreau et al., 1999). Furthermore, the lack of any long-distance dispersal mechanism limits its dissemination in other possible and suitable habitats, despite the fact that it has the ability to colonize new habitats (Burk et al., 1976), and its pioneer capabilities that were observed in disturbed habitats are a result of the capacity for vegetative reproduction (Dallai et al., 2010). On the other hand, because it is a light loving species, along to the ecological succession it is expected to be eliminated by the higher and faster growing plant species.

New sites with *M. quadrifolia* in natural habitats from its known European natural range (Conrad, 2005; Hulina, 1998; Pistoja et al., 2006), and new populations, spontaneously colonized in former sites where it was mentioned, were extinct previously (Pistoja et al., 2006), or in some man-made wetlands that have replaced abandoned farmlands located outside of its natural range (Bremer, 2003; Bremer, 2007; Drok and Weeda, 1999), have been reported in the last years.

The habitats of this pteridophyte are wetlands with heavy clay to sandy substrates. It grows mainly in shallow permanent lakes and at the edges of ponds, as well as in small rivers with slower water flow and lower force. Man-made water bodies (ditches, rice fields) are colonized (Schneider-Binder, 2014). As a hydrophyte, *Marsilea quadrifolia* prefers mesotrophic and eutrophic waters (Lin and Johnson, 2013). Thus *M. quadrifolia* has the ability to remove nitrite from contaminated water (Rawat et al., 2009), that it is beneficial for nutrient mitigation from the fresh water lake and for wetland restoration (Khan and Manzoor, 2010). It occurs also in conditions of light to medium salinity (Schneider-Binder, 2014). Due to the fact that it is sensitive to aquatic environmental pollutant exposures, this fern has been chosen for ecotoxicogenomics research (Miranda et al., 2014; Snape et al., 2004).

According to the Braun-Blanquet approach, this fern occurs in communities that belong to Isoëto – Littorelletea (BR. – Bl. Et. Vlieger 1937), class of vegetation (Mucina, 1997), and recently, in a new conquered habitat, it was found in Eleocharito acicularis – Limoselletum (Malcuit, 1929), association (Bremer, 2013). A review of plant communities where *M. quadrifolia* was found has been made by Schneider-Binder (2014).

Due to populations' decline throughout Western Europe, the protection and conservation of *Marsilea quadrifolia* in European Union states (UE) has started since 1979, when the Bern Convention on the Conservation of European Wildlife and Natural Habitats has been ratified. In the European Habitats Directive (Council Directive 92/43/EEC, 1992), it is listed as a strictly protected species (Council of Europe, 2010), and its habitat which requires protection and conservation is encoded 3130 – "oligotrophic to mesotrophic standing waters with vegetation of Littorelletea uniflorae and/or Isoëto-Nanojuncetea". For this taxa there have been 94 Natura 2000 sites designed in all UE member states.

Also, this taxa is legally protected in non UE countries such as Albania (Kashta, 2007; Xhulaj and Mullaj, 2002), Bosnia and Herzegovina (Schneider-Binder, 2014), Montenegro (Radovic et al., 2008), and Ukraina (Witkowski et al., 2003).

In Romania, *Marsilea quadrifolia* has been a protected species since 1993, after the Government ratified Berne Convention (Law 13/March 11/1993). It is listed as an endangered species on the national red list of plant species (Oltean et al., 1994), but it is not mentioned in the most recent published Red Book of Romanian flora (Dihoru and Negrean, 2009).

In the man-made habitats (rice fields) from South Asia, water clover is a noxious and undesirable weed (Chang, 1970; Luo and Ikeda, 2007; Satapathy and Singh, 1985), difficult to control because it is tolerant to most of the grass killing herbicides used (Kathiresan, 2006), and the anthropogenic habitats (especially drain ditches) from Europe are temporary shelters rather than mainstays, hence the plant can spread further (Nowak and Nowak, 2006). Additionally, the anthropogenic habitats could be a suitable refuge for the plant because they are analogous habitats, broadly similar to natural ones.

The return of *Marsilea quadrifolia* in sites where formerly it has been declared extinct could be interpreted, by the conservation in those sites of sporocarps, as highly resistant to dryness which can "germinate" even after long periods of time of dormancy if the proper environments are re-established (Nagalingum et al., 2006).

Although there is no overwhelming evidence, it is believed that ducks and other waterfowl unintentionally disseminate this species between different bodies of water (Johnson, 1986). The major and frequent flooding of meadows substantially increase the chances of dissemination of sporocarps and rhizome fragments from a site to other suitable habitats.

The objective of this paper is to present an assessment of the ecological success of *Marsilea quadrifolia* population which was found in a drainage channel (Fig. 2) from the Danube Delta in 2004. The possible circumstances of its occurrence in this place are discussed; an introduction is deliberately excluded. The main threats of this new *M. quadrifolia* population from the Danube Delta are assessed due to a very close vicinity of its conquered habitat with a human settlement.

MATERIAL AND METHODS

In order to establish the occurrence and distribution of *Marsilea quadrifolia* in the Danube Delta, the national flora literature was surveyed (Ciocârlan, 1990, 2000; Ţopa, 1952; Dihoru and Negrean, 1976; Sârbu et al., 2013). The distribution of *M. quadrifolia* in the Danube Delta was mapped on 10 x 10 km squares in the UTM grid system, according to bio-cartographic code from Romania (Lehrer, 1977).

The demographical success of the population (λ) was estimated using the evolution of cover area over the 2004-2014 period, based on following formula:

$$\log \lambda \sim [(\log (1 + popsize_{actual})) – (\log (1 + popsize_{initial}))]/year \quad (1),$$

here $popsize_{actual}$ is the population size in 2014, $popsize_{initial}$ is the initial size when it was discovered (in 2004), and year represents the number of years since it was discovered. The population size was estimated as surface cover (m^2).

The nomenclature of plants taxa associated with *Marsilea quadrifolia* is in accordance to Ciocârlan (2000), Sârbu et al. (2013), and Tutin et al. (1993).

Possible ways of colonization of the site from Sfântu Gheorghe were analysed based on information published in relation with the species. The main threats were assessed due to the proximity of a human settlement.

RESULTS

The chorology of *Marsilea quadrifolia* L. in the Danube Delta Biosphere Reserve

For Romanian flora, *Marsilea quadrifolia* is the sole member of the Marsileaceae family (Ciocârlan, 2000; Ţopa, 1952; Sârbu et al., 2013). According to Ţopa (1952), until the middle of 20th century *Marsilea quadrifolia* had not been reported in the Danube Delta although, theoretically at least, in this large wetland there are suitable habitats. Subsequently, it was reported at Sulina (Ciocârlan, 1990; Dihoru and Negrean, 1976; Sârbu et al., 2006), Gârla Magearu, and Canal Rusca (Fig. 1), the last site being estimated with “the largest population of *Marsilea quadrifolia* in the Danube Delta” (Sârbu 2007, Sârbu et al., 2006). Schneider-Binder (2014) mentioned *Marsilea quadrifolia* at Sfântul Gheorghe in 2011. Another two sites are reported in the Ukrainean part of the Danube Delta (Klokow and Dyachenko, 1988).

Study area, habitat description, and population estimation

During floristic investigations at Sărăturile beach ridge in the Danube Delta, a very small population of *Marsilea quadrifolia* was discovered in July of 2004 in the eastern part of Sfântul Gheorghe Village, very close to the mouth of the Sfântul Gheorghe distributary. The geographic coordinates of this population are: 44º53’26” N, 29º36’18” E, UTM grid QK 07.

Sfântul Gheorghe Village is located in the south of Sărăturile beach ridges plain, known as “Grindul Sărăturile”, at the mouth of the Sfântul Gheorghe arm of the Danube River. The climate of this area is temperate continental. In the first decade of XXI century the mean annual temperature was 11.3ºC, with 0.3ºC more than average of the 1896-1960 period and the mean annual rainfall amount decreased from 363 mm to 274 mm. According to the Martonne index of the aridity value, the climate is close to semi-arid type (Strat, 2010).

A small patch of *Marsilea quadrifolia* was found in 2004 at the edge of a heavily clogged and muddy drain channel, exposed to full sunlight, and with an extremely favourable light thermal regime. This channel is part of the network of channels and ditches built around Sfântul Gheorghe Village to drain excess moisture and temporary stagnant waters to the Sfântul Gheorghe distributary due to the shallow water table that is near the topographic surface. The channel waters flow very slowly and have periods of stagnation. The water level in the channel is the highest in spring and the lowest at summer’s end, in close connection with the climate area, Danube level oscillations, and water table oscillation. Also, the drainage channel has an asymmetrical cross-section, with a steep and high bank on one side and a low, flat bank, on the other. Thus, water level changes are more visible on the right bank where the area of shallow waters becomes larger during floods. Because of that, on the right side of the channel, *Marsilea quadrifolia* is adapted to amphibious conditions and there are two forms: *Marsilea quadrifolia* L. f. *natans* Kaulf. and *Marsilea quadrifolia* L. f. *terrestris* Hayek.

The channel, which has not been dredged in the last 25 years, is heavily silted and supports an aquatic flora composed of native emergent, floating leaf plants, and submerged macrophytes species (such as *Ranunculus aquatilis* L., *Cerathophyllum demersum* L., *Myriophyllum spicatum* L., *Potamogeton pectinatus* L., *Potamogeton perfoliatus* L.) in the deeper part.

The total number of extant individuals of *M. quadrifolia* population was difficult to estimate due to the clonal nature of species, but the total area initially covered by fern when it was discovered in 2004 was less than 0.5 m^2.

The initial population was marginally accompanied by *Nymphoides peltata* (S. G. Gmel.), Kuntze, *Ranunculus aquatilis* L., *Butomus umbellatus* L., *Mentha aquatica* L., *Rumex hydropalathum* Huds., *Glyceria fluitans* L., *Ceratophyllum submersum* L.

In the subsequent years, *Marsilea quadrifolia* has migrated downstream the channel and initial nucleus according to shallow water gradient. Therefore, the area occupied by it was estimated to be around 200 m^2 in September 2014, both *natans* and *terrestris* forms being present. Thus, the calculated value of demographical success (log λ) is 0.45.

The fern was found in a few monotypic stands whereas in the rest of the surface individuals were spread in scattered clumps. It has not been determined if the adjacent individuals are clonally or sexually established, but if in the first field works, *Marsilea quadrifolia* was found in aquatic conditions with floating leaves; since 2009 it has also been found in terrestrial form on the right bank of the channel. In aquatic environments it was accompanied by the following enrooted aquatic plants: *Hydrocharis morsus-ranae* L., *Lemna minor*, *Lemna trisulca* and two other ferns – *Salvinia natans* and *Azolla filiculoides*, the last one being an invasive species in the Danube Delta which threaten the communities of *Marsilea quadrifolia* (Anastasiu and Negrean, 2006). In the littoral zone of the channel, the following rooted plants were identified: *Butomus umbellatus* L., *Sparganium erectum* L., *Cicuta virosa* L., *Alisma plantago-aquatica* L., *Mentha aquatica* L., *Schoenoplectus littoralis* (Schrader) Palla, *Typha angustifolia* L., and *Phragmites australis* (Cav.) Trin. ex Steud., *Juncus maritimus* Lam.

DISCUSSION

It is difficult to determine the circumstances and the time when *Marsilea quadrifolia* reached the Sfântul Gheorghe site of the Danube Delta. On the other hand, because the initial *Marsilea quadrifolia* population was very small and then it increased, this fact could explain a recent colonization of the new habitat. Because the value of log λ exceeds zero, this fact could be assessed as a success of population establishing, which means that the conquered habitat – the heavily silted drain channel – ecologically is very similar to the natural ones. This success of colonization could be taken into consideration if the Romanian authorities will decide the appropriateness of reintroduction programs of this rare fern species in the wild just as in other European countries (Estrelles et al., 2001; Nöel et al., 2011). But because the calculated value of log λ is less than one (only 0.45), the habitat has no long-term support capacity for plant population growth and survival. If any human intervention is excluded, ecological succession (transformation of habitat in a reed marsh) is the main threat.

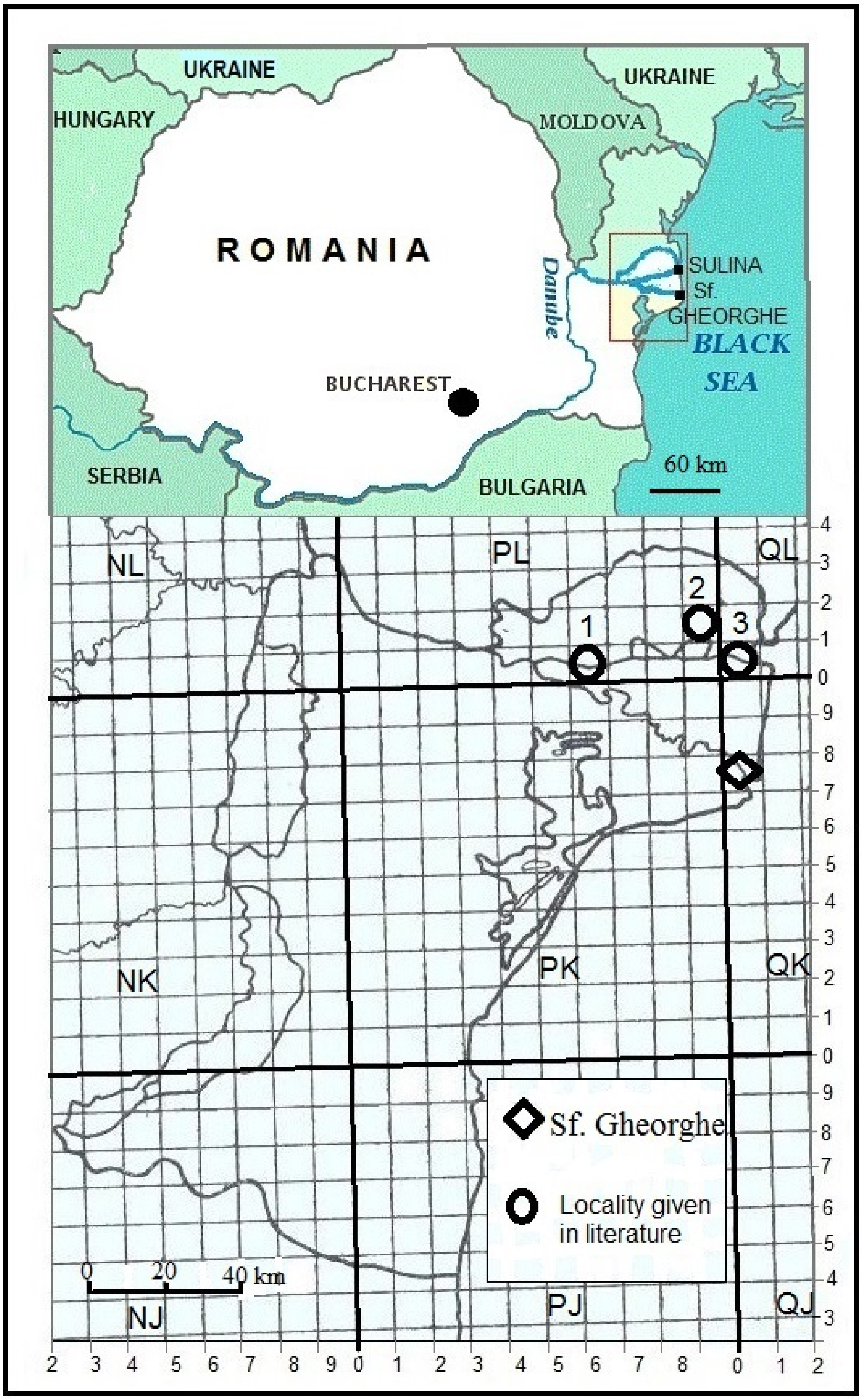

Figure 1: Distribution of *Marsilea quadrifolia* in the Danube Delta, Romania;
1 – Channel Rusca; 2 – Gârla Magearu; 3 – Sulina.

Figure 2: The drainage channel with a dense stand of *Marsilea quadrifolia* in the foreground.

With respect to the origin of this *Marsilea quadrifolia* population, it is difficult to determine the source and vector of propagules. Many Marsileaceous ferns, *M. quadrifolia*, can grow from sporocarps and rhizome fragments. The methods of dispersal of *Marsilea quadrifolia* are not clearly documented, although other species are dispersed by waterfowls (Serviss and Peck, 2008). The reproductive biology of Marsileaceous ferns was described (Johnson, 1986; Schneider and Pryer, 2002).

According to Johnson (1985, 1986), the dispersal of *Marsilea* ferns differs from most ferns because they use biotic rather than abiotic agents, but the wind dispersal is excluded because of the size and weight of sporocarps and because these reproductive structures are submerged. Whereas the entire process of reproduction exclusively occurs in the water and spores are released from sporocarps only in the water. If they previously went through a process of scarification, we presume that there are two plausible possibilities: hydrochory and zoochory. It is not therefore excluded that, during the floods, the disseminules (sporocarps or rhizomes fragments) derived from other *Marsilea quadrifolia* populations of the Danube drainage basin to reach a drainage channel, thus leading to the establishment of a new population.

Also, it is not unreasonable to suppose that the migratory water birds could be responsible for the presence of the water clover in the new site, especially if studies show that the water birds are not only potentially important as agents of long distance dispersal and of colonization of new habitats (Guppy, 1906; Carlquist, 1967), but also as agents of dispersal at a local scale (Figuerola and Green, 2002; Green et al., 2002; Green et al., 2008).

However, endozoochory by waterfowl seems to be a much more important mode of dispersal for aquatic plants, including *Marsilea* ferns, than exozoochory (De Vlaming and Proctor, 1968; Brochet et al., 2010), although there are opinions according to which, this means of transportations of propagules is slightly less efficient when very great distances are involved (Carlquist, 1967).

Considering the Danube Delta is one of the largest wetlands in Europe (with high biodiversity of brooding migratory and sedentary waterfowl, and non-brooding waterfowl in winter) propagules could have been brought from anywhere to the Sfântul Gheorghe site, closer or farther away from this new site. Hypothetically, the nearest potential source is the *Marsilea* population from Sulina, located 30 km north from Sfântul Gheorghe. This possibility is in accordance with the maximum dispersal distance calculated for *M. quadrifolia* for a fixed time period (30 years), if there is climatic suitability and the landscape connectivity increases (Alagador et al., 2011). Thus, the short distance movements of water birds over the Danube Delta could be responsible for dispersal of *Marsilea quadrifolia* propagules.

The assumption concerning the genetic distance between these two *Marsilea quadrifolia* populations, and if there was an eventual gene flow, can be demonstrated only using genetic studies, in the same way as it was done for the *Marsilea strigosa* (Vitalis et al., 2002). However, after all circumstantial suppositions, the following question arises: if the water birds are agents of dispersal of the *M. quadrifolia* and if the Danube Delta is a suitable habitat for it, why are there just several populations in this large and well preserved natural wetland?

For the newly occurred *Marsilea quadrifolia* species population, there are no managed activities in order to protect and preserve it. Besides, within the Danube Delta Biosphere Reserve, its habitat is not located in a strictly protected area; on the contrary it is a zone with economic activities, right next to a human settlement. Consequently, this interesting new established population is highly threatened by the local human activities. The main threat is its specific habitat destruction by mechanical dredging of the channel in order to keep its actual function. Traditional practices of grazing cattle and poultry are other threats. Although cattle did not appear to feed on *Marsilea quadrifolia*, the trampling could cause permanent damage to individual plants, especially for terrestrial form that has only clonal reproduction. But on the other hand, cattle trampling can increase the chances of dissemination of sporocarps and rhizome fragments attached to the hooves from a site to other suitable habitats from this area.

To protect the habitat and to stabilize the currently extant population, the immediate actions are required: develop a management plan for the Sfântul Gheorghe site, and monitor/control all types of socio-economic activities, such as development projects that could affect the site of population. Currently, there is no known development projects planned that would affect the *Marsilea quadrifolia* population, but this area may be considered for development in the future, especially for touristic activities. Hence, in perfect accordance with national legislation and local circumstances, the authorities need to find the adequate solutions to protect this fern species of European interest.

A plant micro-reserve might represent an excellent measure for the in situ conservation, especially the idea of creating small protected areas for singular plant species, which initially started in Spain, is successfully spreading in other European countries (Laguna, 2001; Laguna et al., 2013).

CONCLUSIONS

This paper provides basic information about a new site with *M. quadrifolia* in the Danube Delta Biosphere Reserve, Romania. This threatened fern has colonized the end part of a heavily silted drainage channel. The surface colonized by *M. quadrifolia* had increased in size which means a success of the population occurred and a positive trend for it, but the habitat is not suitable in a long-term view.

The threats of this population include relatively small population size, ecological succession, and human activities which may lead to habitat destruction. Mechanical dredging works of the drainage channel is a major risk.

A possible successful measure to preserve this vulnerable *M. quadrifolia* population could be setting up of a plant micro-reserve.

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BASIC ASPECTS FOR THE ECOLOGICAL RESTORATION OF URBAN WATER COURSES

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KEYWORDS: revitalisation, habitat restoration, urban floodplains, restructuration, model, fine sediments, longitudinal continuum, Austria, Water Framework Directive, ecological status.

ABSTRACT

Due to the fact that urban water courses provide precious natural and recreational areas within urban surroundings and that they contribute to an increase in quality of life, they have gained more and more importance in recent years. The restoration and planning of urban water bodies pose an enormous challenge, because most of them are in a poor ecological and structural state.

This paper deals with the questions and problems concerning the topic and presents basic aspects for the ecological restoration of urban water courses.

ZUSAMENFASSUNG: Grundsätzliche Aspekte für die ökologische Wiederherstellung urbaner Fließgewässer.

In den letzen Jahren kommt den urbanen Stadtgewässern eine immer größere Bedeutung zu, da sie wertvolle städtische Natur-, Freizeit- und Erholungsräume zur Verfügung stellen, die zur Steigerung der Lebensqualität beitragen. Die Sanierung und Entwicklung derartiger Gewässer stellt eine große Herausforderung dar, denn die meisten innerstädtischen Gewässer befinden sich in einem unbefriedigenden ökologischen und strukturellen Zustand.

Die vorliegenden Arbeit beschäftigt sich mit den Fragestellungen und Problemen dieser Thematik und zeigt modellhaft die wichtigsten Aspekte für die ökologische Sanierung urbaner Fließgewässer.

REZUMAT: Aspecte de bază pentru reconstrucţia ecologică a cursurilor de apă urbane.

Datorită faptului că furnizează zone naturale preţioase şi de recreere în cadrul aşezărilor urbane, contribuind la o creştere a calităţii vieţii, cursurile de apă urbane au câştigat o importanţă din ce în ce mai mare în ultimii ani. Restaurarea şi planificarea corpurilor de apă urbane reprezintă o provocare enormă, datorită faptului că o mare parte dintre ele sunt într-o stare ecologică şi structurală precară.

Această lucrare se ocupă cu întrebările şi problemele referitoare la acest subiect şi prezintă aspecte de bază pentru refacerea ecologică a cursurilor de apă urbane.

INTRODUCTION

The morphology of natural rivers is characterised by the dynamics of the stream flow. The general appearance of a water course, its banks and its surrounding area are subject to a constant change. This dynamic balance leads to a continuous rearrangement of structures within the water course, whereas the quantity of structures remains mainly constant. The riparian and aquatic flora and fauna is adapted to this permanent change, some species even rely on it.

Due to the industrialisation and increasing settlement many rivers have been channelled and regulated. This degradation has led to a massive disturbance of the biological system and the groundwater balance. Many river sections have turned into structureless water channels without any natural dynamics. Many specialised animal and plant species lack habitats and fade away gradually, whereas species which are insensitive to environmental influence stand to benefit from this fact and proliferate. (Gumpinger and Scheder, 2008)

Urban water courses are especially affected by the degradation and homogenisation described above. The shortage of space on the one hand and the increasing demands of area for infrastructure and site utilisation on the other hand have led to a constant subtraction of space originally engaged by water courses (Fig. 1). Due to flood protection measures and the misguided belief that rivers must be controlled by means of technical structures, many partly irreparable modifications have been made. Ecological issues were disregarded and water courses were reduced to the function of a water channel. In the late 20th century a change of ideology took place and guidelines like the Water Framework Directive (WFD; European Commission, 2000) support this process.

Figure 1: The Breitsach Brook in Ried im Innkreis (Austria).

Common problems of urban water courses

Urban water courses and their floodplains are affected by intensive anthropogenic use; that is why most of them are confronted with similar problems. Almost all channels are straightened, narrowed and lowered. Beds and banks are frequently constructed and they lack natural structures which ought to be habitats or stepping stones for the aquatic and riparian fauna. Man-made different barriers interrupt the longitudinal river continuum (Fig. 2) and affect the natural dynamic of discharge and also the bed load. In the worst case water courses are actually piped (Fig. 3) and therefore deprived of any ecological function.

Expanded floodplains are extremely rare because of the lack of space, and even narrow riparian groves have been reduced to scattered and isolated structures that have lost their original function. The lateral connectivity between the water course and its surroundings is interrupted, which leads to an enormous loss of structure and habitats. Intact aquatic and semi-aquatic ecosystems are composed of a mosaic of small-scale habitats in different stages of development. There are many interactions between the ecosystem-complexes and furthermore between the particular habitats (Ulmann and Peter, 1994) that are missing in regulated channels. Natural river banks and riparian woods offer a large number of ecological niches and precious back-up habitats or refuge areas for threatened species and would be necessary especially in urban areas, where there is mostly a total lack of those structures.

The restoration of urban water courses offers a significant high ecological potential, therefore a professional appropriate planning is highly necessary to achieve the maximum benefits.

Unprofessional restoration can easily lead to monotonous, ecologically worthless areas with low biodiversity, even if they look intact in the eyes of a non-professional. Especially in urban areas the appearance of landscapes is important because of its health-related quality and function of recovery for human beings. A professional planner must be able to consider both the ecological and human demands.

Flood protection is one of the main topics in urban areas. As mentioned above, floodplains have been reduced to a minimum; and consequently so have the natural potential of retention. This fact leads to higher discharges that are intensified still by the enforced run-off from sealed soil surfaces.

Figure 2: The Sulzbach Brook nearby Bad Ischl is an example for the missing longitudinal connectivity in water courses.

Figure 3: The Schweinbach Brook as an example for a tubed water course.

Ecological considerations on the restoration of urban water courses

Due to the lack of space in the surroundings of urban water courses many compromises have to be accepted; an entire ecological restoration is hardly ever possible. Infrastructure, canal systems or ductings, tighten the possibilities for a comprehensive restoration because of their expensive relocation.

The first step in planning a restoration is the elaboration of a model for the water course. In the model development targets are defined in order to implement them by means of concrete concepts and reconstruction measures. First of all, a visionary model is derived from the original state, which means a situation unaffected by mankind. In the operational model that follows, anthropogenic conditions are considered and principles of conception that can be obtained under these conditions are developed. For the definition of the operational model fish core species, aerial photographs, old maps and historical reports are used. All this information is merged by an expert in order to achieve an archetype for the water course and to devise the main aims for its development. Below, the most frequently defined aims are listed:

- establishment of a water corridor (= active channel) and a low water channel;
- restoral of the typical stream course;
- increase of the diversity of structures and habitats;
- restoration of the longitudinal continuum;
- increase of retention and flood protection;
- reduction of fine sediments and sediment deficits;
- enhancement of the connection between water and riparian areas.

Establishment of a water corridor (= active channel) and a low water channel

Depending on the type and size of the water course, the corridor conform to the model can be quite wide (up to several hundred meters). Unfortunately, the establishment of such a corridor is illusory and so the existing profiles can only be widened as far as the neighbouring land-use allows.

Within this newly established corridor the low water channel should be able to move freely. The course of the low water channel is set roughly by placing structural elements (rootstocks, trunks, and stones, etc.) and gravel banks at appropriate positions in the channel bed. By lowering the land area in the corridor, many waterlogged zones are created, which are very important for the semi-aquatic fauna. In the case of increased discharges the corridor offers enough space for the riskless runoff of the water masses.

Restoral of the typical stream course

One of the most important measures concerning restoration is the removal of technical control structures in beds and banks and the insertion of natural sediments and wooden or stony structural elements (Figs. 4 and 5). The removal of inflexible technical control structures raises the potential for the development of a more dynamic water course. By integrating structural elements, the effect can be enhanced furthermore.

Figure 4: An artificial water course in Linz called “Urfahraner Sammelgerinne” before the restoration. The technical control structures that reach from the bed to the upper edge of the banks are not visible as they are covered with soil and vegetation.

Figure 5: The “Urfahraner Sammelgerinne” in Linz after the restoration.

Increase of the diversity of structures and habitats

Increasing the diversity of structures and habitats is important for the water course as well as for its surroundings. The development of structures and habitats in the water course is supported by a nature-like course and the insertion of structural elements. These elements have two functions. On the one hand they direct the flow and on the other hand they increase the diversity of structures. They represent natural materials like rootstocks, trunks, trees and roughly laid boulders. Stones are only used if it they conform to the model. Depending on their position and size structural elements induce sedimentation or erosion in the bed and banks, and thereby raise the diversity of structures and habitats.

Restoration of the longitudinal continuum

The longitudinal continuum is one of the most important criteria for an intact water course. Nearly all aquatic organisms migrate within the river system. Especially fish, but also benthic invertebrates require different biotopes and habitats during different developmental stages. In the majority of cases, man-made barriers inhibit migration and at worst even cut off the genetic exchange between different populations. In fish species, especially medium distance migrants like barbel (*Barbus barbus*), nase (*Chondrostoma nasus*) and Danube salmon (*Hucho hucho*) are heavily affected. But also short distance migrating fish like grayling (*Thymallus thymallus*), brown trout (*Salmo trutta*) or chub (*Squalius cephalus*) are impaired by the disruption of the longitudinal continuum.

Reduction of fine sediments and sediment deficits

In addition to enabling the longitudinal migration for aquatic organisms, the unhindered transportation of water and sediments must be guaranteed. Many water courses suffer from a lack of coarse sediments in downstream stretches, as gravel is retained by transverse constructions in upstream reaches. Due to this fact the proportion of fine sediments and the tendency of bed erosion increase. Fine sediments are characterised as particles smaller than 0.02 mm and show a high proportion of clay, silt and organic material. High impacts of fine sediments cause a clogging of the hyporheic interstitial, which leads to a shortage of oxygen in the pore-system, the most important habitat for the benthic fauna and for the fish reproduction. The clogging finally results in the destruction of the interstitial biocoenosis.

There are two possibilities for dealing with the problem of fine sediments. An effective way is the prevention of the input of fine sediments. Many water courses lack shelter belts or riparian woods, which assume the role of buffers or filters in landscapes. Due to this deficit, a constant and diffuse load of fine sediments is transported into watercourses by wind, rain and intensive agricultural farming. The establishment of riparian woods is one of the most important measures because they regulate the exchange and spreading rates of chemical compounds between terrestrial and aquatic systems. On the one hand they are mechanical filters for air-borne fine material and on the other hand they function as a biological filter by absorbing nutrients from the soil. Furthermore, the vegetation stabilises the banks and prevents them from being eroded (Zalewski and Wagner-Lotwowska, 2004).

A reduction of the fine sediment load can also be achieved by increasing the stream velocity. This can be obtained by augmenting the gradient of the river bed, by restricting the profile or by increasing the flow rate. In most cases, the restriction of the profile is the only practicable possibility. The Venturi effect states that if a moving fluid passes through a constriction, its velocity increases. Such a constriction can be achieved by placing elements like rootstocks, trunks, trees or boulders (Figs. 6 and 7) at appropriate positions. When the stream velocity is increased at these positions, the transportation of fine sediments is enhanced.

In urban areas the enhancement of the flow velocity is the most effective strategy. As the fine sediment loads often originate from upstream agrarian areas, the restriction of the profile is more useful and practicable than the establishment of a buffer in form of a riparian grove. Nevertheless, bushes and trees in the riparian areas are fundamental.

Figure 6: The paved bed of the “Urfahraner Sammelgerinne” in Linz before the restoration.

Figure 7: Nature-orientated bed of the “Urfahraner Sammelgerinne” in Linz after restoration.

Enhancement of the connection between water and riparian areas

As broad active channels should be established in a first step when restoring a water course, enough space will then be available to enhance the connectivity between aquatic and riparian areas. Profiles should provide a small channel in which the entire discharge is transported during low water situations. The remaining shallow banks should be shaped with variable slopes and hollows that fill with water when the discharge increases, in order to enhance the possibility for the development of ecotones with precious habitats and ecological niches. These areas also offer important reproduction areas for the semi-aquatic fauna and other water-bound animals. The hollows in the banks are flooded during phases of slightly elevated water levels, and therefore they are subject to a constant changing. Such pioneer-areas are very rare and therefore scarce and valuable biotopes.

In urban areas there is hardly ever enough space for such a broad corridor, but the removal of the technical control structures and the structuring of the banks already improve the connectivity between the water course and its surroundings markedly.

Increase of retention and flood protection

Flood protection is one of the most important topics in urban areas. Due to the absence of natural expanded floodplains the potential of retention and infiltration is minimised. The increased sealing of the soil surface in urban areas intensifies this problem even more and causes extreme flooding.

In order to handle this problem effectively, the whole catchment area must be taken into account, because the occasion of extreme flooding results from the interaction of diverse factors. If that is not possible, at least the profile of the water course in the project area should be widened as largely as possible.

DISCUSSION AND CONCLUSIONS

The practical experience from restorations that have already been realised provides evidence of a positive ecological and dynamic development in quite a short period of time. Especially during higher discharges the inserted wooden elements fulfil their function as structures and habitats.

In order to quantify these improvements, monitoring should be carried out after each restoration project. On the one hand a monitoring helps to find the best way of construction for the respective types of running waters. On the other hand structure-improving is an important measure to fulfil the general objective of the WFD concerning the protection and improvement of water bodies and therefore needs to be measured. The WFD claims the good ecological and chemical status for all bodies of surface water and accordingly the good ecological potential for heavily modified or artificial water bodies until the year 2015 (European Commission, 2000). Due to that fact it is important to quantify the effects of a restoration on the ecological status. In the determination of the ecological status the proof of a typical community of fish species is the most important parameter in Austria. Fish reveal perfect indicator values for the hydro-morphology of a water course due to their mobility on the one hand and their dependency on structures on the other hand.

From the results of a monitoring basic guidelines for the restoration of urban water courses need to be deduced, because this field of work is still young and the experience quite short. Only by learning from each other's experience the complexity of aquatic ecosystems can be understood and strategies to restore and conserve them can be deduced.

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MANAGEMENT ELEMENTS PROPOSAL FOR SUTLA NATURA 2000 SITE

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ABSTRACT

Following the accession of Croatia to the EU, a study was carried out on a Croatian Natura 2000 site which includes habitats used by the following fish species of conservation interest: *Eudontomyzon vladykovi*, *Rhodeus sericeus amarus*, *Gobio uranoscopus*, *Romanogobio kesslerii*, *Barbus meridionalis*, *Zingel streber* and *Cottus gobio*. Harmful effects on fish fauna were found due to: poorly-integrated water management, over-extraction of water for irrigation, fragmentation of riparian vegetation, low cooperation between environment institutions in Croatia and Slovenia, abuse of pesticides, uncontrolled waste water, sources of chemicals and heavy metals, leakage of nitrogen, habitats fragmentation due to dams and canals, non-native fish species, invasive species and gravel extraction. Specific management actions are proposed that take account of the different fish species of conservation interest and their specific biological and ecological requirements.

RESUMEN: Propuesta de elementos de manejo para el área de Sutla dentro de la red Natura 2000.

En conformidad con el acuerdo de Croacia y la unión Europea, se realizó un estudio en un área natural croata dentro de la red Natura 2000, que incluyó hábitats utilizados por peces de interés para la conservación: *Eudontomyzon vladykovi, Rhodeus sericeus amarus, Gobio uranoscopus, Romanogobio kesslerii, Barbus meridionalis, Zingel streber* y *Cottus gobio*. Se detectaron efectos negativos en la ictiofauna, los cuales fueron relacionados con: manejo poco estructurado del agua, sobre extracción de agua para riego, fragmentación de vegetación riparia, poca cooperación entre instituciones ambientales de Croacia y Eslovenia, falta de control de aguas residuales, diversas fuentes de químicos contaminantes y metales pesados, fragmentación de hábitats por construcción de presas y canales, introducción de especies foráneas, especies invasivas y extracción de grava. Se proponen acciones específicas de manejo que toman en cuenta tanto a las diferentes especies de interés para la conservación y a sus requerimientos biológicos y ecológicos específicos.

REZUMAT: Propuneri de elemente de management pentru Situl Natura 2000 Sutla.

După aderarea Croației la UE s-a efectuat un studiu asupra sitului croat Natura 2000 dsemnat pentru protecţia speciilor de peşti: *Eudontomyzon vladykovi, Rhodeus sericeus amarus, Gobio uranoscopus, Romanogobio kesslerii, Barbus meridionalis, Zingel streber* și *Cottus gobio*. S-a demonstrat că ihtiofauna este afectată în mod negativ de următoarele: managementul incorect al apelor, prelevarea unui volum prea mare de apă pentru irigații, fragmentarea vegetației ripariene, lipsa de cooperare între instituțiile de mediu din Croația și Slovenia, abuzul de pesticide, deversarea necontrolată de ape uzate, poluarea cu substanțe chimice și metale grele, poluare difuză cu azot, fragmentarea habitatelor datorită digurilor și canalelor, prezența unor specii alohtone de pești, a unor specii invazive și prezența balastierelor. Sunt propuse măsuri de management specifice care țin cont de structura comunităţilor de peşti, de carateristicile biologice şi ecologice ale speciilor de peşti de interes conservativ precum şi de starea habitatelor caracteristice din zona de referinţă.

INTRODUCTION

EU conservation legislation and Croatia's accession to the EU

The Republic of Croatia (Republika Hrvatska) has been a member of the Convention on Biological Diversity since 1992, together with other 193 states. The Convention aspires to guarantee the worldwide conservation and sustainable use of species, habitats and ecosystems diversity. A new opportunity to study the effect of such legislation on conservation occurred on the first of July 2013, when Croatia became the 28th member of the European Union after a decade of trying to fulfil the needed reforms to align to the EU concept, laws and standards, including those related with the environment protection and conservation. Croatia will share not only the benefits of EU membership, but also the responsibilities that make the EU a successful union today.

The basic aspirations of the EU leadership with regard to the environment are the protection and conservation of environment structures and functions, with a specific focus on the protection of ecosystem services and ecological resources, including those from aquatic and semi-aquatic ecosystems. Over the last few decades, biodiversity issues have been considered very important in this context.

The European Community's action on biodiversity conservation is stated within the Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC). These two European Directives have as the central ambition an intention to preserve the biodiversity in European Union territory, through a protected areas network (called Natura 2000) which preserves key habitats and species specific for all the biogeographic regions of Europe: Arctic, Boreal, Atlantic, Continental, Alpine, Pannonian, Mediterranean, Macaronesian, Steppic, Black Sea and Anatolian (Fig. 1).

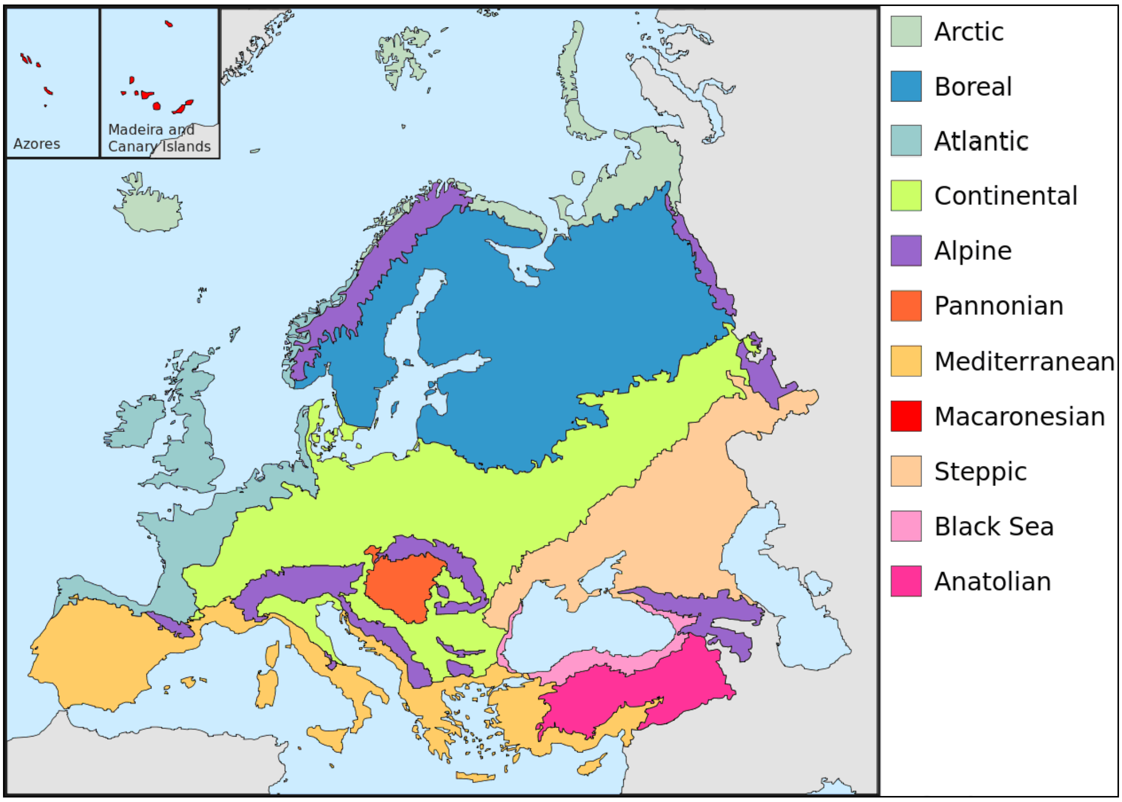

Figure 1: European biogeographic regions; European Environment Agency – www.eea.eu.in

Croatia has a relatively diverse biogeographic richness compared to some EU states, covering four biogeographic regions: Continental, Alpine, Pannonian and Mediterranean (Fig. 1). As part of its EU accession process, Croatia needs to take conservation measures to preserve and re-establish the favourable status of Natura 2000 habitats and species, in relation to the cultural, social and economic needs in both local and regional contexts.

One central element to fulfil the goals of these European Directives is the establishment of an optimum Natura 2000 network of sites within Croatia, a network which should include specific biodiversity monitoring plans for each habitat and species, including fish of conservation interest, and also including proper management plans on local, regional and national levels. In order to achieve this to a standard matching the EU environmental policies, the most up to date scientific and technical information should be considered.

Last, but not least, protection measures must include management plans configured for distinct areas and linked to other plans for neighbouring areas, and these must include proper statutory and administrative measures which correlate with the specific needs of the Natura 2000 species and habitats, to avoid their degradation. Across Europe's Natura 2000 network, management plans are necessary tools to provide the specific management that is required to safeguard a favourable status and to deal with situations where conflicts can appear.

Study site: Sutla

The Croatian Natura 2000 Site Sutla (HR2001070) covers around 192 ha in area and is situated in the Continental biogeographical region and encompasses diverse riparian and fresh-water habitats along the Sutla River. It is inhabited by seven fish species of conservation interest: *Eudontomyzon vladykovi*, *Rhodeus sericeus amarus*, *Gobio uranoscopus*, *G. kesslerii*, *Barbus meridionalis*, *Zingel streber* and *Cottus gobio*, and by other, non-fish species of conservation interest including *Unio crassus* and *Lutra lutra*.

The Sutla River is a tributary of the Sava, and part of the Danube Basin. For some of its length, it marks the border between Croatia and Slovenia. It is 92 km long, rising in the Macelj Mountains in Croatia/Slovenia, at 625 m altitude. Its confluence with the Sava River is at Ključ Brdovečki. The majority of the Sutla River affluents are flowing from the Republic of Slovenia. The river basin is of 582 km^2, of which 22% are located on the Croatian territory where Sutla River is passing mostly hilly sectors cutting sometimes narrow valley sectors.

This article provides an outline management plan for the above-mentioned fish species, with reference to identified challenges and issues in managing water quality and freshwater resources in the study area and the region more broadly.

RESULTS AND DISCUSION

Pollution and alternation of the river Sutla

Historic management of the Sutla River

The Sutla River has a history of management problems. A dam was built in 1980 to block flooding in lower reaches, and to provide water for irrigation and tourism through the creation of a reservoir, Sutlanska Lake. Subsequent to its creation, and due to pollution issues, the reservoir was emptied, but the dam infrastructure still stands, and remains an obstacle to the upstream-downstream movement of fish. Additionally to this dam, there are other, smaller anthropogenic structures along the river, especially in the lower sectors, constructed to provide flood protection to agricultural riverine lands. These include alteration of the riverbed from wide and frequent meanders to more straightening course. These alterations to both river structure and the nature of water and other flow patterns have negatively impacted the fish fauna.

Water quality issues in the Sutla River

The Sutla River in both Croatia and in Slovenia has serious water quality issues, due to pollution with heavy metals in the upper part of the river and with nitrates in its lower part. The main sources of pollution in the Sutla River are considered to be communal and industrial waste water, agricultural pesticides and fertilizers, waste disposal and waste transportation. In some sectors of the river, sewage and water treatment plants are in action, whilst in many other settlements these are still missing.

Agricultural pollution sources

The landscape around the Sutla River is diverse with a combination of woodlands, grasslands and agricultural fields. The agriculture in the area relies extensively on fertilizers and pesticides, and also includes significant livestock production, both key sources of nitrate and chemical pollution.

The Sutla River basin has a high risk of pollution of surface waters from diffuse sources (including nutrients, organic substances, heavy metals and organic micropollutants). The diffuse pollution sources mostly stem from agriculture and include inadequate storage or inappropriate use of livestock manure, nitrate leaching from agricultural lands and illegal use of pesticides. In particular, nutrient loading into water sources causes eutrophication, especially in slow-moving or stagnant waters, which can induce changes in fish fauna structure, typically with a decrease in species diversity.

Dangerous substances can induce toxicity, can be persistent and may bioaccumulate in the aquatic environment. Organic substances produce a significant impact on the aquatic ecosystems through changes in species composition, decreasing species biodiversity, decreasing fish abundance and fish mass mortality. In 2009 for example Croatia produced 3,879 tons of pesticides, imported 5,760 tons, and exported 1,000 tons, leaving high quantities of pesticide for local use. Before accession to the EU, pesticides in Croatia could be bought without any competence certificate for pesticide use or storage, or any documentation regarding its use in farming and related business. Near Ključ Brdovečki and Drenje Brdovečko localities in the study area, studies of agricultural lands reveal temporary increases in the concentration of some metals as a result of sporadic emissions or leaks of farm manure into the river water; this can be correlated with the fact that the K_2O, CO, copper sulphate and Ti, are chemical elements used in fertilizers. In the same area the number of enterococci (typically indicative of faecal contamination) in the river water was significantly increased, as the concentrations of total N and total P. The agriculture is a major source of P, N and enterococci for aquatic ecosystems. As a consequence of the increased use of fertilizers in agriculture, additional humic substances entering river water can occur as a result of their use as additives for fertilizers.

Urban/settlement pollution sources

The main point sources of nitrate loading solution in the Sutla River are represented by human settlements in the area that lack a sewer system and a wastewater treatment plant. In addition, the efficiency of industrial units is a key potential source of urban pollution. In the Sava River basin, Croatia, over 90 cities discharge sewage into the river without any treatment.

However some of the most important potential sources of water pollution are waste landfills. These have been generally well-managed, reducing their potential to contributed pollution to the river.

Woodlands have a good effect for water sources, decreasing the negative impact of agricultural water pollution and contributing to the protection of water quality. The forests along River Sutla are mainly owned by individuals, and consist of beech, hornbeam and oak.

Rural households in Croatia are generally characterized by poor access to infrastructure equipment for water and sanitation compared to urban areas. Even in rural situations where households are connected to sewage systems, domestic water is not always treated, this having a negative impact on the environment (e.g. in 2007 42% of the Croatian Danube Basin were connected to sewage systems, which water was only 0.4% treated in a tertiary step).

Managing the fish species of River Sutla

Article 17 of the EU Habitats Directive compels Croatia to submit reports on the implementation of the measures taken under the Directive every six years. An improving situation for the seven fish species of conservation interest can only achieve favourable conservation status in the six-yearly reports if proper management measures will be identified, adapted and implemented on the ground. A favourable conservation status of these species means that they are prospering and have optimum conditions to remain the same in the medium and long term future. Some of the specific management measures for the conservation of these seven species are highlighted in the rest of this paper.

In the river Sutla there are four sport fishing associations: SRD "Sutla" Klanjec, SRD "Maple" Hum, SRD "Pike" Brdovec and SRD "Carp" Zapresic, all Croatian, and on the Slovene side Ribiška Sotli, Fellowship Ribiška and Fellowship Brežice. All of these sport fishing associations manage some sectors of the river Sutla on permitted management plans which specifically focus on fish management. Accepted fishing volumes vary in average between seven to eight kg/ha per year. Restocking with fish is done once or twice a year, with indigenous and also alien species.

All the positive and negative influences on the fish species of conservation interest and the management proposals were initially selected based on meetings with: experts, local stakeholders, Croatian Ministry of Environment and Nature Protection, State Institute for Nature Protection, (SINP), Natura 2000 Management and Monitoring (MANMON) team, Consortium Ramboll Denmark, Nature Bureau, etc. (Fig. 2).

Figure 2: Workshop with project team and stakeholders in Bdroveck locality.

Relatively numerous negative influences on fish populations were identified at the workshops with stakeholders and in the field: non-integrated water management, over-irrigation, improper maintenance of coastal and riparian vegetation, fisheries rivalry, unprofessional management of ponds, poor cooperation between environmental institutions in Croatia and Slovenia, misuse of pesticides in agriculture, unresolved issues of waste water in the entire area, waste leaks, sources of chemicals and heavy metals, leakage of nitrogen from farms, dams and canals that interfere with the continuity of river habitats, fisheries management plans created and implemented without the approval of the nature protection institutions, introduction of inappropriate foreign fish species and other, potentially invasive species, and gravel extraction.

The workshops also identified positive influences, including: adoption of ecologically-friendly agricultural systems, increasing awareness of environmental issues, sustainable forest management, protection of a part of Sutla River, agri-environment incentives, good cooperation with the Croatian Waters Administration, many wastewater treatment plants already operating, and rational fishing planning.

Species related data

Eudontomyzon vladykovi Oliva and Zanandrea, 1959 (Natura 2000 code 2485). Cephalaspidomorphi, Petromyzontiformes, Petromyzontidae, Lampetrinae. This freshwater, demersal fish species needs well-oxygenated and clear aquatic habitats commonly found in piedmont and mountain areas. Ammocoetes live in sands rich in detritus or clay sediments and eat detritus and microorganisms. Its known distribution covers the upper and middle Danube River basin, including the Sava River basin, and it is known to be present in our study area of the Sutla Basin. This species is protected by the Bern Convention and European Directive 92/43. In general, in its all distribution area the Danubian brook lamprey is sensitive to alteration in habitat quality (including from mineral extraction, drainage, and water pollution).

Rhodeus sericeus amarus (Bloch, 1782) (Natura 2000 code 1134). Actinopterygii, Cypriniformes, Cyprinidae. This benthopelagic and freshwater fish species needs still or slow-flowing water habitats with relatively compact aquatic vegetation and sandy-silty ground as canals, slow flowing lotic sectors, ponds, oxbows and backwaters, where mussels are present, especially mussels in the *Unio* and *Anodonta* families which are needed for reproduction. It feeds mainly on plants and debris, and secondarily on invertebrates. Its known distribution is the Danube Basin, including the Sava Basin, and it is also present in our research area of the Sutla Basin. It is protected by Annex 3 of the Bern Convention and Annex 2 of the Habitats Directive. The bitterling is in general sensitive to habitat deterioration.

Gobio uranoscopus (Agassiz, 1828) (Natura 2000 code 1122). Actinopterygii, Cypriniformes, Cyprinidae, Gobioninae. This benthopelagic and freshwater fish species lives in the riffles of small fast-flowing rivers (70-115 cm/s) and on the bottom of big rivers with relatively high water velocities and stone substrata in submountain lotic sectors. The alevines stand in not so fast flowing water sectors with sandy substrata. Its food consists of bioderma and rheophilic invertebrates. Its distribution is in the Danube Basin, including the Sava Basin, and it is present in our study area of the Sutla Basin. It is protected by the Bern Convention and European Directive 92/43/EEC. Generally speaking Danubian longbarbel gudgeon is vulnerable to organic pollution and sedimentation that appear due to the hydrotechnical constructions. This species is affected also by other disturbance of their habitats by humans.

Gobio kessleri (Dybowski, 1862) (Natura 2000 code 1124). Actinopterygii, Cypriniformes, Cyprinidae, Gobioninae. This benthopelagic and freshwater fish species is present in general in fast flowing piedmont zone rivers with large areas of sand substrate. This species eats diatoms and small psammophile organisms. Its range is in the Dniester/Nistru Basin, upper Vistula Basin and tributaries of lower and middle Danube Basin, including the Sava Basin, and is also present in the Sutla Basin. This fish species is under the care of the Bern Convention Annex 3, Habitats Directive Annex 2 and the IUCN Red List Kessler's gudgeon can be negatively affected by human induced changes in watercourses and drains and the extraction of sand and gravel, and to pollution including organic pollution.

Barbus meridionalis (Riso, 1827) (Natura 2000 code 1138). Actinopterygii, Cypriniformes, Cyprinidae, Barbinae. It is a benthopelagic, freshwater fish species, which can be found in hilly and mountainous lotic systems, especially those with springs. It prefers the clear and fast flowing water of lotic zones with hard substrata. Its food consists primarily of benthic aquatic invertebrates (tendipedes, ephemeropterans, trichopterans, gamarids, oligochetes and, rarely, plants). Its distribution is widespread through the Danube Basin, including the Sava Basin, the Sutla Basin. This species is listed on the IUCN Red List and protected by the Habitats Directive. The Mediterranean barbel is vulnerable to water pollution and abstraction, and environmental changes from drainage and mineral exploitation.

Zingel streber (Siebold, 1863) (Natura 2000 code 1160). Actinopterygii, Perciformes, Percidae, Luciopercinae. This demersal and freshwater fish species lives in the central course of small to large lotic systems and in sectors with relatively high water velocity, with riverbeds formed of pebbles, sand or clay, in the hilly and plain rivers, sometimes being present in sandy areas. Its food consists principally of aquatic insects, amphipods and worms, and occasionally of roes and fish alevines. Its distribution range is the Dniester/Nistru and Danube basins, including the Sava Basin, and it is present in our study area of the Sutla Basin. It is under protection by Bern Convention Annex III, Habitats Directive Annex 2 and listed as XX on the IUCN Red List. The Danube streber is negatively affected by human impact like pollution and habitat changes such as canalisations and dams.

Cottus gobio (Linnaeus, 1758) (Natura 2000 code 1163). Actinopterygii, Scorpaeniformes, Cottidae. This demersal and freshwater fish species lives exclusively in warm, mountainous lotic freshwater, and is rare in lakes which lack deep and relatively slow water sectors. Its food consists of insect larvae, amphipods, roes and alevines. It is protected by the Bern Convention and the Habitats Directive. Its known distribution includes much of the Danube Basin, including the Sava Basin, and it is present in the Sutla Basin too. The bullhead is threatened in general by pollution, changes in aquatic and riverine habitats, such as river canalisations and microhydropower plants and the accumulation of fine sediments.

Management elements of the Sutla River for the future

There is a necessity for supportive collaboration among Croatia, Slovenia, other Danube Basin and European Union countries across all sectors and stakeholders involved in the river, including academic institutions, experts, civil society, public administration and research networks. In particular, there is a need for joint, applied extensive and intensive specific studies, and for concentrated capacity building capacities through exchanging ideas and specific expertise. This way is essential to promote and boost Croatia's awareness, by sharing specific expertise to identify lotic sectors where management improvements are required. As an important first step, a joint Croatian-Slovenian network needs to be built to communicate emergencies and decide management solutions.

The Sutla Basin management plans required by Natura 2000 should include opportunities for improving the physico-chemical state of aquatic and riverine habitats to ensure favourable conditions for all the fish species of conservation interest in the Natura 2000 area. Specific management tasks that would improve the water quality and address the issues around availability of habitat discussed above can be grouped into four key areas: firstly, improving water quality, through building wastewater treatment plants, regulating discharges to the sewage networks, building sewage networks in the Sutla Basin for settlements currently lacking them, managing riverine dumps, discouraging illegal riverine dumps, and regular waste clean-up activities along the lotic and lentic sectors of the river. Secondly, addressing agricultural sources of water pollution, for example through starting training programmes on organic and ecological farming techniques include the use of nature-friendly fertilization and pest management, pesticide monitoring. Thirdly, by addressing loss of habitat/access to habitat that were caused by historic engineering projects or through ongoing land uses, including maintenance and restoration of riparian and basin vegetation, preserving favourable hydrological regimes when present, supporting natural water flow and river morphology conservation, improving habitat conditions, constructing new fish migration paths, improving the hydrological conditions of the dead river branches. Finally, by managing the multiple stakeholders involved in the river, for example working with fishing and angling groups to prevent the introduction of alien fish species, removing invasive fish species, collaborating with fishing sports societies in matters of stocking exotic species and preventing poaching, yearly official justification for restocking, initiating cross-border cooperation regarding fish populations assessment, monitoring and management, monitoring and controlling the exploitation of minerals including sand and gravel, and carrying out monitoring of the implementation of water works.

To preserve vital populations of Natura 2000 fish species in the Sutla River basin, the populations of target and key species like the ones listed above, should be extensively and intensively investigated.

One obvious way to address the need for monitoring of the river is to use existing monitoring stations and enlarge them to include studies on the target species in the Natura 2000 list. Sutla River has several stations where water chemistry is regularly monitored for nitrate (ammonium, nitrate, nitrite, total nitrogen, total phosphorus), heavy metals (Cu, Zn, Pb, Hg, Cr and Ni), nitrates, specific pollutants, dissolved macro elements (Na, K, Ca, Mg), dissolved trace elements (Al, As, Ba, Cd, Co, Cr, Cs, Cu, Fe, Li, Mn, Mo, Ni, Pb, Rb, Sb, Sn, Sr, Ti, Tl, U, and V), chemical state, microbes indicator (*Escherichia coli*, total coliforms, enterococci, heterotrophic bacteria), aquatic invertebrates, phytobenthos and macrophytes, BOD5 (biological oxygen demand), the ecological status (Lupinjak, Rogatec, Prišlin, Zelenjak, Harmica, Harmica, Rigonce, and Rakovec). However, we would recommend that the monitoring should be done on a river and basin scale rather than being restricted to within national borders, requiring cross-border agreements and standards.

For the identification of poor land and water management, and good or bad influences on the ecological state of the Sutla River biocoenosis, a second category of monitoring stations is needed, these to be permanent monitoring stations. These should be placed at the borders of the following municipalities on the Sutla River as follows: Đurmanec/Hum na Sutli, Hum na Sutli/Zargoska Sela, Zargoska Sela/Kumrovec, Kumrovec/Klanjec, Klanjec/Kraljevec na Sutli, Kraljevec na Sutli/Dubravica, Dubravica/Marija Gorica, Marija Goric/Brdovec.

A third category of sampling sites represents stations in which the presence of anthropogenic structures causes permanent modifications in the lotic habitats physical and/or chemical characteristics. A good example in this respect is the Zelenjak Dam area.

In the fourth category should enter those sections which did not fit in the previous three categories of sections, but which are necessary for range of the species monitoring.

This combination of various criteria for monitoring sections facilitates the detection of potentially problematic sectors for the target species and allows a proper managerial response at the local and/or basin level, which is especially important in periods of low/base-flow when the river typically experiences a build up of pollutants, which generally lasts approximately two thirds of the year.

CONCLUSIONS

There are seven fish species of conservation interest in the Natura 2000 site Sutla River in Croatia, each with different biological and ecological requirements, all affected by identified human impact pressures and threats. There are a range of possible different management aspects to consider, which this paper has outlined.

For *Eudontomyzon vladykovi, Barbus meridionalis* and *Zingel streber*, the position and impact of hydrotechnical works (dams, canals, etc.) that induce lotic fragmentation should be determined; hydrotechnical works negatively effects mitigation or removal in a way to allow upstream-downstream and downstream-upstream connection.

For *Rhodeus sericeus amarus*, the possibility of restoration of the river in the lower part of the flow should be considered: a move away from river embankment, towards re-establishment of a natural flooding regime, linking to stagnation in the period of flooding oxbows and dead branches restoration and maintenance.

For the species *Cottus gobio, Eudontomyzon vladykovi, Gobio uranoscopus, Gobio kesslerii, Rhodeus sericeus amarus, Barbus meridionalis, Zingel streber*, the following actions can have a positive impact: implementation of the Water Framework Directive, implementation of the Nitrates Directive, restoration and preservation of riparian zone woody vegetation (minimum 10 m) especially in areas of intensive agriculture, identification of the causes of the increased presence of mercury and mitigation options.

Important for the species *Cottus gobio, Eudontomyzon danfordi, Gobio uranoscopus, Gobio kesslerii, Rhodeus sericeus amarus, Barbus meridionalis, Zingel streber* are: planting and preservation of riparian zone vegetation (woody vegetation) with a minimum width of 10 meters along the watercourse, removal of existing artificial hydrological objects where possible, and a prohibition on removal sand and gravel from riverbeds.

Finally, all these fish species need updated research about the habitats quality and populations' structure and functions in order for good management to be designed and implemented.

Special attention should be focused on: water integrated management, too high water volume used for irrigations, riparian vegetation fragmentation, lack of collaboration among Croatian and Slovenian environmental institutions, pesticides use abuse, uncontrolled waste water discharging, pollution with different chemical substances and heavy metals, habitat fragmentation due to the banks embankments and channels, the presence of some invasive species and riverbed mineral exploitations, etc.

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SABANEJEWIA AURATA (DE FILIPPI, 1863) POPULATIONS MANAGEMENT DECISIONS SUPPORT SYSTEM FOR ROSCI0132 (OLT RIVER BASIN)

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KEYWORDS: golden spined loach, Natura 2000 site, management, Romania.

ABSTRACT

The ADONIS: CE was used to design a specific management model for the *Sabanejewia aurata* (De Filippi, 1863) populations. The proposed model is based on this species, in situ identified biological/ecological necessities in relation to the habitats, the conservation status indicators and appropriate management actions and the pressures and threats founded in the study area. Such on species, on habitats and on site based management system was done to complete this approach for ROSCI0132, the other fish species which are living there being treated already in this respect.

ZUSAMMENFASSUNG: Ein unterstützendes Entscheidungssystem für das Management der Populationen von *Sabanejewia aurata* (De Filippi, 1863) im Natura 2000 Gebiet ROSCI0132 (Einzugsgebiet des Olt/Alt Flusses).

ADONIS: CE wurde zur Entwicklung eines spezifisches Managementmodells für die Populationen von *Sabanejewia aurata* (De Filippi, 1863) verwendet. Das vorgeschlagene Modell stützt sich auf die biologisch/ökologischen Anforderungen dieser in situ festgestellten Art in Beziehung zu den Habitaten, Indikatoren des Erhaltungszustandes sowie die entsprechenden Managementmaßnahmen aber auch zu den Gefahren und Bedrohungen der Art im Untersuchungsgebiet. Dieses auf die Art, ihre Lebensräume und das Gesamtgebiet bezogene Managementsystem wurde zur Vervollständigung dieser Herangehensweise für das Natura 2000 Gebiet ausgearbeitet. Die anderen in dem Gebiet lebenden Fischarten von naturschutzfachlicher Bedeutung wurden von diesem Gesichtspunkt aus bereits behandelt.

REZUMAT: Sistem suport decizional de management al populațiilor de *Sabanejewia aurata* (De Filippi, 1863) pentru ROSCI0132 (bazinul râului Olt).

ADONIS: CE a fost utilizat pentru a proiecta un model de management specific pentru populaţiile de *Sabanejewia aurata* (De Filippi, 1863). Modelul propus se bazează pe necesităţile biologice/ecologice ale acestei specii identificate in situ în relaţie cu habitatele, indicatorii stării de conservare şi acţiunile adecvate de management, şi cu presiunile şi ameninţările identificate în aria studiată. Acest sistem de management bazat pe specie, habitate şi sit a fost realizat pentru completarea acestei abordări pentru ROSCI0132, celelalte specii de peşti de interes conservativ care trăiesc acolo au fost deja tratate din acest punct de vedere.

INTRODUCTION

With the concern of ensuring the survival of the vulnerable species of Europe, the European Union countries governments established an agreement with the Habitats Directive in 1992. Based on this international agreement, all these countries must ensure that the needed circumstances are met, for the conservation of the species and habitats included in Directive (Annex 2), along with the ultimate goal to protect and if is possible to increase their ecological status. The admission of Natura 2000 sites propositions depend on explicit criteria like the following: stable, unspoiled and healthful fish populations, advantageous geographic location, characteristic natural habitats and minor anthropogenic impact. There are some distinct directions through which the EU Natura 2000 network strategy intends to improve the member countries' nature quality like: the expanding of the natural areas space; boosting information; institutional capacity construction; proper field assessment; integrated monitoring and appropriate management actions in integrated management plans for the protected areas. (Bănăduc, 2007; Bănăduc et al., 2012)

Sabanejewia aurata (De Filippi, 1863) is a fish species of Community interest. It is a freshwater and demersal species, appearing commonly in the upper and middle sectors of the lotic systems. The existence of the sand substrata is an essential habitat characteristic. The food of this species consists of small macroinvertebrates. (Bănărescu, 1964; Bănărescu and Bănăduc, 2007)

The structure of the fish communities, where *Sabanejewia aurata* species is found, in Oltul Mijlociu-Cibin-Hârtibaciu Natura 2000 site (ROSCI0132) calls attention to relatively decreasing individual numbers as a result of the anthropogenic impact. The discontinuity on the area of this fish species and their relatively low abundance demonstrates the Olt Basin aquatic habitat's diminishing quality (Bănăduc, 1999, 2000; Curtean-Bănăduc and Bănăduc 2001, 2004; Curtean et al., 1999; Curtean-Bănăduc et al., 2007).

In the contemporary universal shift the lotic systems becomes more incalculable natural capital, the anthropogenic stress on it will reduce the human society use of it (Curtean-Bănăduc and Bănăduc, 2012).

If this trend will advance, any general management plan will not be adequate in dissimilar protected natural areas, as a matter of fact numerous and diverse habitat components should be initially investigated. As well, the adapted management aspects have to tailor and advocate the local habitats/species discrete situation.

Recently, the components of the modelling process are used more to obtain an "extensive image" of individual systems and/or actions of distinct spheres. The components of the process are helpful in discerning the process phases for a pragmatic and practical management. Essentially the modelling means are expressed by software products, which are used to design models of work organizations, and to expose data about the models. There are three major operations: confirm the current state, evaluate the consequences of potential modifications and recommend a program to adjust the current state in a needed way. Finally are proposed diverse methods to create diagrams which reveal particular management components (Hall and Harmon, 2005).

This study's goals are: to underline the current state of the populations of *Sabanejewia aurata* in ROSCI0132 area; to illustrate the present anthropogenic threats and pressures; and to recommend through management proposals the recovery of the fish species' conservation status based on a expressly designated model of management – which combine habitat preconditions of the fish species and habitat indicators as a decisional management system.

MATERIAL AND METHODS

The Natura 2000 site ROSCI0132 is located in the Romanian administrative areas (judeţe/counties) Sibiu, Braşov and Vâlcea (45.682778 latitude, 24.324444 longitude, 2826.10 ha surface, 314 and 568 a.s.l. m). This protected area is positioned in the Continental and Alpine European bio-geographic zones. It was proposed to include ten species of fish of conservative interest-species listed in the Annex 2 of the Habitats Directive (92/43/EEC), (*Sabanejewia aurata* De Filippi, 1863 – Natura 2000 code 1146, *Cobitis taenia*, *Barbus meridionalis*, *Pelecus cultratus*, *Zingel zingel*, *Zingel streber*, *Rhodeus amarus*, *Aspius aspius*, *Romanogobio kesslerii* and *Romanogobio uranoscopus*).

The river sectors of the researched zone where the species *Sabanejewia aurata* was found are shown in figure 1.

The *Sabanejewia aurata* individuals were sampled in 2010-2013, with fishing nets, identified and freed in their habitat.

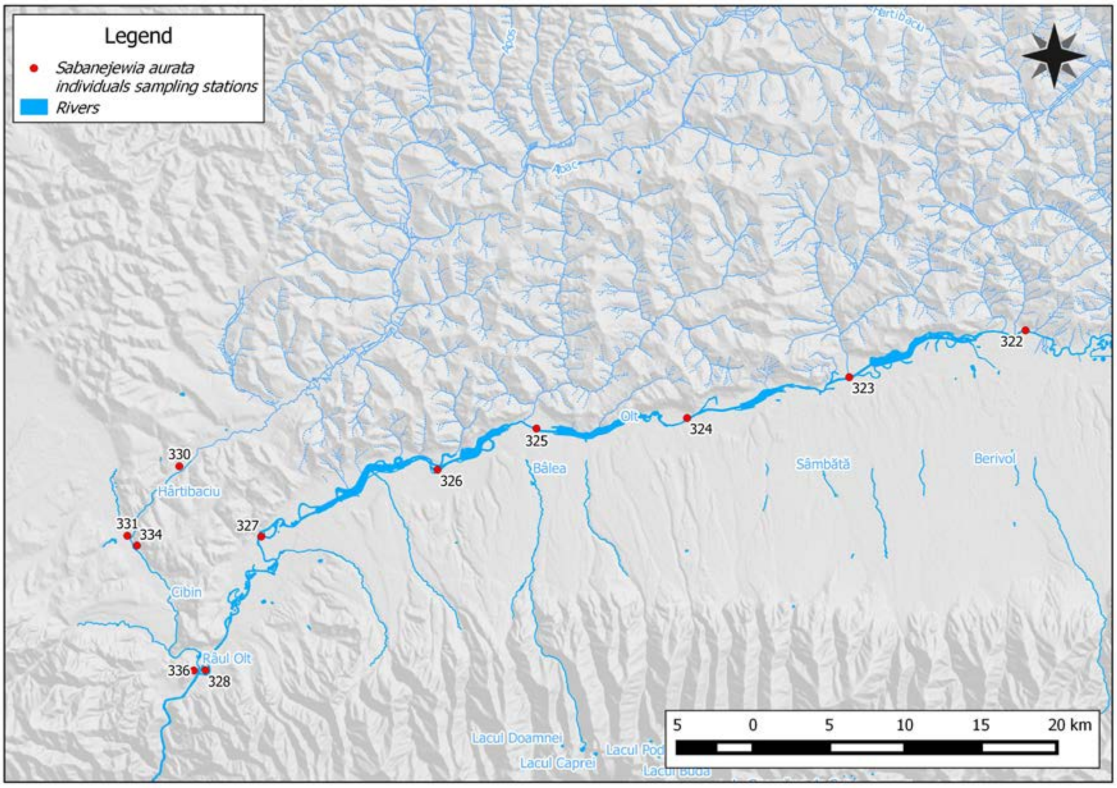

Figure 1: *Sabanejewia aurata* individuals sampling stations in: Cibin River (334 and 336), Hârtibaciu River (330 and 331) and Olt River (322, 323, 324, 325, 326, 327, 328) (Geographic Information System support Mr. Pătrulescu A.).

Sabanejewia aurata populations were under evaluation during this study period and their ecological condition was assessed in connection to the local anthropogenic pressures and threats on this species' habitats and populations.

The ecological condition of the fish population was assessed based on certain criteria: size of the area dispersal, balanced distribution of fish on age classes, population size and a high/low number of fish species individuals in the local communities.

The *Sabanejewia aurata* fish species habitat necessities, pressures, and threats were studied in relation with their status of existence, and the dependence between them and the fish conservation condition.

An adjusted management model was proposed in order to set up the proper management components that are anticipated to help in protecting the fish species that are present in the study area, in addition to emphasize the necessary process. For that reason, ADONIS:CE was tested, created by Business Object Consulting. ADONIS: Community Edition, a charge-less tool provided by the BOC Group, which can be use in taking efficient action as a point of access to Business Process Management. ADONIS:CE is an easy, stand-alone form of ADONIS with some constraints (in contrast with the commercial edition). Business Process Model and Notation (BPMN) is a standard modelling terminology which helps to bring light to particular processes. These processes can be modelled depending on consistent notation.

RESULTS AND DISCUSSION

Sabanejewia aurata populations ecological state assessment elements

The conservation state of *Sabanejewia aurata* in the **Olt** River sampling sectors (322, 323, 324, 325, 326, 327, and 328) (Fig. 1) can be classified as good in 322, 324, 325, 326 and 328 and low in 323 and 327 in the general background of: balanced distribution of fish individuals on age classes, population sizes, and an average percentage of individuals of this fish species in the local fish fauna structure. The aquatic habitats of the researched area fish communities are in an average conservation state, regarding the *Sabanejewia aurata* ecological necessities.

The conservation status of *Sabanejewia aurata* in the **Cibin** River sampling sectors (334 and 336) (Fig. 1) can be considered as good in 336 and low in 334. These aquatic habitats are in an average conservation state, in respect of *Sabanejewia aurata* ecological necessities.

The conservation state of *Sabanejewia aurata* fish species in the **Hârtibaciu** River sampling sectors (330 and 331) (Fig. 1) can be considered as good. The researched habitats are in an average state of conservation, in respect of *Sabanejewia aurata* ecological necessities.

Human pressures and threats

Research show that, the main pressure on *Sabanejewia aurata* species is water pollution. The identified threats are: water pollution, riverine lands erosion and the accentuated presence of mud in the riverbed as a result of the bad agricultural practices in the basin, the destruction of the riverine vegetation and/or the illegal waste dumps in the rivers' proximity. This can negatively affect this species trophic base and its necessary substrata for reproduction.

For the reason that the sectors that have appropriate environment conditions are decreasing due to anthropogenic impact, all the river sectors which presently provide good habitats are essential for this fish species' conservation status; and the destruction of these good habitats causes overpopulation, the creation of conditions for parasites, infections, illnesses and invasive fish species, and later the diminishing of the individuals' number.

Specific requirements

Generally, this species needs river sectors with relatively average water speed flow, a substrate that is formed of sand mixed with pebbles or pure sand and ligneous riparian vegetation. The reproduction occurs between May and July. Both the adults and juveniles are sensitive to pollution. (Bănărescu, 1964; Bănărescu and Bănăduc, 2007)

Specific habitat indicators

In the context of the *Sabanejewia aurata* presence/absence and abundance in the studied sectors, some habitat indicators are recommended: average speed flowing water surface percentages (50%), mixed sandy-pebbles (33%) or sandy substratum surface percentages (33%), river banks with riparian vegetation percentages (50%).

Management measures

The main management measures in this case are: keeping the natural morphology of the riverbed and banks, prohibit the abandonment of any kind of waste in the riverbed and surrounding wetlands of watercourses, implementation of an integrated monitoring system for ichtyofauna conducted by qualified/specialised personal.

Site adjusted management model

The onsite designated *Sabanejewia aurata* management model proposes a scheme of the species and the conditions which provide in with a good conservation status.

As a matter of fact, we modelled the ecological needs of the *Sabanejewia aurata* species applying the ADONIS:CE (Hall and Harmond, 2005) modelling tool and the elements are: activities (), decisions (), subprocesses (), variables () and generators (). The flow logic is displayed through the insertion of connectors, specifically through the relation “Subsequent” (⟶). Through this relation, which joins any object with the next object, the logical flow of this specific model can be identified (ADONIS:CE Help).

Figure 2 shows how management model is organised using two business process model (BPM): *Sabanejewia aurata 1* – which is the main model process and *Indicators and management measures 1* – which is a subprocess included in the basic process model.

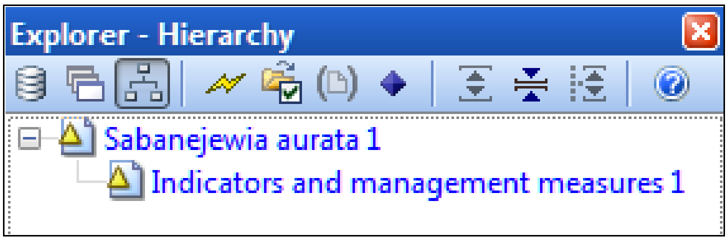

Figure 2: *Sabanejewia aurata* hierarchy models.

The basic process (is set of activities, subprocesses, decisions to be followed in order) presents the ecological requirements fact sheet of the species and is named *Sabanejewia aurata* 1 (Fig. 3). The objects used to model this process are: six activities () presents the steps of a process and fields as description, comments; can also be attached via supporting documents to certain activity, one subprocess (allows sub-structuring for easy browsing) and one decision (forms of verification) with variable and generator () variable represents the indicator name and through generator (). We assigned the percentage, obtained on the field during measurements, for an indicator that ensures favourable preservation status.

The first three activities describe the **habitat characteristics**, its **specific requirements** and also the **field observations**. Following the subprocess **“Indicators and management measures”** where possible indicators are browsing from one to another to see if the percentage obtained on the ground is the same one that provides a favourable conservation status, and also what management measures are to be taken. The main process continues with the decision **“The conservation state is favourable?”**, that verifies whether or not the species is in favourable conservation status. If it goes on “Yes” branch (**“Conservation_state = Yes”, Probability = 99%**), the process continues with three activities which present additional characteristics of the species (**other ecological requirements**, which is the **breeding period**, highlighting the main **pressures and threats** of the species) and the process is completed (●). If the species does not meet the condition of being in favourable conservation status (the “No” branch – **“Conservation_state = No”, Probability = 1%**), then returns to activity **Specific requirements** and repeat until the species has a favourable conservation status (our aim is to preserve the species).

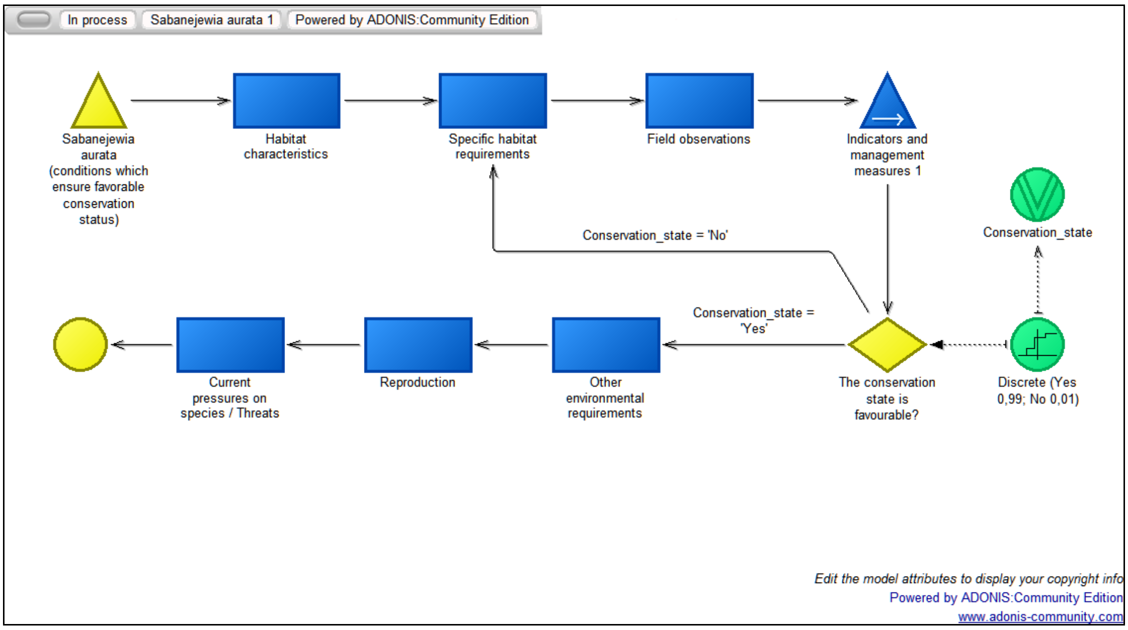

Figure 3: *Sabanejewia aurata* – main process.

As mentioned earlier, the second process modelled is subprocess *Indicators and management measures* for *Sabanejewia aurata* species (Fig. 4) and is called from basic *Sabanejewia aurata* model process. The subprocess has the same characteristics as a process – in which it is checked if possible indicators (measured on the ground) ensure favourable conservation status of the species.

The subprocess was modelled using four decisions (possible indicators measured) and three activities that represent the management measures to be taken to ensure the species conservation. For each decision we have a variable and a generator.

Each generator was assigned the percentage for each indicator that ensures the favourable conservation status. As a result of the decision, if it goes on the "Yes" branch (e.g.: "The actual state of sandy substrate weight is 33%?, Sandy_substrate = Yes", Probability = 90% or "The actual state of average water speed flow is 50%?", Water_speed_flow = "Yes", Probability = 80%), then proceed to the next decision/indicator. If the percentage does not fit into the standards of conservation (e.g.: "The actual state of sandy substrate weight is 33%?", Sandy_substrate = "No", Probability = 10% or "The actual state of average water speed flow is 50%?", Water_speed_flow = "No", Probability = 20%), using the parallelism ( ) and merging ( ) are presented the management measures that are to be taken to ensure the well-being/welfare of the species: keeping natural morphodynamics of riverbeds, prohibit the abandonment of any kind of waste in the river bed and wetlands surrounding watercourses. The process finishes with the activity implementation of an integrated monitoring system for ichtyofauna performed by qualified/specialized staff (which is also a measure of management).

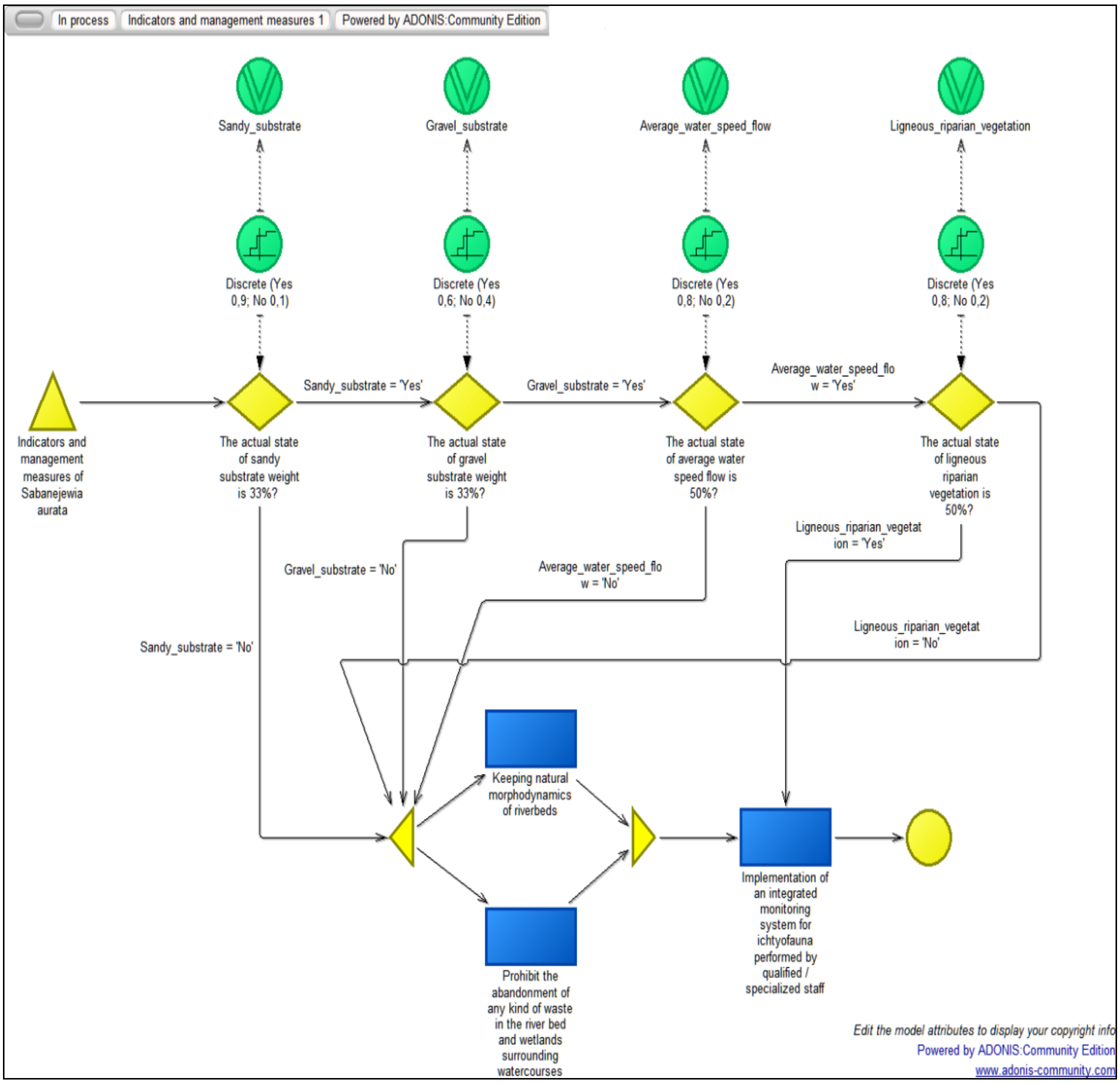

Figure 4: Indicators and management measures for *Sabanejewia aurata* species.

CONCLUSIONS

In order to have a favorable conservation status in ROSCI0132 Natura 2000 site for *Sabanejewia aurata* the principal identified threats to this fish species are: water pollution, riverine land erosion and riverbed over silting with mud. The identified pressure was the water pollution.

Important issues that need to be addressed for the *Sabanejewia aurata* fish species conservation are: preservation the natural morphology of the riverbed and banks, ban the abandonment of waste in the riverbed and neighboring wetlands of rivers, creation of an integrated monitoring system for fish fauna coordinated by competent persons.

In this research, an indispensable management model in order to back the *Sabanejewia aurata* populations in a specific site (ROSCI0132 Natura 2000 site) was created.

The ADONIS:CE was used in this research in the nature concervation context, indicating a management model of *Sabanejewia aurata* that enclose its most important needs in relation to the habitat, the indicators that describe a favorable ecological status – the appropriate management to avoid and/or eliminate the pressures and threats which distress this fish species populations.

If the proposed management aspects will be not implemented, *Sabanejewia aurata* will have a decreasing conservation status in the next 10-20 years in the researched area.

This specific on-site, on-habitats and on-species management elements sustaining model for *Sabanejewia aurata*, should be incorporated in an integrate management model for the ROSCI0132 site ichthyofauna.

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MANAGEMENT OF ALLUVIAL FORESTS INCLUDED IN NATURA 2000 91E0* HABITAT TYPE IN MARAMUREŞ MOUNTAINS NATURE PARK

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KEYWORDS: alluvial forests, habitat management, riverbanks, sediments.

ABSTRACT

The Natura 2000 habitat type 91E0* Alluvial forests of *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) include three subtypes of forests. In the Maramureș Mountains Nature Park (MMNP) the alluvial forests are represented by *Alnus incana* forest situated on the banks of mountain rivers. Starting from 2007, 70% of the MMNP is also a Natura 2000 site of community interest. In the standard form for the site are listed 18 Natura 2000 habitat types, but that of alluvial forests 91E0* is not listed either due to an error or lack of available research data. Our study seeks to provide information regarding this high conservation value habitat such as: structure, distribution, management measures and monitoring protocol. The purpose of this paper is to offer a management tool for this conservation value habitat which is also exposed to human impact more than any other priority habitat in MMNP.

RÉSUMÉ: Gestion des forêts alluviales faisant partie du type d'habitat Natura 2000 91E0* dans le Parc Naturel des Montagnes de Maramureș.

Le type de habitat Natura 2000 91E0* des Forêts alluviales avec *Alnus glutinosa* et *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) regroupe trois catégories de forêts, les forêts alluviales du Parc Naturel Les Montagnes de Maramureș (PNMM) étant principalement représentées par des aulnes blanches, *Alnus incana*, situées au bord des rivières. Depuis 2007, 70% de la surface du PNMM fait partie du site Natura 2000 ROSCI Les Montagnes Maramureș. Dans le formulaire standard du site existent 18 habitats Natura 2000, mais l'habitat 91E0* Forêts alluviales avec *Alnus glutinosa* et *Fraxinus excelsior* n'en fait pas partie, probablement à cause d'une erreur ou de l'absence d'études détaillées dans la région. Grâce à cette étude nous souhaitons contribuer avec des informations sur: la structure, la distribution, le suivi de gestion et la surveillance de cet habitat à haute valeur de conservation. Le but du présent travail est de fournir des outils de gestion pour cet habitat qui fait partie des habitats prioritaires les plus exposés à l'impact anthropogénique.

REZUMAT: Managementul pădurilor aluviale incluse în Habitatul Natura 2000 de tip 91E0* din Parcul Natural Munţii Maramureşului.

Tipul de habitat Natura 2000 91E0* Păduri aluviale cu *Alnus glutinosa* și *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) include trei subtipuri de păduri, în Parcul Natural Munții Maramureșului (PNMM) pădurile aluviale fiind reprezentate în principal de aninișuri de anin alb, *Alnus incana*, situate pe malurile râurilor. Începând din anul 2007, 70% din suprafața PNMM este inclusă în situl Natura 2000 ROSCI Munții Maramureșului. În formularul standard al sitului sunt incluse 18 habitate Natura 2000, dar habitatul 91E0* Păduri aluviale cu *Alnus glutinosa* și *Fraxinus excelsior* nu este inclus, probabil din cauza unei erori sau din lipsa studiilor în zonă. Prin acest studiu dorim să contribuim cu informații precum: structura, distribuția, măsuri de management și monitorizare a acestui habitat cu valoare ridicată de conservare. Scopul lucrării este de a oferi instrumente de management pentru acest habitat cu valoare conservativă, care este și cel mai expus impactului uman dintre habitatele prioritare.

INTRODUCTION

The "Habitats" Directive (Council Directive 92/43/EEC) is a European Community legislative instrument in the field of nature conservation that establishes a common framework for the conservation of wild animal and plant species and natural habitats of Community importance; it provides for the creation of a network of special areas of conservation, called Natura 2000, to "maintain and restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest". Annex I of "Habitats" Directive lists today 218 European natural habitat types, including 71 priority habitat types. In the meaning of the directive, priority habitat is a habitat type in danger of disappearance and whose natural range mainly falls within the territory of the European Union (***, 2003).

The object of our study is the priority habitat type 91E0* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) in Maramureș Mountains Nature Park and Natura 2000 site of community interest site.

Starting with the CORINE Programme, the term habitat has become familiar in Europe: *senso stricto*, it means place of life, representing the abiotic environment where a distinct organism or biocoenosis exists. This environment is a geotope with a correspondence to an ecotope. This ecotope transformed by the biocoenosis is a biotope. The habitat is defined by this meaning in classic biology and ecology works. However, the meaning of habitat given by the CORINE programme and then by the other classification systems which followed, was, in fact, an ecosystem, that is a "habitat" *senso stricto* and the corresponding biocoenosis which occupies it (Doniţă et al., 2005, 2006). This evidently results from the name and description of the habitat types where references are made not only to the features of the ecotope, but especially to those of the biocoenoses occupying the respective sites (Gafta and Mountford, 2008). In this paper we will use the term habitat with the meaning given by the Habitats Directive and by Doniţă et al., 2005.

Maramureș Mountains Nature Park is one of the largest nature parks in Romania (133,354 ha), declared as a protected area by the Governamental Decision 2151/2004 and it has its own administration starting from 2005. Maramureș Mountains Nature Park is a protected landscape IUCN Category V, created to protect and sustain important landscapes and the associated nature conservation and other values created by interactions with humans through traditional management practices.

Protected landscape is defined by IUCN Global Protected Areas Programme as a protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.

Starting from 2007, about 70% of MMNP is also Natura 2000 site of communitarian interest. In the standard form of the site are listed 18 Natura 2000 habitats, but the habitat of alluvial forest 91E0* is not listed due to an error or due to the lack of available research. Our study comes to provide information regarding this high conservation value habitat such as: structure, distribution, management measures and monitoring protocol.

For an appropriate management of a nature park, the internal zoning is needed. It includes special conservation zone, where no human interventions are allowed, the sustainable management area where the nature resources are managed in a traditional way and the human activities sustainable development area which includes the human communities. The alluvial forests in MMNP are mostly situated in the area of human activities sustainable development area where the anthropic pressure is increased.

By our current study we intended to offer the park administration a management tool for this habitat. So we elaborated a distribution map, described the structure of this habitat, identified anthropic pressures, developed a set of management recommendation and a monitoring protocol in order to monitor its conservation status in time.

We also provided a template for a data collection form which helps in standardisation and easy interpretation of data.

The purpose of this paper is to provide a management tool for this high conservation value habitat which is also exposed to human impact more than any other priority habitat in MMNP.

MATERIAL AND METHODS

Identification of habitat types was performed by the recognition of phytocoenoses that characterises them. That means by considering the significant (generally prevailing) species and ecological and/or coenological markers, as well as by recognition of the characteristics of the site, first by geographical location, altitude, relief, rock and soil.

By mapping the habitat types, we employed the following cartographic materials: Ortophotoplans, satellite images, topographic maps (1:25,000), forest maps (1:20,000 and 1:50,000). The information on these maps has been transposed into a GIS (Geographical Information System) system. We set the limits of the habitats to the changes of the phytocoenoses and sites characterizing them. The positioning of habitats on the map is performed by means of the GPS coordinates collected from the field, by using the GPS Trimble ProXH receptor with a zephir antenna and GPS Trimble ProXT. The data were processed in ArcGIS 9.3 programme.

We proposed a monitoring protocol in order to evaluate the evolution of the habitat in time and also to evaluate the effectiveness of implementing the management plan. The protocol is directly oriented to the reality in the field and is designed according to the MMNP Administration resource, human and material. Some management measures are recommended in order to assure the maintenance of the conservation status of this habitat type or improve it.

RESULTS AND DISCUTION

At national level the priority Natura 2000 habitat 91E0* Alluvial forests of *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) includes three subtypes of forests: first, forest of *Alnus gutinosa* and *Fraxinus excelsior* situated in wet meadows in the plains and hills vegetation floor; second, *Alnus incana* forest situated on banks of mountain rivers; and, third, wooded galleries composed of tall trees of the species *Salix alba, S. fragilis* and *Populus nigra* along rivers of the mountains, foothills and plains. In our study area we identified the first two habitat types in the field (Danci, 2011).

Habitat description

91E0*Alluvial forest with *Alnus glutinosa* and *Fraxinus excelsior* – R4401 South-East Carpathian forest of grey alder (*Alnus incana*) with *Telekia speciosa* habitat subtype

Corresponds to:

NATURA 2000: 91E0*Alluvial forest with *Alnus glutinosa* and *Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)*

EMERALD: –

CORINE: –

PAL.HAB: 44.214 Eastern Carpathian grey alder galleries

EUNIS: G1.1214 Eastern Carpathian grey alder galleries

Plant associations: *Telekio speciosae-Alnetum incanae* Coldea (1986) 1991

Distribution in Maramureș Mountains Nature Park: The phytocoenoses of the association *Telekio speciosae-Alnetum incanae* were identified and mapped in the riverbed of Bistra, Frumuşeaua, Repedea and Rica valleys (Fig. 2); the mapping process continues in the park area (Fig. 4).

Structure: The phytocoenoses are identified by boreal and European species. The tree layer is exclusively composed of grey alder (*Alnus incana*) with a few examples of spruce (*Picea abies*), fir (*Abies alba*) and beech (*Fagus sylvatica*). The coverage is aproximatively 80-100% and the height is 15-25 m at the age of 50. The shrub layer, which is missing or poorly developed, includes *Salix triandra*, *Corylus avellana*, *Lonicera xylosteum* and *Prunus padus*. The herb layer is well developed, and dominated by *Petasites albus* and *Telekia speciosa* (Fig. 1) (Doniţă et al., 2005).

Figure 1: *Telekia speciosa*.

Conservation value: very high.

Composition:
– Identifying species: *Alnus incana.*
– Characteristic species: *Telekia speciosa.*
– Other important species: *Angelica sylvestris, Aegopodium podagraria, Athyrium filix-femina, Carex remota, Cardamine impatiens, Chaerophyllum hirsutum, Circaea lutetiana, Cirsium oleraceum, Dryopteris filix-mas, Glechoma hederacea, Geranium phaeum, Festuca gigantea, Impatiens noli-tangere, Mentha longifolia, Myosotis sylvatica, Matteuccia struthiopteris, Oxalis acetosella, Petasites hybridus, P. kablikianus, Ranunculus repens, Salvia glutinosa, Stachys sylvatica, Stellaria nemorum, Tussilago farfara*, etc.

Figure 2: Grey alder forest in Rica Valley, Maramureș Mountains Nature Park.

91E0* Alluvial forest with *Alnus glutinosa* and *Fraxinus excelsior* – R4402 Forest of black alder (*Alnus glutinosa*) with *Stellaria nemorum* on hilly meadows habitat subtype.

Corresponds to:
NATURA 2000: 91E0*Alluvial forest with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)
EMERALD: –
CORINE: –
PAL.HAB: 44.323 Pre-Carpathian stream ash – alder woods
EUNIS: G1.2123 Pre-Carpathian stream ash – alder woods
Plant associations: *Stellario nemori-Alnetum glutinosae* (Kästner 1938) Lohm. 1957

Distribution in MMNP: Phytocoenosis of plant association *Stellario nemori-Alnetum glutinosae* were identified on 44 ha on the riverbed of Vaser Valley (Fig. 3) and Novăț Valley (Fig. 4).

Structure: Phytocoenoses are identified by European nemoral species and boreal species. The tree layer comprises black alder (*Alnus glutinosa*) exclusively or mixed with narrow-leaved ash (*Fraxinus angustifolia*), white elm (*Ulmus laevis*), black and white poplar (*Populus nigra*, *P. alba*), willows (*Salix fragilis, S. alba*) and field maple (*Acer campestre*). The coverage is around 70-80% and the height is 20-25 m at 100 years old. The shrub layer is moderately developed and is made up of *Cornus sanguinea*, *Sambucus nigra*, *Corylus avellana, Viburnum opulus, Crataegus monogyna* and *Humulus lupulus*. The herb and subshrub layer often contains *Rubus caesius* and *Aegopodium podagraria.*

Conservation value: very high.

Species composition:

– Identifying species: *Alnus glutinosa*.

– Characteristic species: *Alnus glutinosa*, *Stellaria nemorum*, *Ranunculus ficaria*.

– Other important species: *Agrostis stolonifera*, *Bidens tripartita, Brachypodium sylvaticum, Carex remota, Circaea lutetiana, Eupatorium cannabinum, Galium aparine, Glecoma hederacea, Geranium robertianum, Impatiens noli-tangere, Lamium galeobdolon, Matteuccia struthiopteris, Mentha longifolia, Myosotis scorpioides, Petasites albus, Ranunculus repens, Salvia glutinosa*, *Sambucus ebulus*, *Solanum dulcamara*, *Tussilago farfara*, etc. (Doniţă et al., 2005).

Figure 3: Black alder trees in the Vaser Valley.

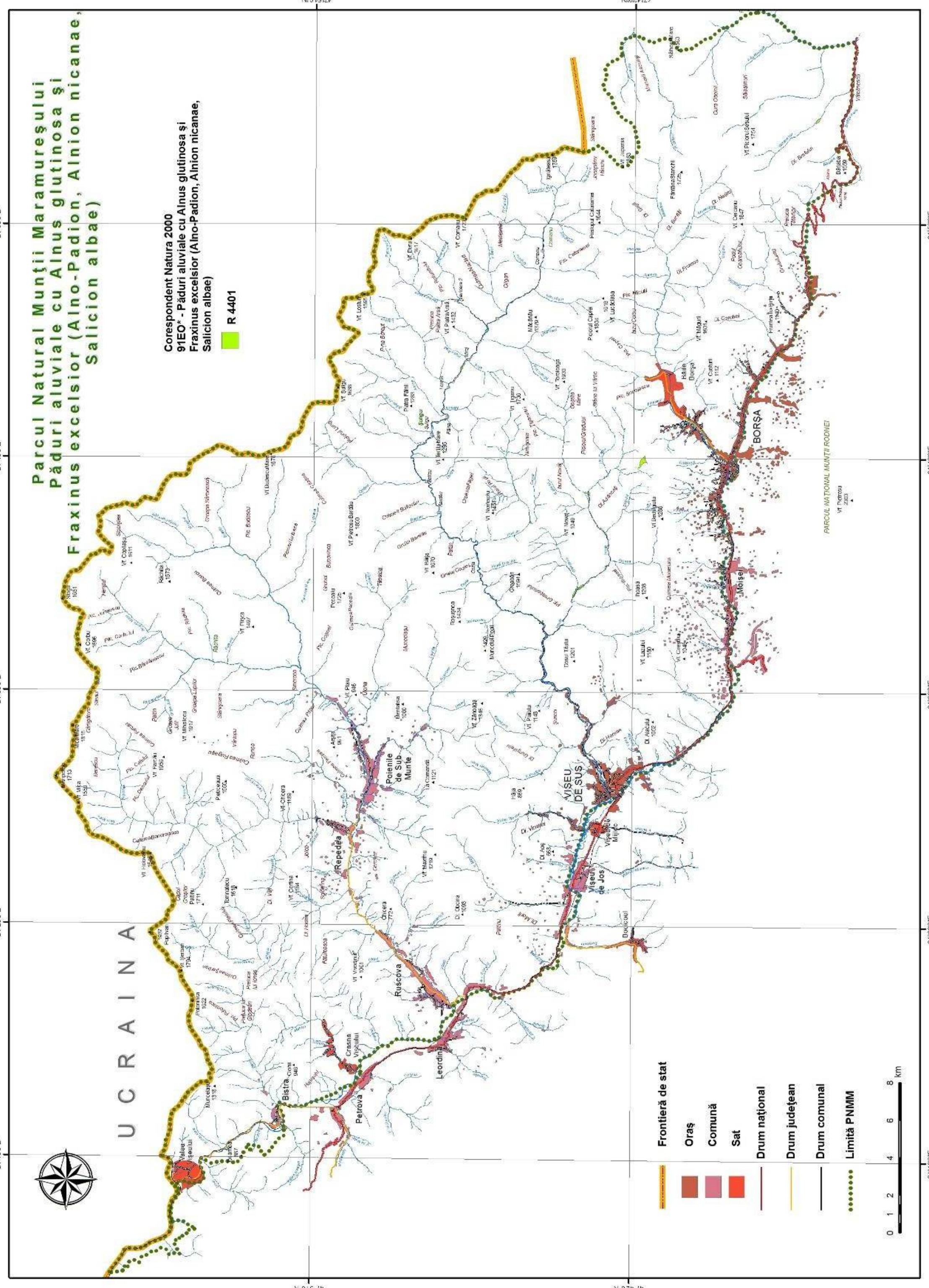

Figure 4: Partial distribution map of alder alluvial forest in Maramureș Mountains Nature Park.

Monitoring

Alluvial forests of alder have high conservation value not on account of the species that identify this habitat, but due to the functions of the habitat such as: flood prevention and regulation, an ecological corridor for large mammals, a feeding and nesting habitat for bird species. The presence of this habitat is directly related to the presence of water floods and new sediment deposits. Due to the fact that most of the alluvial forest included in 91E0* habitat in Maramureș Mountains Nature Park is situated in the human communities development area and also due to its high conservative value, we decided to provide instruments for monitoring the conservation status of this habitat. The evolution of conservation status is the reflection of the effectiveness of the management of the park (Elzinga et al., 2001). The monitoring protocol (Tab. 1) is designed to fit to the conditions of MMNP and it is adapted to the human and material resources of the park administration.

Table 1: Alder alluvial forest monitoring protocol in Maramureș Mountains Nature Park.

Protocol number	**3 (for MMNP)**
Title	**Alder alluvial forest monitoring protocol**
Priority	1
Monitoring question	Is the conservation status of alder alluvial forest maintained in MMNP?
Indicator	Presence of plant association characteristic to 91E0* habitat type, edifying species, characteristic species.
Justify	The habitat of alluvial forest with *Alnus glutinosa* and *Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)* is a priority habitat at European level. It has an important role in fixing the sediments, gravels, riverbank stabilisation, prevention or minimising the effect of floods.
Attributes	Modifies in species composition.
Sampling protocol	
Number of sampling plots	Three sampling plots on every important water course riverbanks in MMNP.
Distribution and selection of sampling plots	Along the riverbanks, where the surface is enough.
Sampling size	20 x 20 m
Sampling plots location	The GPS coordinates of the sampling plots will be recorded and marked on the map. It is recommended to mark on the field the corners of the sampling plot with wooden sticks.

Table 1 (continued): Alder alluvial forest monitoring protocol in Maramureș Mountains Nature Park.

Data collection protocol	
Detailed information related to the data that will be collected	Species composition, anthropisation degree, regeneration degree.
Data collection format	Format is standard, the data collection sheet is an annex of this protocol (Tab. 2)
Quality assurance and standardisation	The same staff will collect data at every survey on all valleys.
Frequency and period of collecting data	Once per year.
Data management and analyse	
Data storage and management of information	Data will be stored both on paper (data collection field sheet) and electronic (.xls) format. Additional copies will be kept in safe place.
Data analyse procedure	The data collected will be annually analysed.
Reporting format and results communication to the management	A report regarding the conservation status of the habitat will be elaborated annually. It will include a map with the sampling plots marked. According to the result, the park biologist will elaborate management recommendations. The report will be short and compendious.
Resources allocation	
Human resources	The MMNP biologist and two rangers.
Time resources	20 field days and five days for data analyse and reporting.
Equipment	Car, fuel, maps, GPS, photo camera, plant identification guide
Maintenance and calibration of equipment	The responsibility for maintenance and calibration belongs to the monitoring team.

Table 2: Annex to the protocol 3. Data collection sheet for evaluation of the conservation status on alder alluvial forest.

<table>
<tr><td colspan="6">Data collection sheet for evaluation of conservation status on alder alluvial forest.</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Date:</td><td colspan="5"></td></tr>
<tr><td>Observers name:</td><td colspan="5"></td></tr>
<tr><td>Code Natura 2000 site</td><td>Name of protected area</td><td>County</td><td colspan="3">Land owner</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td>State/ private</td><td colspan="2">Name</td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td>OS (forest department)</td><td>UP (production unit)</td><td>UA (administrative unit)</td><td>Forest type code</td><td>Natura 2000 habitat code</td><td>Romanian habitat code</td></tr>
<tr><td></td><td></td><td></td><td></td><td>91E0*</td><td></td></tr>
<tr><td>ZPI (special conservation zone)</td><td></td><td>ZMD (sustainable management area)</td><td></td><td>ZDD (human activities sustainable development area)</td><td></td></tr>
<tr><td>GPS Coordinates</td><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td>Surface (20 x 20 m)</td><td>Surface affected by human activities %</td><td colspan="4">Destabilising factors</td></tr>
<tr><td rowspan="3"></td><td></td><td colspan="4"></td></tr>
<tr><td></td><td colspan="4"></td></tr>
<tr><td></td><td colspan="4"></td></tr>
<tr><td colspan="2">Trees Layer</td><td colspan="3">Coverage (1-100%)</td><td></td></tr>
<tr><td colspan="2">Alive trees</td><td colspan="4">Dead trees</td></tr>
<tr><td rowspan="2">Species name</td><td rowspan="2">%</td><td rowspan="2">Species name</td><td rowspan="2">%</td><td colspan="2">Number</td></tr>
<tr><td>vertical</td><td>At soil level</td></tr>
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<tr><td colspan="2">Shrubs layer and coppice</td><td colspan="3">Coverage (1-100%)</td><td></td></tr>
</table>

Table 2 (continued): Annex to the protocol 3. Data collection sheet for evaluation of conservation status on alder alluvial forest.

Shrubs		**Coppice**			
Species name	%	Species name		%	regenerated (no.)
Herbs layer		Coverage (1-100%)			
Native species		Alien invasive species			
Animals					
Name	Presence	Marks	Spreading	Crossing	Resident
Observations					
Photos					

In order to establish the conservation status of one habitat or species it is necessary to establish some parameters that will be analysed. For alluvial forests of grey and black alder in MMNP we selected, according to Stăncioiu et al. (2008), and adapted some parameters to the specific of this priority habitat and to the specific of the study area.

In table 3 we proposed some parameters in order to interpret the data collected in the field for the conservation status evaluation. These parameters represent quantifiable indicators that can be used by the park administration.

If all parameters are according to the accepted limit, we can accept that the conservation status is at least good. If one or a few parameters are exceeding the limits, the conservation status should be determined in accordance with the importance of the parameter and proportionally to the destabilisation.

Table 3: Indicators used for data interpretation (Stăncioiu, 2009 – modified).

Parameters	Observations	Accepted level
Surface		
Surface dynamics	Habitat loss	maxim 5%
Trees layer		
Species composition	According to the identifying plant association	Minim 70%
Non-native species	% in the composition	Maximum 20%
Regeneration	Seeds	minimum 40%
Coverage	canopy	Minimum 70%
Number of dead trees	vertical	Minimum one dead tree/ha
Number of dead trees on putrefaction	At soil	Minimum one dead tree/ha
Seedling		
Species composition	According to the identifying plant association	Minimum 70%
Coverage	Canopy and seedlings	Minimum 70%
Non-native species	% in the composition	Maximum 20%
Regeneration	Seeds	minimum 50%
Coppice		
Species composition	According to the identifying plant association	Minimum 70%
Non-native species	% in the composition	Maxim 20%
Herbs layer		
Species composition	According to the identifying plant association	Minimum 70%
Non-native species Invasive alien species	% in the composition	Maxim 20%
Disturbances		
Stress factors, limitative situations.	% of surface affected	Maxim 10%

CONCLUSIONS

The priority habitat 91E0* Alluvial forest with *Alnus glutinosa* and *Fraxinus excelsior* is represented in Maramureș Mountains Nature park by two of the three habitats subtypes in Romania: R4401 South-East Carpathian forest of grey alder (*Alnus incana*) with *Telekia speciosa* and R4402 Forest of black alder (*Alnus glutinosa*) with *Stellaria nemorum* on hilly meadows.

The structure and distribution of the habitat in MMNP represents the basis for elaborating the monitoring protocol. The monitoring protocol that we have elaborated is designed to fit the parks needs to increase the conservation status. A data collecting sheet was done in order to assure the standardisation of the process of data collection and to assure more accurate data from the field. We also analysed some parameters that can help in order to interpret the data collected in the field and to establish the conservation status of the habitat. Monitoring protocol, data collection sheet and indicators used in data interpretation were tested by us in the field.

Even if the 91E0* Habitat is not listed in the standard form of Natura 2000 Maramureș Mountains communitarian interest site, it exists in the field and its importance and conservation value are very high. Monitoring instruments provided by this paper can be used by the MMNP Administration for monitoring and management of this habitat and can be included in reviewed Maramureș Mountains Nature Park Management Plan.

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DETERMINING THE REFERENCE EPHEMEROPTERA COMMUNITIES IN THE EASTERN PART OF THE BLACK SEA REGION FOR THE IMPLEMENTATION OF THE WATER FRAMEWORK DIRECTIVE IN TURKEY

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ABSTRACT

In this study, we aimed to determine the reference sites and their reference Ephemeroptera communities according to the Water Framework Directive methods in the Eastern Part of the Black Sea Region of Turkey between 2008-2011. From the area, twenty-four collecting sites were chosen. There were thirty Ephemeroptera species identified, belonging to seven families and eleven genres. Cluster analysis based on Bray-Curtis similarities was applied. Reference habitat conditions of the studied sites and their reference Ephemeroptera communities were determined by combining both ecological and statistical results. As a result, sixteen sites had reference habitat conditions and their reference Ephemeroptera species were identified.

RÉSUMÉ: Déterminer les communautés de référence des Ephéméroptères dans la partie est de la région de la Mer Noire pour implémenter la Directive Cadre de l'Eau en Turquie.

Dans cette étude, nous avons cherché à déterminer les sites de référence et les communautés de référence d'Ephemeroptera selon les méthodes préfigurées par la Directive Cadre de l'Eau dans la partie orientale de la région de la Mer Noire de la Turquie entre 2008-2011. Vingt-quatre sites d'échantillonnage ont été choisis dans la région. Une trentaine d'espèces d'Ephemeroptera ont été identifiées, appartenant à sept familles et onze genres. L'analyse de cluster basée sur des similitudes de Bray-Curtis a été appliquée. Les conditions d'habitat de référence des sites ont été étudiées et leurs communautés de référence des Ephemeroptera ont été déterminées en combinant à la fois les résultats écologiques et statistiques. En conséquence, seize sites présentaient des conditions d'habitat de référence et leurs espèces Ephemeroptera de référence ont été identifiées.

REZUMAT: Determinarea comunităţilor de efemeroptere de referinţă, în partea estică a regiunii Mării Negre pentru implementarea Directivei Cadru Apă în Turcia.

Acest studiu are ca scop identificarea siturilor de referinţă conform Directivei Cadru Apa, din perspectiva structurii comunităţilor de efemeroptere şi a habitatelor carecteristice pentru acestea, din partea de Est a regiunii Mării Negre a Turciei. Studiul s-a derulat în perioada 2008-2011. Au fost alese 24 de staţii de prelevare a probelor din aria de referință. S-au identificat 30 de specii de efemeroptere, aparținând la şapte familii și unsprezece genuri și s-a aplicat analiza Cluster bazată pe similaritățile Bray-Curtis. Datele ecologice și statistice au fost utilizate pentru a determina condițiile de habitat și structura comunităţilor de referinţă. Rezultatul arată că şaisprezece dintre situri au respectat condițiile de habitat pentru speciile de efemeroptere, în aceste situri au fost identificate speciile indicatoare de stare favorabilă a sistemului acvatic, cu succes.

INTRODUCTION

The European Union Water Framework Directive (WFD) is a legislation which aims to achieve at least a good ecological quality of all surface and groundwater ecosystems for all member states of the union by 2015 (Council of European Communities, 2000). According to this directive, all member states have to change their water management plans, especially on river basins. Aquatic ecology and the reference site concept are on the basis of these management plans in WFD (Council of European Communities, 2000). It is emphasized that water is not a commercial product, it is a necessary source that should be cared for and protected. The aims of the WFD could be summarized as: prevention of devastation on aquatic ecosystems, improvement of aquatic ecosystems' health, and long-term protection of the present water resources (Van Wijk et al., 2003).

The concept of "River Basin Management" is a new and very important approach for the member states of the EU because water bodies are not evaluated according to the governmental and political borders, but rather divided into river basins according to natural, geographical and hydrological basis (Çoşkun, 2010).

Turkey is conducting accession negotiations with the EU as the environment constitutes one of the significant areas in aquis communautaire. Turkey, as a candidate country, is obliged to get in line with the WFD in time for membership. In this concept, there have been many studies carried out by the Ministry of Forestry and Water Affairs of Turkey. Twenty-five river basins were specified in Turkey, and the Eastern Part of the Black Sea Region is one of them.

Benthic macroinvertebrates, especially aquatic insects, have great importance in aquatic ecology (Rosenberg and Resh, 1993; Clarke et al., 2013). Aquatic insects can be found in almost all kinds of freshwater ecosystems. Many orders are sensitive to water quality such as Ephemeroptera, Plecoptera, Odonata, Trichoptera, Coleoptera, etc. Ephemeroptera is the most important insect order in running water ecosystems (Bănăduc and Olosutean, 2013; Buffagni et al., 2001; Moog et al., 1997). There are many indicator species of clean and undegraded freshwater habitats in this order (Metcalfe, 1989; Hubbard and Peters, 1978). Many of them are very sensitive to organic pollution, physical degradation and habitat loss.

In this study, the Eastern Part of the Black Sea Region of Turkey was chosen; the reason being that there are several mountain running waters in this region and Ephemeroptera fauna of this area is very rich compared to the other parts of Turkey. This region is also important because of the Caucasian Biodiversity Hotspot (Kazancı, 2013; Türkmen and Kazancı, 2015; Kazancı et al., 2011, 2013). The running waters in this region are generally unpolluted and many of them can be accepted as reference sites. However, investments and activities in tourism have recently been increasing in this region. Increasing tourism activities are starting to bring urbanization as well. Furthermore, and possibly the most devastating, there are many hydroelectric power plants already constructed on some running waters and many of them are planned for construction.

All of these factors are affecting the area in terms of the loss of aquatic habitats, reference sites and aquatic communities, (especially the Ephemeroptera species). Many Ephemeroptera species may face the danger of extinction. For this reason, determining the reference Ephemeroptera communities in this region has a great importance for the future of aquatic ecosystem studies. The knowledge about these communities gives us an opportunity for the comparative studies and the preparation of biotic indices for the region.

MATERIAL AND METHODS

In this research, 24 sites were examined in some streams in the Eastern Part of the Black Sea Region of Turkey between 2008 and 2011. Benthic macroinvertebrate samples were collected from these sites by standard kick-net and kept in 4% formaldehyde solution. After the samples were brought to the laboratory, they were washed and the Ephemeroptera individuals were separated and kept in an 80% ethyl alcohol solution. All Ephemeroptera individuals were identified to species level.

Habitat characteristics and stream zonation of the sites were given. Cluster analysis (Bray-Curtis Similarity) was applied to compare the sites in terms of their Ephemeroptera species composition and habitat type. Reference habitat conditions of the studied sites and their reference Ephemeroptera communities were determined by combining both ecological and statistical results.

This study is part of the PhD Thesis, "Systematic and Ecologic Research on the Ephemeroptera Fauna of the Eastern Black Sea Region to Take Part in the Implementation of Water Framework Directive (WFD)" (Türkmen, 2013).

Description of the study area

In this study, the Eastern part of the Black Sea Region of Turkey was chosen as the study area (Fig. 1), because, there are many mountain running waters in this region and Ephemeroptera fauna of this area is very rich compared to the other parts of Turkey. This region is also important since it is part of the Caucasian Biodiversity Hotspot. The running waters in this region are generally unpolluted and many of them can be accepted as reference sites.

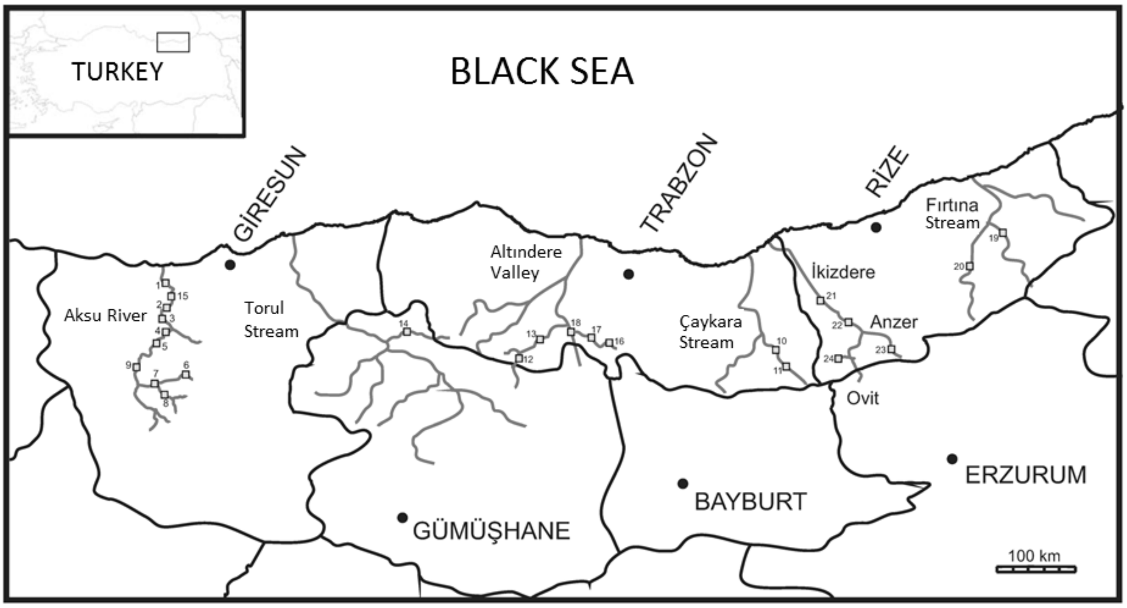

Figure 1: Study area, streams and the location of the sites.

RESULTS AND DISCUSSION

In this study, a total of 12,252 Ephemeroptera individuals belonging to seven families, 11 genere and 30 species were identified (Tab. 1). According to the results, the highest genere and species numbers belonged to Heptageniidae with four genere and 17 species, while the highest individual numbers belonged to Baetidae with 7,586 individuals. Percentage distributions of species, genere and individual numbers were shown in table 2. All sites were classified according to System A and System B classification in WFD methods (Tab. 3). In addition to these classification parameters, we added the stream zonation. In table 3, physical degradation effects and reference habitat conditions were also given.

Table 1: List of the Ephemeroptera families, genera and species.

Family	Genus	Species
Baetidae	*Baetis*	*B. rhodani*
		B. gemellus
		B. lutheri
		B. fusca
		B. milani
	Alainites	*A. muticus*
Caenidae	*Caenis*	*C. luctuosa*
		C. macrura
		C. martae
Leptophlebiidae	*Habroleptoides*	*H. modesta*
Ephemerellidae	*Serratella*	*S. ignita*
Ephemeridae	*Ephemera*	*E. danica*
Potamanthidae	*Potamanthus*	*P. luteus*
Heptageniidae	*Rhithrogena*	*R zelinkai*
		R. beskidensis
		R. semicolorata
		R. germanica
		R. puytoraci
		R. iridina
	Epeorus	*E. zaitzevi*
		E. alpicola
		E. sylvicola
		E. caucasicus
		E. znojkoi
	Ecdyonurus	*E. starmachi*
		E. macani
		E. helveticus
		E. picteti
	Electrogena	*E. quadrilineata*
		E. affinis

Table 2: Percentage distributions of Ephemeroptera genera, species and individuals.

1. Baetidae	18.2	20	61.92
2. Caenidae	9.1	10	0.08
3. Leptophlebiidae	9.1	3.3	1.09
4. Ephemerellidae	9.1	3.3	6.20
5. Ephemeridae	9.1	3.3	0.01
6. Potamanthidae	9.1	3.3	0.35
7. Heptageniidae	36.4	56.7	30.35

Table 3: System A and System B classification of sites and their stream zonation, physical degradation effects and reference habitat conditions; Abbreviation: in the headings; S. A., System A; S. B., System B; Alt. Typo., Altitude typology; ER, Ecoregion; Lat., Latitude; Long., Longitude, S. z., Stream zonation; P. d., Physical degradation; RHC, Reference Habitat Condition. In the table; L, Lowland; M – a, Mid – altitude; H, High; M, Medium; Y, Y ecoregion; N, North; E, East; Mp, Metapotamon; Er, Epirhithron; Hc, Hypocrenon; Mr, Metarhithron; Hr, Hyporhithron.

Sites	Alt. Typo. (S. A.)	Alt. (S. B.)	Catchment area (S. A.)	ER (S. A.)	Lat. (S. B.)
S-1	L (< 200 m)	184 m	M (100-1,000 km^2)	Y	40°46'42.6" N
S-2	M-a (200-800 m)	210 m	M (100-1,000 km^2)	Y	40°46'15.1" N
S-3	L (< 200 m)	186 m	M (100-1,000 km^2)	Y	40°46'44.4" N
S-4	M-a (200-800 m)	557 m	M (100-1,000 km^2)	Y	40°41'01.08" N
S-5	M-a (200-800 m)	607 m	M (100-1,000 km^2)	Y	40°40'49.01" N
S-6	H (> 800 m)	1,867 m	M (100-1,000 km^2)	Y	40°34'07" N
S-7	H (> 800 m)	1,581 m	M (100-1,000 km^2)	Y	40°32'31" N
S-8	H (> 800 m)	1,542 m	M (100-1,000 km^2)	Y	40°32'22" N
S-9	H (> 800 m)	1,582 m	M (100-1,000 km^2)	Y	40°32'19" N
S-10	H (> 800 m)	1,256 m	M (100-1,000 km^2)	Y	40°35'48.43" N
S-11	H (> 800 m)	1,254 m	M (100-1,000 km^2)	Y	40°35'52.39" N
S-12	H (> 800 m)	1,944 m	M (100-1,000 km^2)	Y	40°37'21.55" N
S-13	H (> 800 m)	1,857 m	M (100-1,000 km^2)	Y	40°39'50.69" N
S-14	H (> 800 m)	1,658 m	M (100-1,000 km^2)	Y	40°40'32.34" N
S-15	L (< 200 m)	55 m	M (100-1,000 km^2)	Y	40°50'67.5" N
S-16	H (> 800 m)	2,394 m	M (100-1,000 km^2)	Y	40°36'06.7" N
S-17	H (> 800 m)	2,128 m	M (100-1,000 km^2)	Y	40°35'99.7" N
S-18	H (> 800 m)	1,919 m	M (100-1,000 km^2)	Y	40°37'37.2" N
S-19	M-a (200-800 m)	568 m	M (100-1,000 km^2)	Y	41°01'32" N
S-20	M-a (200-800 m)	495 m	M (100-1,000 km^2)	Y	40°59'03.6" N
S-21	M-a (200-800 m)	450	M (100-1,000 km^2)	Y	40°48'59" N
S-22	M-a (200-800 m)	560 m	M (100-1,000 km^2)	Y	40°42'48" N
S-3	H (> 800 m)	1,970 m	M (100-1,000 km^2)	Y	40°36'07.8" N
S-24	H (> 800 m)	2,679 m	M (100-1,000 km^2)	Y	40°37'55.8" N

Table 3 (continued): System A and System B classification of sites and their stream zonation, physical degradation effects and reference habitat conditions; Abbreviation: In the headings; S. A., System A; S. B., System B; Alt. Typo., Altitude typology; ER, Ecoregion; Lat., Latitude; Long., Longitude, S. z., Stream zonation; P. d., Physical degradation; RHC, Reference Habitat Condition. In the table; L, Lowland; M – a, Mid – altitude; H, High; M, Medium; Y, Y ecoregion; N, North; E, East; Mp, Metapotamon; Er, Epirhithron; Hc, Hypocrenon; Mr, Metarhithron; Hr, Hyporhithron.

Sites	Long. (S. B.)	Jeology (S. A.)	S. z.	P. d.	RHC
S-1	38°26’35.6” E	Siliceous	Mp	+	–
S-2	38°26’23.7” E	Siliceous	Mp	+	–
S-3	38°26’38.8” E	Siliceous	Mp	+	–
S-4	38°26’29.71” E	Siliceous	Er	–	✓
S-5	38°26’41” E	Siliceous	Er	–	✓
S-6	38°28’67” E	Siliceous	Er	–	✓
S-7	38°23’40” E	Siliceous	Er	–	✓
S-8	38°24’06” E	Siliceous	Er	–	✓
S-9	38°21’35” E	Siliceous	Hc	–	✓
S-10	40°19’17.60” E	Siliceous	Er	–	✓
S-11	40°19’20.31” E	Siliceous	Hc	–	✓
S-12	39°35’37.67” E	Siliceous	Hc	–	✓
S-13	39°35’55.05” E	Siliceous	Er	–	✓
S-14	39°25’04.30” E	Siliceous	Mr	–	✓
S-15	38°27’62.3” E	Siliceous	Mp	+	–
S-16	39°38’42.8” E	Siliceous	Hc	+	–
S-17	39°37’00” E	Siliceous	Er	+	–
S-18	39°35’63.8” E	Siliceous	Er	+	–
S-19	41°02’48” E	Siliceous	Mr	–	✓
S-20	40°57’82.2” E	Siliceous	Mr	–	✓
S-21	40°32’26.21” E	Siliceous	Hr	–	✓
S-22	40°37’28.42” E	Siliceous	Hr	–	✓
S-23	40°31’39.2” E	Siliceous	Hc	–	✓
S-24	40°47’00” E	Siliceous	Er	+	–

Similar habitats have similar species composition (Odum and Barrett, 2005). In this respect, similar aquatic habitats have similar Ephemeroptera species compositions. Similarities between collecting sites are determined with the species compositions in these sites. Different species in similar habitats or similar species in different habitats are detected by similarity analysis and these analyses provide important information about distribution of species and their ecological demands (Kocataş, 1992; Ter Braak, 1986).

In this study, Bray-Curtis similarity analysis was applied and a cluster dendogram was generated to demonstrate the proximity relationship between the collecting sites (Fig. 2).

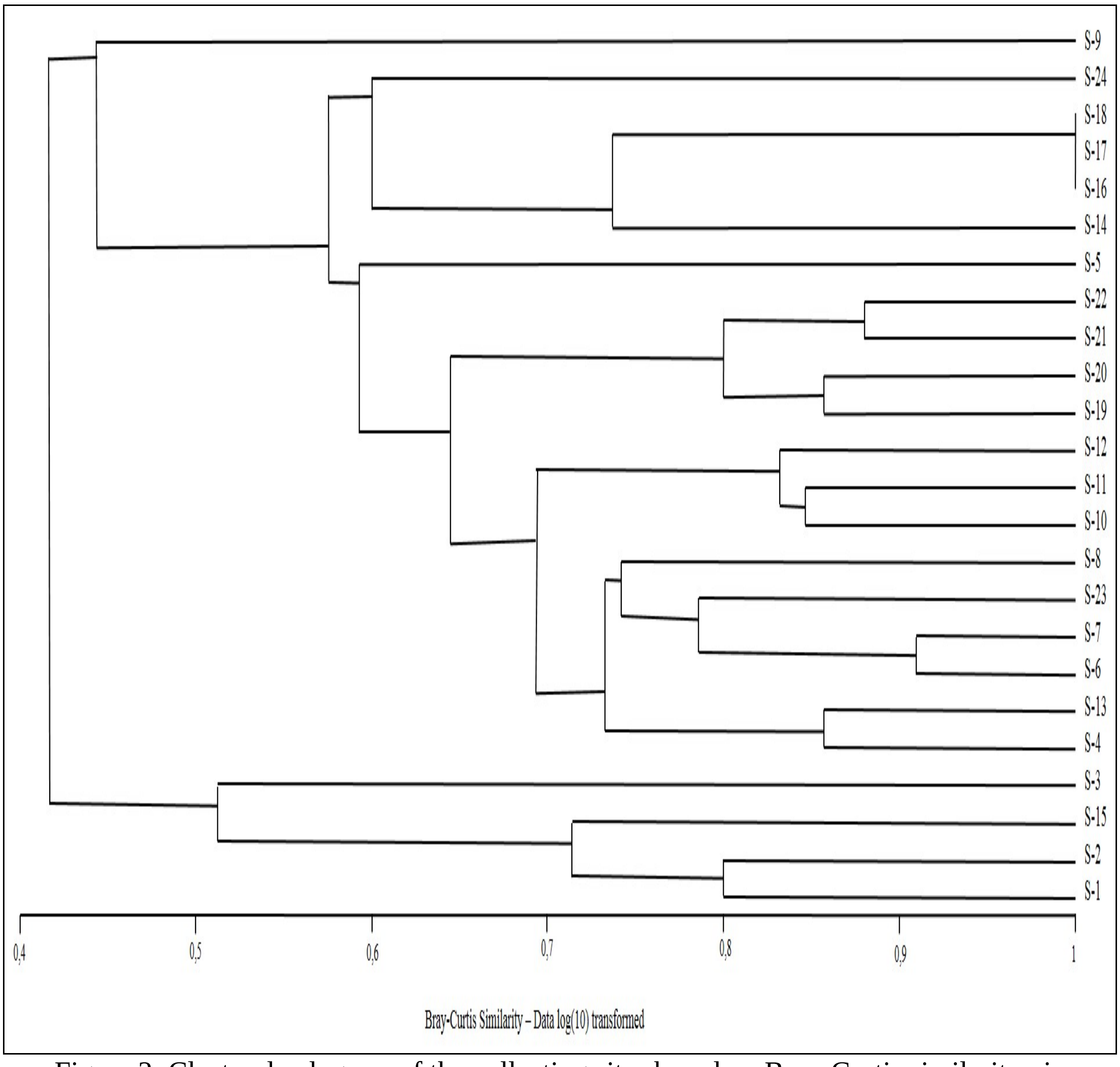

Figure 2: Cluster dendogram of the collecting sites based on Bray-Curtis similarity via Ephemeroptera species composition.

According to the System A and System B classifications, environmental factors and the cluster analysis results, 16 sites have reference habitat conditions while the other eight sites do not due to environmental degradations (Tab. 3).

S-1, S-2, S-3 and S-15, which did not have reference habitat conditions, differed from the other sites, because of having different typology. As it can be seen in the cluster dendogram, these sites were clustered together. Different typology caused different Ephemeroptera species compositions and this was reflected on the dendogram (Fig. 2).

Different typology conditions are not clearly spotted in System A and System B classification. Thus, stream zonation data of the collecting site(s) were added to help with the decision making. The sites with different typology (S-1, S-2, S-3 and S-15) were situated downstream (metapotamon) (Tab. 3). Environmental characteristics and physico-chemical variables of this zone are different from the upstream zones. These differences lead to different species composition. *Caenis martae, C. macrura, C. luctuosa, Ephemera danica,* and *Potamanthus lutheus* were only found in these four sites. Stream zonation preferences of these species are mostly potamon zones (epi-, meta- and hypo-potamon) of running waters (Bauernfeind and Moog, 2002; Buffagni et al., 2009). These species prefer beta-mesosaprobic and alpha-mesosaprobic habitats rather than oligosaprobic and ksenosaprobic habitats (Bauernfeind and Moog, 2002; Buffagni et al., 2009). Saprobic characteristics of the sites where these species were found were beta- and alpha-mesosaprobic (Tab. 4). These species were compatible with not only the stream zonation preferences, but also with the habitat preferences of the sites where they were found in this study. Sites S-1, S-2, S-3 and S-15 were clustered together because they have different typology. In this concept, it would be a mistake to compare these sites to other sites. Therefore, these sites should be considered separately. The reason why these sites did not have reference condition was physical degradations around the sites.

Sites S-16, S-17 and S-18 had similar typology with the other sites, unlike S-1, S-2, S-3 and S-15. Thus, they can be compared to the others. These sites did not have reference habitat conditions (Tab. 3). Also these sites were clustered together and they had the highest similarity ratio according to the Bray-Curtis similarity analysis (Fig. 2). Physical degradations and animal husbandry around the sites caused them to lose reference habitat characteristics. In these sites, *Baetidae* species (especially *B. rhodani*) had become quite dominant. In site S-16, dominancy of *B. rhodani* was 45%, entire dominancy of Baetidae species was 97%; in site S-17, dominancy of *B. rhodani* was 46%, entire dominancy of Baetidae species was 94%; in site S-18, dominancy of *B. rhodani* was 46%, entire dominancy of Baetidae species was 89% (Tab. 5). Moreover, dominancies of the species of Heptageniidae family, which have several clean and undegraded habitat indicator species, were very low in these sites (Tab. 5).

In this study, we also found that the dominancies of Baetidae species were high in non-reference sites, while the dominancies of Heptageniidae species were low. Reversely, the dominancies of Heptageniidae species were high in reference sites, while the dominancies of Baetidae species were low. Only five sites (S-5, S-6, S-9, S11 and S-14) out of twenty-four sites did not fit that result. The physical conditions, such as structure of substrate, current velocity, etc., of sites S-5, S-6, S-9 and S11 were not preferable for Heptageniidae species. Heptageniidae species mostly prefer high current velocity and rocky substratum (Bauernfeind and Moog, 2002; Buffagni et al., 2009). Therefore, the dominancies of Heptageniidae species were low in these sites in spite of having reference habitat conditions. According to the physico-chemical variables, site S-14 was beta-mesosaprobic (Tab. 4). In this site, there were no physical degradations or any other damaging effects, but the dominancy of Baetidae species was higher than Heptageniidae species. It was assumed that there could have been a degradation in the past and that would have affected the sensitive Heptageniidae species in time.

According to the environmental and statistical results, reference sites were determined and their reference Ephemeroptera communities were given as in table 6.

Table 4: Reference habitat condition and saprobity status of collecting sites; *RHC, Reference habitat condition.

Sites	RHC*	Saprobity Status	Sites	RHC*	Saprobity Status
S-1	–	Alpha-mesosaprobic	S-13	✓	Oligosaprobic
S-2	–	Beta-mesosaprobic	S-14	✓	Beta-mesosaprobic
S-3	–	Beta-mesosaprobic	S-15	–	Beta-mesosaprobic
S-4	✓	Beta-mesosaprobic	S-16	–	Beta-mesosaprobic
S-5	✓	Beta-mesosaprobic	S-17	–	Beta-mesosaprobic
S-6	✓	Oligosaprobic	S-18	–	Oligosaprobic
S-7	✓	Oligosaprobic	S-19	✓	Oligosaprobic
S-8	✓	Beta-mesosaprobic	S-20	✓	Oligosaprobic
S-9	✓	Beta-mesosaprobic	S-21	✓	Beta-mesosaprobic
S-10	✓	Oligosaprobic	S-22	✓	Beta-mesosaprobic
S-11	✓	Oligosaprobic	S-23	✓	Beta-mesosaprobic
S-12	✓	Oligosaprobic	S-24	–	Beta-mesosaprobic

Table 5: Species dominancy of Baetidae and Heptageniidae in the collecting sites; *Reference habitats.

Sites	Dominancy of Baetidae species (%)	Dominancy of Heptageniidae species (%)	Sites	Dominancy of Baetidae species (%)	Dominancy of Heptageniidae species (%)
S-1	73.93	3.41	S-13*	36.71	56.96
S-2	30.29	6.85	S-14*	99.28	0.72
S-3	65.38	6.41	S-15	76.59	1.95
S-4*	43.55	55.65	S-16	97.20	2.80
S-5*	62.50	37.50	S-17	94.09	5.91
S-6*	61.37	31.52	S-18	88.79	11.21
S-7*	34.69	65.22	S-19*	18.31	74.13
S-8*	20.46	77.52	S-20*	19.67	59.83
S-9*	70.19	22.12	S-21*	31.40	56.07
S-10*	23.47	74.65	S-22*	16.43	76.95
S-11*	70.97	26.73	S-23*	14.66	73.29
S-12*	35.00	58.57	S-24	71.00	29.00

Table 6: Reference Ephemeroptera communities.

Ref. sites	Reference Ephemeroptera Communities
S4 (Fig. 3)	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Alainites muticus, Rhithrogena germanica, Epeorus caucasicus, Epeorus alpicola, Epeorus sylvicola, Epeorus znojkoi, Habroleptoides modesta.*
S5	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Rhithrogena iridina, Epeorus caucasicus, Epeorus alpicola, Epeorus znojkoi.*
S6	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Alainites muticus, Rhithrogena semicolorata, Rhithrogena zelinkai, Rhithrogena germanica, Rhithrogena puytoraci, Rhithrogena iridina, Electrogena quadrilineata, Electrogena affinis, Epeorus caucasicus, Epeorus alpicola, Epeorus sylvicola, Epeorus znojkoi, Habroleptoides modesta.*
S7 (Fig. 4)	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Alainites muticus, Rhithrogena semicolorata, Rhithrogena zelinkai, Rhithrogena germanica, Rhithrogena puytoraci, Rhithrogena iridina, Ecdyonurus starmachi, Ecdyonurus helveticus, Electrogena quadrilineata, Epeorus caucasicus, Epeorus alpicola, Epeorus sylvicola, Epeorus znojkoi, Habroleptoides modesta.*
S8	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Rhithrogena semicolorata, Rhithrogena zelinkai, Rhithrogena germanica, Rhithrogena puytoraci, Ecdyonurus picteti, Ecdyonurus helveticus, Epeorus caucasicus, Epeorus sylvicola, Epeorus znojkoi, Habroleptoides modesta.*
S9	*Baetis rhodani, Baetis gemellus, Epeorus alpicola, Epeorus sylvicola, Habroleptoides modesta.*
S10 (Fig. 5)	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Baetis fuscatus, Baetis milani, Rhithrogena semicolorata, Rhithrogena zelinkai, Rhithrogena germanica, Rhithrogena puytoraci, Rhithrogena iridina, Epeorus caucasicus, Epeorus alpicola, Epeorus sylvicola, Epeorus znojkoi, Habroleptoides modesta.*
S11	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Baetis fuscatus, Baetis milani, Rhithrogena zelinkai, Epeorus caucasicus, Epeorus alpicola, Epeorus sylvicola, Epeorus znojkoi, Habroleptoides modesta.*
S12	*Baetis gemellus, Baetis fuscatus, Baetis milani, Rhithrogena semicolorata, Rhithrogena zelinkai, Epeorus caucasicus, Epeorus alpicola, Epeorus sylvicola, Epeorus znojkoi, Habroleptoides modesta.*
S13 (Fig. 6)	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Alainites muticus, Rhithrogena semicolorata, Rhithrogena zelinkai, Epeorus caucasicus, Epeorus alpicola, Epeorus sylvicola, Epeorus znojkoi, Habroleptoides modesta.*
S14 (Fig. 7)	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Baetis fuscatus, Baetis milani, Epeorus caucasicus, Epeorus sylvicola, Epeorus zaitzevi.*
S19 (Fig. 8)	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Baetis fuscatus, Alainites muticus, Baetis milani, Rhithrogena semicolorata, Rhithrogena zelinkai, Rhithrogena germanica, Rhithrogena puytoraci, Rhithrogena iridina, Rhithrogena beskidensis, Ecdyonurus picteti, Electrogena affinis, Epeorus caucasicus, Epeorus sylvicola, Epeorus znojkoi, Serratella ignita, Habroleptoides modesta.*

Table 6 (continued): Reference Ephemeroptera communities.

S20 (Fig. 9)	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Baetis fuscatus, Rhithrogena semicolorata, Rhithrogena zelinkai, Electrogena quadrilineata, Epeorus caucasicus, Epeorus sylvicola, Epeorus znojkoi, Serratella ignita.*
S21 (Fig. 10)	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Baetis fuscatus, Rhithrogena semicolorata, Rhithrogena puytoraci, Rhithrogena iridina, Rhithrogena beskidensis, Electrogena affinis, Epeorus caucasicus, Epeorus sylvicola, Epeorus znojkoi, Serratella ignita.*
S22 (Fig. 11)	*Baetis rhodani, Baetis gemellus, Baetis lutheri, Alainites muticus, Rhithrogena semicolorata, Rhithrogena puytoraci, Rhithrogena iridina, Rhithrogena beskidensis, Epeorus caucasicus, Epeorus sylvicola, Epeorus znojkoi, Serratella ignita.*
S23	*Baetis rhodani, Baetis gemellus, Alainites muticus, Rhithrogena semicolorata, Rhithrogena iridina, Ecdyonurus starmachi, Ecdyonurus picteti, Ecdyonurus helveticus, Electrogena quadrilineata, Epeorus caucasicus, Epeorus alpicola, Epeorus znojkoi, Habroleptoides modesta.*

Figure 3: Reference Ephemeroptera community (S4).

Figure 4: Reference Ephemeroptera community (S7).

Figure: 5 Reference Ephemeroptera community S10.

Figure 6: Reference Ephemeroptera community S13.

Figure 7: Reference Ephemeroptera community S14.

Figure 8: Reference Ephemeroptera community S19.

Figure 9: Reference Ephemeroptera community S20.

Figure 10: Reference Ephemeroptera community S21.

Figure 11: Reference Ephemeroptera community S22.

CONCLUSIONS

Determining the reference habitats and reference communities has a great importance in Water Framework Directive. Only through this way is it possible to compare the current situation of running water with the previous one if there was any degradation in the past.

Recently, several hydroelectric power plants were constructed on some running waters in the Eastern Part of Black Sea Region and there are plans to construct several others. These constructions will create a significant effect over the running waters by destroying the natural habitats and causing loss of sensitive Ephemeroptera fauna members in the area. Therefore, it is crucial to clearly determine and show the magnitude of the variation from past to present days by comparing the Ephemeroptera communities. One of the highly emphasized subjects in WFD is the reference habitat condition, because it is necessary to detect how the current status differs from the expected status.

By using the list of reference Ephemeroptera communities, it will be possible to decide which areas have reference habitat condition or how areas are affected from different kinds of degradation.

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