TRANSYLVANIAN REVIEW OF SYSTEMATICAL AND ECOLOGICAL RESEARCH

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Editors

Doru Bănăduc, Sophia Barinova & Angela Curtean-Bănăduc

Sibiu – Romania
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International Association for Danube Research	"*Lucian Blaga*" University of Sibiu	Ecotur Sibiu N.G.O.	Applied Ecology Research Center of *LB*US	Broward College, Fort Lauderdale	Institute of Evolution, University of Haifa

Sibiu – Romania
2021

Scientifical Reviewers

IN MEMORIAM

Marian-Traian Gomoiu

(1936 – 2021)

Marian-Traian Gomoiu was a Romanian marine biologist, researching particularly benthic fauna such as sponges, molluscs, crustaceans, echinoderms and coelenterates.

He was born into a family of teachers, in the town of Bazargic (in Southern Dobruja, at that time Romanian territory); the turmoil of historical events relocated the family to the village of Gura Dobrogei and then to Constanţa – the ancient Tomis on the Black Sea coast. This city of exile of the Roman poet Ovid was no exile for *Gomoiu* but the space he called home, in spite of his numerous travels, including for research, around the world.

Educated in good schools like "*Mircea cel Bătrân*" National College, from where he graduated in 1954, and later the Faculty of Natural Sciences and Geography of "*Victor Babeş*" University in Cluj (1954–1958), *Gomoiu* found it a natural progression to settle into the professional area of scholarship and natural sciences.

He worked all his life as a teacher and researcher, mostly in the newly established Oceanography Laboratory of the Romanian Academy in Constanţa. After the establishment of the Romanian Institute for Marine Research in Constanţa, he worked within this institution and, over time, climbed the steps of the scientific hierarchy from a researcher to a senior scientist, reaching the position of head of the Agigea Laboratory within the institute.

In 1973 he received the PhD title in biology (invertebrate zoology, biological oceanography, limnology, marine ecology, benthos, malacology and sedimentology) at the Bucharest Institute of Biological Sciences, where he submitted the thesis entitled "Contributions to the knowledge of the ecology of psamobiotic molluscs from the sandy submarine beaches on the Romanian Black Sea littoral".

He was an excellent organizer or member of international oceanological expeditions, on the basis of which the professional experience of he and his colleagues grew constantly, among them expeditions in the Black Sea, Sargasso Sea, Batabano Bay (Cayman Islands), Isefjord (Denmark) area, etc.

He attended numerous experience-enhancing visits and training at for example the Zoological Museum and the Institute of Physiology and Research Marine Centre in Helsingor (Denmark), and Duke University Marine Laboratory, Beaufort (USA).

His publication list of over 200 titles of scientific papers is impressive. Among his numerous scientific contributions: he was the author of epibiosis on ships and submersible constructions, and the marine gelatinous plankton, he set the course for studying the biology of invasive species in the Black Sea littoral, he made important contributions in the field of ecological reconstruction of shallow marine areas through the building of artificial reefs, etc.

Answering the request of the scientific community in Constanţa, he joined in 1990, immediately after the fall of the communism in Eastern Europe, the initiative group that established the "Ovidius" University, after which he became a professor within the Faculty of Natural Sciences and Agricultural Sciences.

Between 1990 and 1993, he was in charge of the Danube Delta Biosphere Reserve, as its first Governor, organizing this new institution and managing the new protected area.

In 1993 he was elected as a correspondent member of the Romanian Academy and later, in 2015, he became a full member.

In his last years of life he had to face severe health problems which he endured with dignity as he had done over all the hard times in his life … *Marian-Traian Gomoiu*, as professor, PhD adviser, manager, editor, academician, or a simple man, he proved a superlative, strong, hard-working character, who opened up in a large variety of ways new roads for the next generations of naturalists to follow.

The Editors

CONTENTS

Preface

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

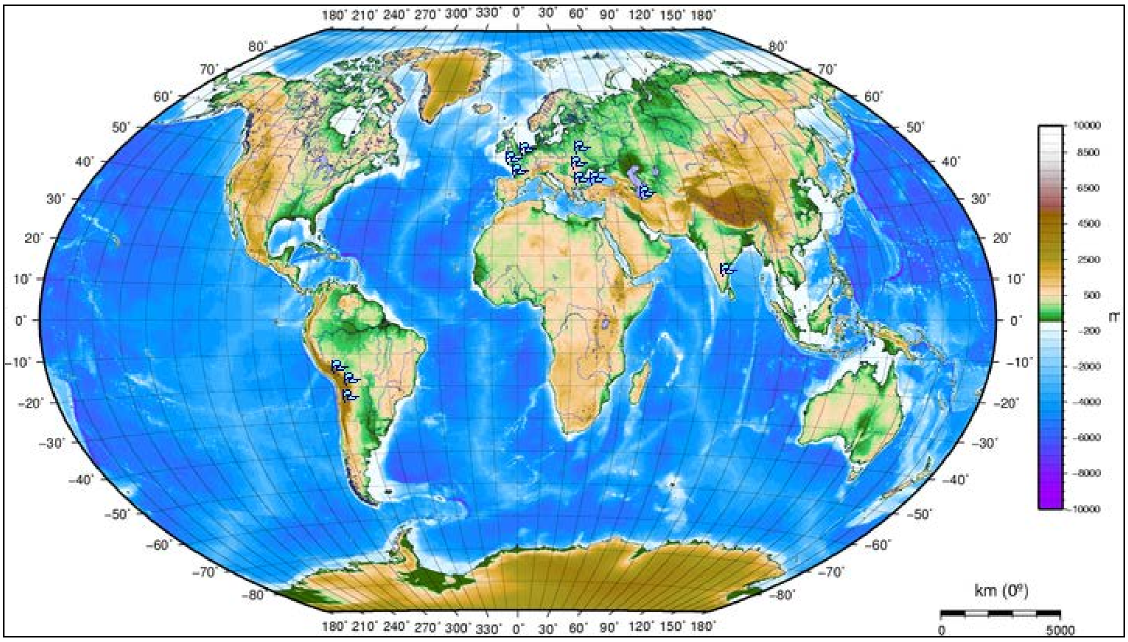
The causes, effects, trends and possibilities of human society to positively intervene to slow down this process or to adapt to it involve a huge variety of aproacess and efforts.

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

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

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

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



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

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

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The editors would like to express their sincere gratitude to the authors and the scientific reviewers whose work made the appearance of this volume possible.

The Editors

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LONG-TERM DYNAMICS OF TROPHIC STATE INDICATORS IN PHYTOPLANKTON OF THE COOLING RESERVOIR OF A NUCLEAR POWER PLANT

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KEYWORDS: nuclear power plant, cooling reservoir, thermal pollution, phytoplankton, bioindicators, trophic state, Ukraine.

ABSTRACT

The dynamics of long-term indicators of trophicity in the cooling pond of a nuclear power plant in Ukraine was analyzed by phytoplankton biomass and bioindicators of trophicity. Greater species richness correlated with the number of species-indicators of greater trophicity. During the contourization processes caused by the introduction of filter-feeding mollusks and changes in the operating mode of the nuclear power plant, there was a decrease in the abundance of phytoplankton and trophic state. During decontourization, there was a sequential “return” of previously eliminated taxa and the restoration of the number of indicator species.

ZUSAMMENFASSUNG: Langzeitdynamik trophischer Zustandsindikatoren im Phytoplankton des Kühlreservoirs eines Kernkraftwerks.

Die Dynamik von Langzeitindikatoren für die Trophäe im Kühlteich eines Kernkraftwerks in der Ukraine wurde mit Phytoplankton-Biomasse und Bioindikatoren für die Trophäe analysiert. Ein größerer Artenreichtum korrelierte mit der Anzahl der Artenindikatoren für eine größere Trophäe. Während der Konturierungsprozesse, die durch die Einführung von Mollusken mit Filterfütterung und Änderungen der Betriebsart des Kernkraftwerks verursacht wurden, nahm die Häufigkeit von Phytoplankton und der trophische Zustand ab. Während der Dekontourisierung gab es eine sequentielle “Rückgabe” zuvor eliminierter Taxa und die Wiederherstellung der Anzahl der Indikatorarten.

REZUMAT: Dinamica pe termen lung a indicatorilor stării trofice în fitoplanctonul rezervorului de răcire al unei centrale nucleare.

Dinamica indicatorilor de troficitate pe termen lung în iazul de răcire al unei centrale nucleare din Ucraina a fost analizată prin biomasa fitoplanctonică și bioindicatorii troficității. O bogăție mai mare de specii este corelată cu numărul de specii-indicatoare de troficitate mai mare. În timpul proceselor de contorizare cauzate de introducerea moluștelor care alimentează filtrul și modificările modului de funcționare al centralei nucleare, a existat o scădere a abundenței fitoplanctonului și a stării trofice. În timpul decontorizării, a existat o „revenire” secvențială a taxonilor eliminați anterior și restabilirea numărului de specii indicatoare.

INTRODUCTION

The structure and processes of functioning of aquatic ecosystems are highly dynamic and change over time. In reservoirs of techno-ecosystems, the main triggers of changes are the features of the operation of technical objects, including emergency situations that can arise both exogenously and endogenously relative to the techno-ecosystem. For example, exogenous changes can be caused by invasion of alien species, which cause serious restructuring of the entire ecosystem of the reservoir (Karatayev et al., 1997; Zdanowski and Protasov, 1998; Cuhel and Aguilar, 2013; Beshkova et al., 2014, 2017). Cooling reservoirs (WO) of thermal and nuclear power plants are technologically heavily loaded water bodies. Their sanitary condition, water quality, which determines the cleanliness of the surface of heat exchange equipment, significantly depends on the level of development of aquatic organisms, in particular phytoplankton (Novoselova and Protasov, 2015). Phytoplankton characteristics, in turn, can act as an indicator of changes in the state of the entire ecosystem (Barinova et al., 2006, 2019; Protasov et al., 2017).

The aim of our work was to show the reaction of phytoplankton to changes in the trophic status of the cooling pond (CP) of the Khmelnitsky NPP (KhNPP) in a long-term aspect based on bioindication, in particular, based on the dynamics of trophicity indicators.

MATERIAL AND METHODS

Description of study site

The KhNPP site is located in the northwestern part of Ukraine (Fig. 1a, b). Cooling of the circulating waters of the two power units is provided by a cooling pond with an area of about 20 km^2 and a volume of 120 million m^3. Detailed characteristics are presented in (Protasov et al., 2011). The technogenic load experienced by the CP KhNPP in comparison with other cooling ponds of TPPs and NPPs of the temperate climate zone corresponds to the average level (Novoselova and Protasov, 2015, 2016). The paper presents the results of studies of CP KhNPP for 1998-2019. The studies were carried out in summer and early autumn when phytoplankton was most developed.

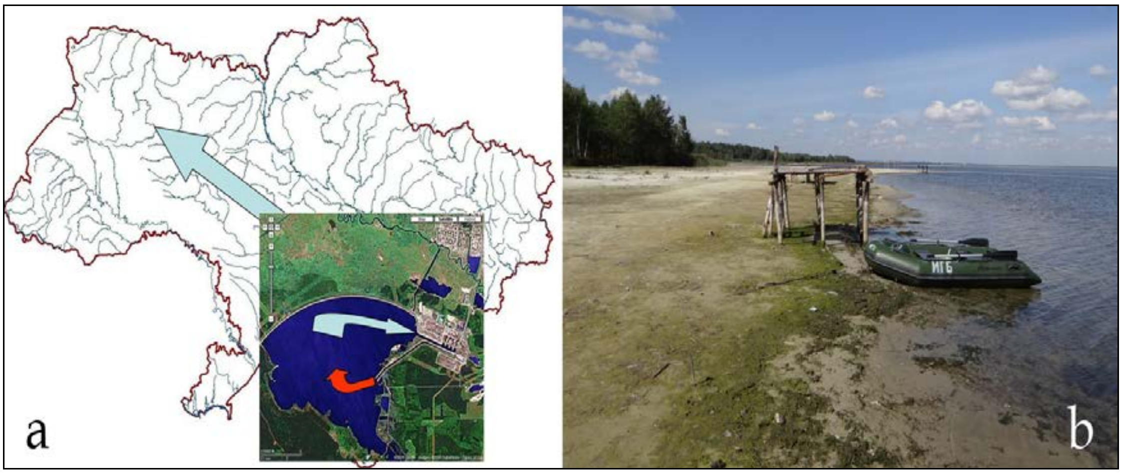

Figure 1: Map of studied reservoir on the territory of Ukraine,
a. blue arrow marked water input, red arrow is hot water outlet to inlet channel of nuclear power plant, b. view of drained part of the coast of the reservoir.

Sampling and laboratory study

We have analyzed the parameters of phytoplankton since the start of regular monitoring in the reservoir. The study was conducted during three periods. In 1998-2001 (hereafter referred to as the first period, I), only one unit of the NPP was operating. Since 2004, the second power unit started operation, while the cooling pond was infested by the zebra mussel *Dreissena polymorpha* (Pallas), most probably in the two years before (2002-2003) (Protasov et al., 2011). In the second period (II), the studies were carried out in 2005-2008. In the third period (III), the studies were conducted from 2010 to 2015. A second species of the family Dreissenidae, the quagga mussel *Dreissena bugensis* (Andrusov, 1897), was recorded for the first time in the cooling pond in 2012 (Fig. 2).

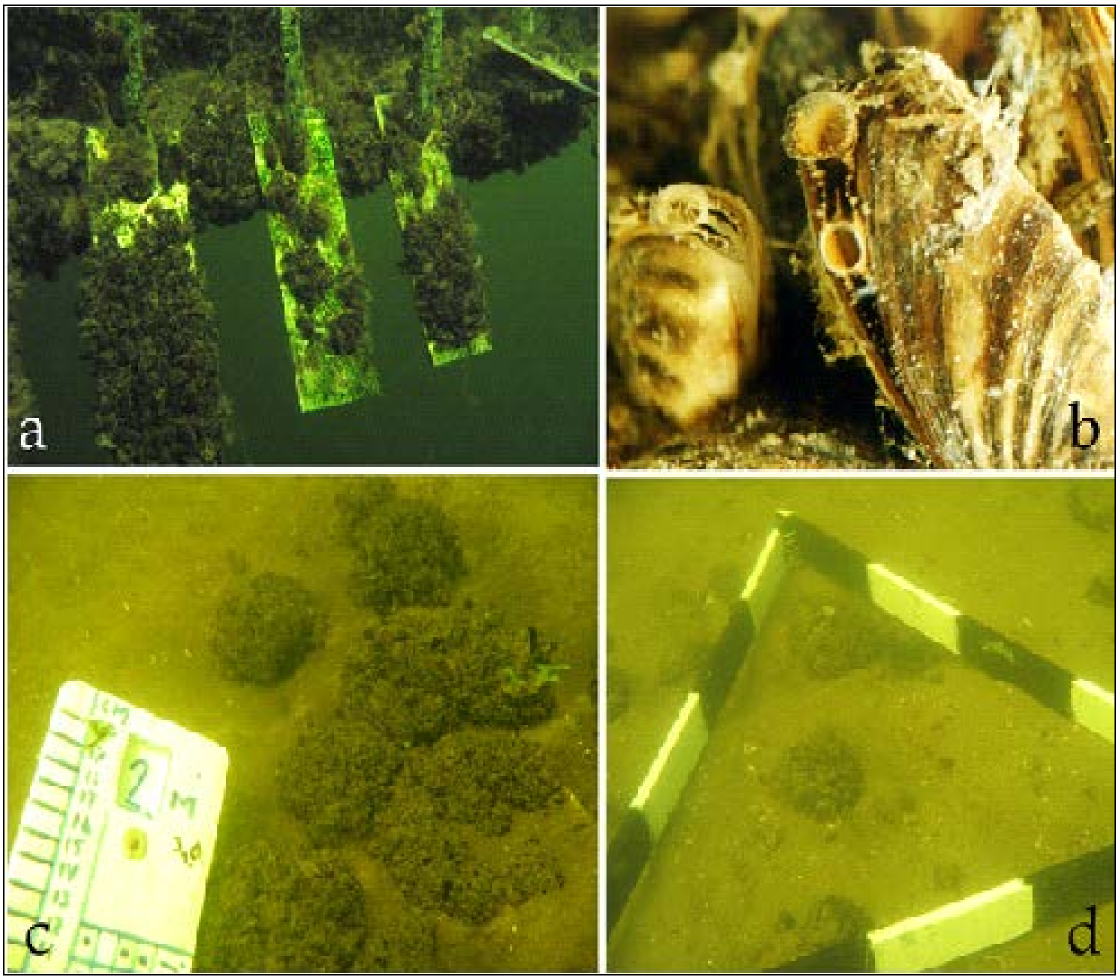

Figure 2: Experimental substrates of algae and zebra mussel fouling and different bottom substrates in cooling reservoir on the territory of Ukraine:
experimental substrata in the NPP inlet channel with zebra mussel fouling (a);
Dreissena polymorpha fouling (b);
bottom site on two m depth with zebra mussel drizes (c);
experimental square for the mollusk's druses measurements, black part is 10 cm (d).

The complex hydrobiological studies were carried out according to standard methods (Arsan et al., 2006; Protasov et al., 2011). The transparency was measured using a Secchi white disk with a diameter of 30 cm. The phytoplankton samples were taken in the pelagic part of the cooling pond over the entire water area, from the surface horizon, using a Patalas bathometer.

The hydrochemical data was received from the Ecological-chemical Laboratory of the Khmelnitsky NPP. The term "the lowest determined taxon" (LDT), which denotes taxa of both species and higher rank defined in accordance with the identification capabilities, was used after Bakanov (1997) to describe the taxonomic richness and diversity of algae. The names and systematic affiliation of phytoplankton taxa were according to the Algaebase database (Guiry and Guiry, 2019). More than 92% of taxa have been identified to species level. The phytoplankton determination of species-indicators of trophic conditions, followed the recommendations of Barinova et al. (2006, 2019). The trophic level was determined by indicators of the abundance of phytoplankton (Oksiyuk et al., 1994). The diversity of algae communities was calculated by the Shannon function, log base was 2 (Arsan et al., 2006); use richness of indicator groups.

RESULTS AND DISCUSSION

Physical and chemical variables

The average water transparency over the cooling pond in the summer months during the first study period varied from 1.03 ± 0.03 m in June 1998 to 1.33 ± 0.17 m in July 1999. After introducing *D. polymorpha* (II), the transparency index changed significantly (Fig. 3). The highest average values, 3.02 ± 0.23 m, within the water body was detected in September 2008 in the inflow canal, where the colonies of *D. polymorpha* were found at all surfaces of the covering concrete in the temporary absence of flowage (both units did not operate during the study period because of preventive maintenance) (Fig. 1). In some points here, transparency reached four m.

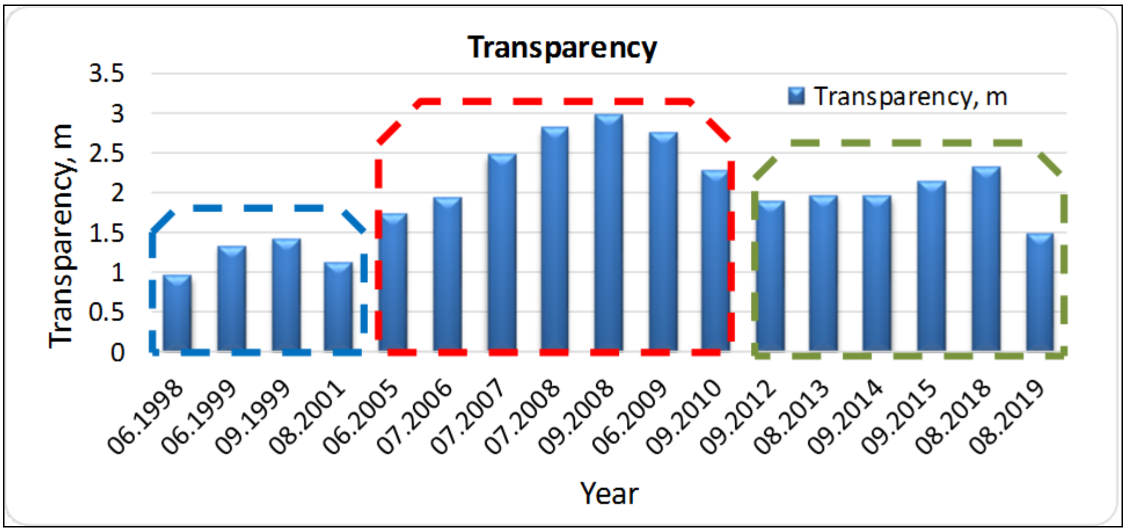

Figure 3: Changes of water transparency in the Khmelnitsky NPP cooling pond in period of investigations (1998–2019).
The dashed lines indicate three periods.

In the period I, the average annual content of calcium ions (Ca^{2+}) varied from 49.71 to 54.85 mg/dm^3, while the concentration of sulphate ions (SO_4^{2-}) was between 41.25 and 95.67 mg/dm^3. The sum of ions in the cooling pond averaged 352.58 mg/dm^3, which is a relatively low indicator of mineralization.

Period II of the studies was characterized by a gradual increase in the content of bicarbonate ions and chlorine ions and, in general, total mineralization up to 438.7 mg/dm^3. During this period, the trend of decreasing in the concentration of calcium ions continued (the average values in 2006-2010 were 44.86 mg/dm^3, reaching 38.0 mg/dm^3 in August-September 2006), along with an increase in the sulphate ions content and the concentration of phosphate ions.

In this period, the average content of phosphate ions in the water of the cooling pond increased more than twice, from 0.028 to 0.066 mg P/dm^3. The balance between nitrogen and phosphorus changed, being 9:1 in the first period and 5:1 in the second.

In period III, the transparency decreased to about 1.5-2.0 m. The concentration of calcium ions in water increased to 52.85 mg/dm^3 in 2014 and 55.85 mg/dm^3 in 2015 (average annual values). In those years, the content of sulphate ions was, on average, 90.36 and 100.95 mg/dm^3, respectively. The indicators of mineralization continued to increase to 566.80 mg/dm^3 on average in 2015. The entire studied period (since 1998) was marked by an increase in the content of phosphate ions. In period III, their average annual concentration reached 0.228 mg P/dm^3 in 2014 and 0.263 mg P/dm^3 in 2015. The balance between nitrogen and phosphorus decreased to 2:1 in this period.

Phytoplankton species richness

During the study period, 383 taxa of algae and cyanobacteria from eight divisions were found in phytoplankton of the pelagic part of the CP and channels. The main part of algae (352 species and infraspecies) was identified to a species or lower systematic level. The most widely represented was Chlorophyta (144 taxa) and Bacillariophyta (109), Cyanobacteria numbered 54, Euglenophyta 20, Streptophyta (Charophyta) 18, Chrysophyta and Xanthophyta 17, Miozoa (Dinophyta) eight, and Cryptophyta three. Distribution is represented in figure 4, where the Standard Deviation line cut off most of the richest divisions – diatoms, green algae, and cyanobacteria.

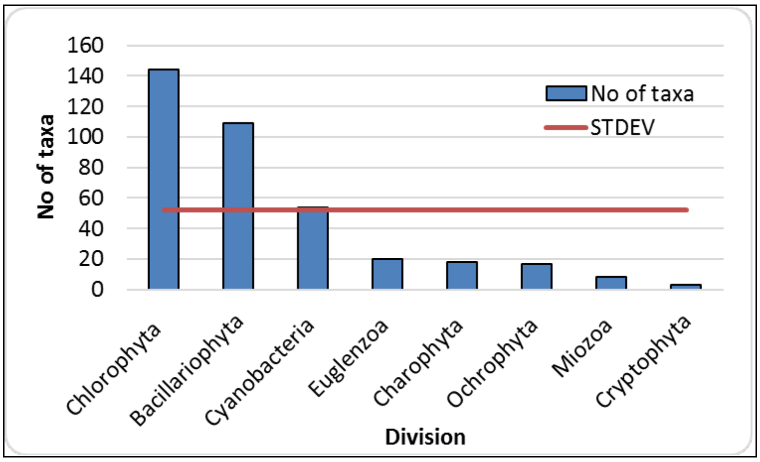

Figure 4: Distribution of revealed taxa of algae and cyanobacteria over taxonomic division in phytoplankton of the Khmelnitsky NPP cooling pond in period of investigations (1998-2019).

Algae-indicators of trophic state

Algae-indicators of trophicity made up 34% of the total phytoplankton composition and were found throughout the observation period. The list of indicators was formed by representatives of three divisions, in which charophytes replaced green algae in comparison to figure 4. Among them, diatoms numbered 83 species-indicators, cyanobacteria 27, and charophyte 11. The most represented were indicators of meso-eutrophic (me) conditions (38 taxa), oligo-mesotrophic (o-m) there were 24, eutrophic (e) 20, mesotrophic (m) 16, oligotrophic (ot) and oligo-eutrophic (o-e) 10, hypertrophic (he) three taxa. Thus, there were 72 broadly specialized, 49 highly specialized. The share of indicators in the list of species was 50.1% in cyanobacteria, 60.9% in charophytes, and 69.7% in diatoms (Fig. 5).

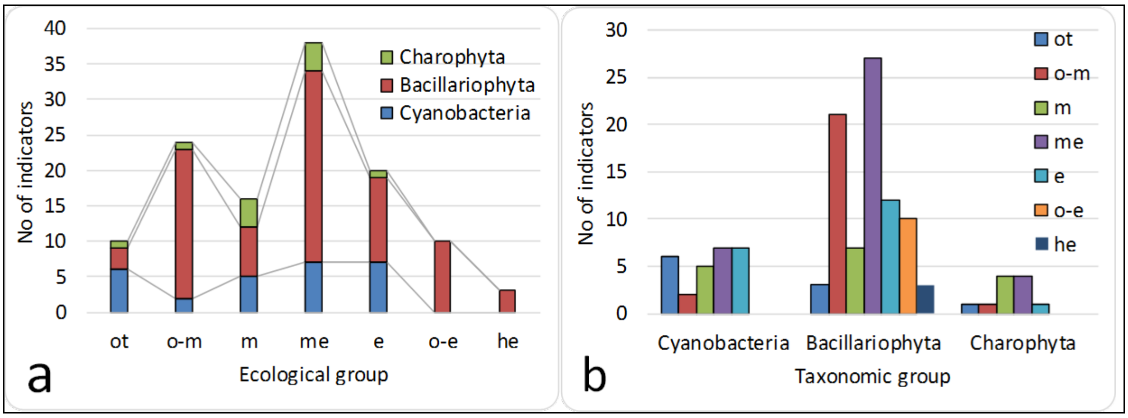

Figure 5: The number of indicator species in the three most representative divisions of algae in trophicity categories, arranged in increasing trophicity from left to right (a), and their ratio (b) in the divisions to which they belong.

Since the process of transformation of the CP ecosystem during the study period was described in detail earlier (Protasov et al., 2011, 2017; Protasov and Silaeva, 2014; Novosolova and Protasov, 2016), we only briefly note the main structural changes in phytoplankton in different periods of existence of technoecosystem.

In the initial (first) period of research (1998-2001), phytoplankton was characterized by a rich species composition (73-104 taxa), a high level of development, with dominance predominant of cyanobacteria and green algae. At the same time, biomass was dominated by green algae and diatoms. After introducing of *Dreissena* in the cooling pond, a decrease in the species richness of phytoplankton was observed (second period). Since 2006, representatives of Cryptophyta, Miozoa, Ochrophyta, Charophyta, and Cyanobacteria have progressively dropped out of the floristic list, and in September 2008, phytoplankton contained only nine taxa from three divisions. The restoration of species richness took place from 2009 to 2012 in the reverse order. In the second period, significant fluctuations in abundance and a decrease in biomass were observed. During the depression of the composition and abundance of phytoplankton (in 2008), quantitative indicators were formed mainly by diatoms. In the third period, a gradual increase in the abundance of phytoplankton was observed, the abundance was dominated by cyanobacteria and greens, in the biomass – green, diatoms, and cyanobacteria. The species richness ranged from 46 to 115 taxa.

The composition of species in phytoplankton and the richness of trophic indicator groups, and the cooling pond's trophic level have changed during the observation period.

Changes in the trophic state based on bioindication

In 1998-2001, the level of water trophicity varied from “eupolitrophic” to “hypertrophic” (Fig. 6). The floristic spectrum of phytoplankton included indicators of all trophicity categories. Species-indicators of meso-eutrophic waters prevailed, the second and third places were among representatives of the categories oligo-mesotrophic and eutrophic waters (Figs. 7 and 8). This ratio was maintained for almost the entire duration of the research. It should be noted that the indicator species of these categories of trophicity reached a high level of development and were part of the dominant phytoplankton complexes (Tab. 1).

Table 1: Dynamics of species-indicators of trophic state (Tro) in the dominant complexes with the highest abundance of phytoplankton species in the CP KhNPP.

Tro	Taxa	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998	06.1998
	Cyanobacteria																
m	*Aphanizomenon flosaquae* Ralfs ex Bornet and Flahault	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–
me	*Aphanocapsa incerta* (Lemmermann) G. Cronberg and Komárek	+	+	–	–	–	–	–	–	+	–	+	–	–	–	+	–
me	*Aphanothece stagnina* (Sprengel) A. Braun	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
e	*Microcystis aeruginos*a (Kützing) Kützing	+	–	–	–	+	–	–	–	+	+	+	+	+	+	–	+
me	*Oscillatoria planctonica* Woloszynska	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
me	*Snowella lacustris* (Chodat) Komárek and Hindák	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Bacillariophyta																
me	*Aulacoseira granulata* (Ehrenberg)	–	–	–	–	+	–	+	+	–	–	+	+	–	+	+	+
o-m	*Lindavia comta* (Kützing) T. Nakov et al.	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–
me	*Melosira varians* C. Agardh	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
o-m	*Stephanodiscus hantzschii* Grunow	+	–	–	–	–	–	+	–	–	–	+	–	–	–	–	–

As noted above, the response of phytoplankton to changes in the exploitation regime and the introduction of *Dreissena* was a decrease in its taxonomic richness. In the second period of research, the quantitative indicators of phytoplankton corresponded to trophicity categories from “oligotrophic” to “eutrophic”, i.e., decreased by three categories. The number of indicators of trophicity has decreased significantly. Indicators of hypertrophic waters dropped out. Widely specialized indicators of oligo-mesotrophic waters were stably met. Representatives of other categories in different years of this period were either absent or noted in the list of species (Figs. 7 and 8). Most often, indicators of meso-eutrophic waters dominated in quantitative terms (Tab. 1).

In the third observation period, after a significant decrease in the abundance of the *Dreissena polymorpha* population occurred in the benthos and periphyton, an increase in trophicity to the “meso-eutrophic” – “eupolytrophic” level was observed (Fig. 6).

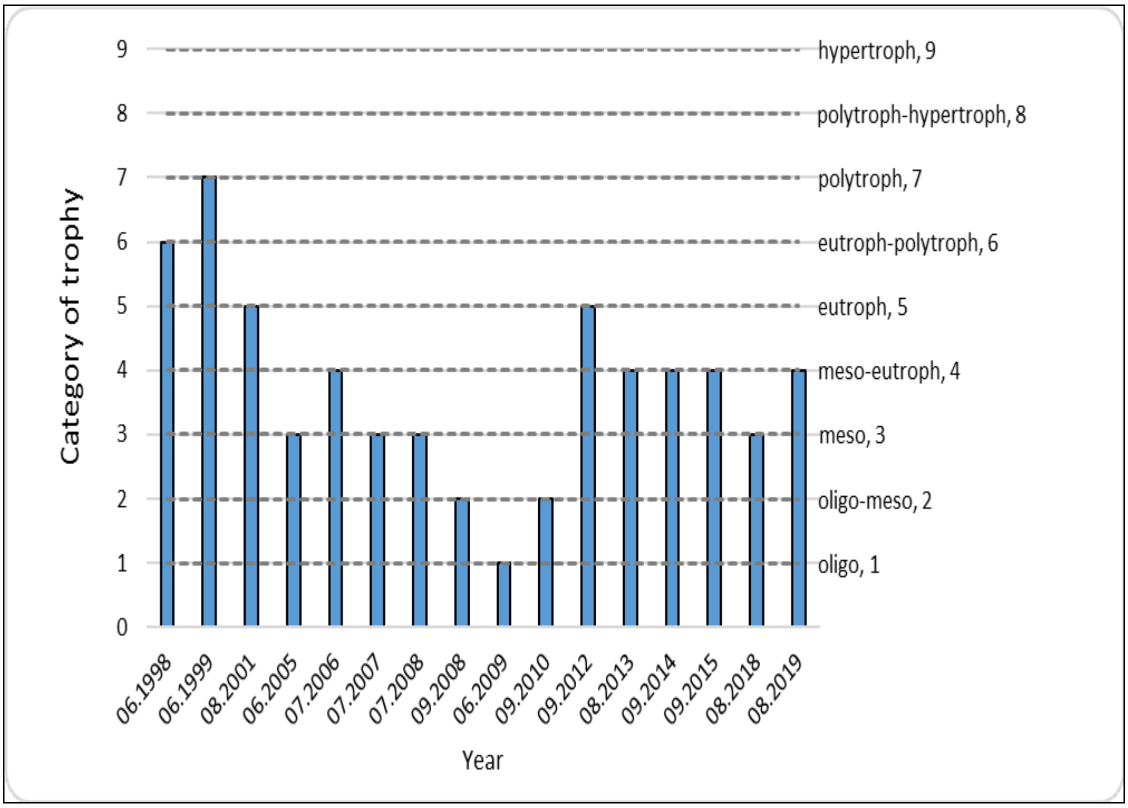

Figure 6: Long-term dynamics of trophicity categories of the CP KhNPP by indicators of the level of phytoplankton development (Oksiyuk et al., 1994).

In phytoplankton, the list of trophicity indicators expanded, and hypertrophs reappeared. The dominant observed assemblages, as well as at the initial stage of the research, included indicator species of oligo-mesotrophic, meso-eutrophic, and eutrophic waters.

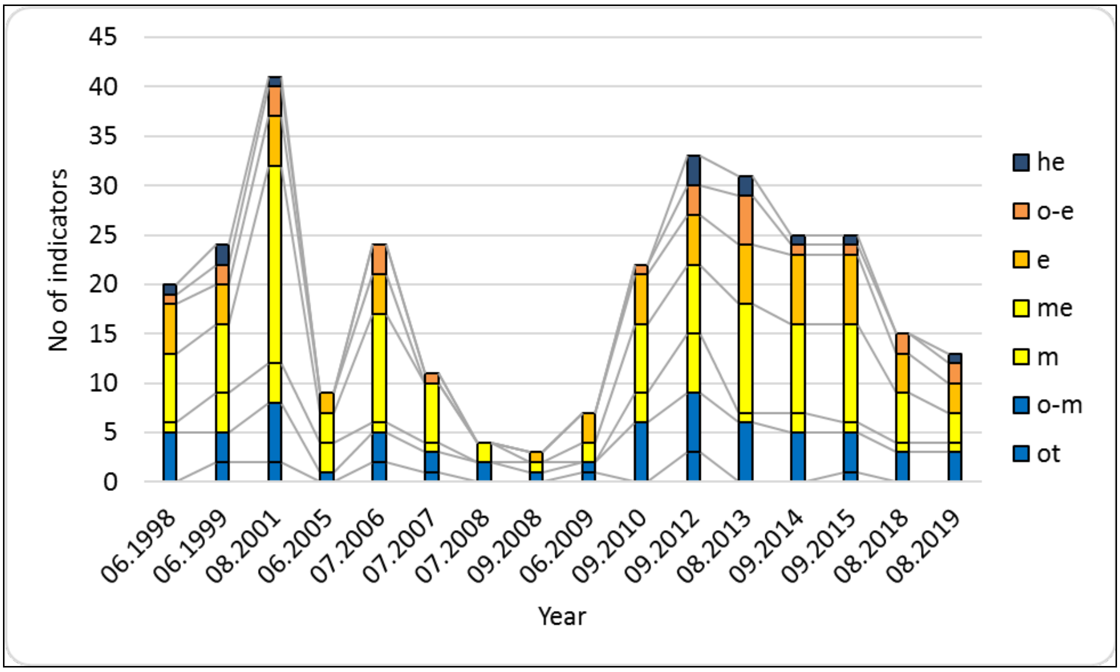

Figure 7: Long-term dynamics of taxonomic richness of trophic indicator species in phytoplankton of CP KhNPP. Groups of oligotrophic (blue) mesotrophic (yellow), eutrophic (orange) and hypertrophic indicators (black) are painted with the same color.

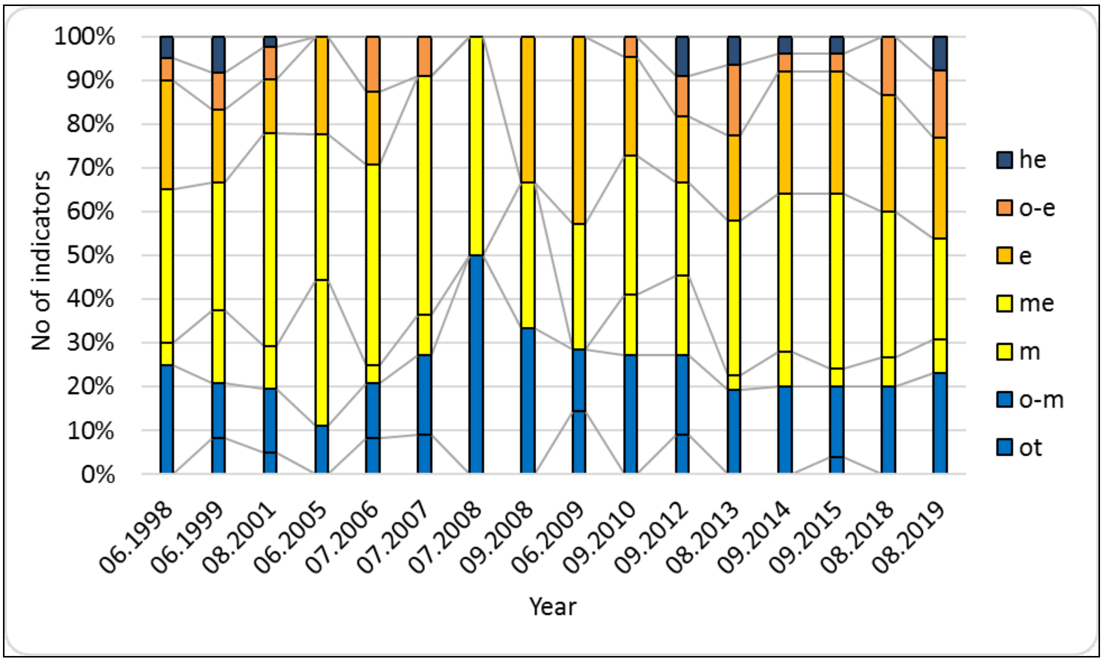

Figure 8: Long-term dynamics of groups of indicators of trophicity in phytoplankton of the CP KhNPP. Groups of oligotrophic (blue) mesotrophic (yellow), eutrophic (orange) and hypertrophic indicators (black) are painted with the same color.

It should be noted that the grouping of indicator species, a kind of "sub-community"/quasi-community of indicators, is, apparently, not just a list formed by researchers for the convenience of environmental assessments, but a real coenotic grouping. This is indicated by the fact that the dynamics of the indicator of the diversity of indicator groups (Fig. 9) had certain tendencies of change. For example, in 1998, the grouping of indicators included five types of oligomesotrophs, one type of oligoeutrophs, one type of mesotrophs, seven types of mesoeutrophs, five species of eutrophs, one type of hypertrophs. In summer 2008, the structure was as follows: two types of oligomesotrophs and two types of mesoeutrophs. After the general depression of phytoplankton, the quasi-community of indicators gradually recovered during 2009-2012. This process in the ecosystem (we previously called it decontourization (Protasov and Silaeva, 2014) took a long time. Then the indicators of diversity went to average, as it was before contourization processes, after the introduction of *Dreissena*, the level is about two bits/ind. group.

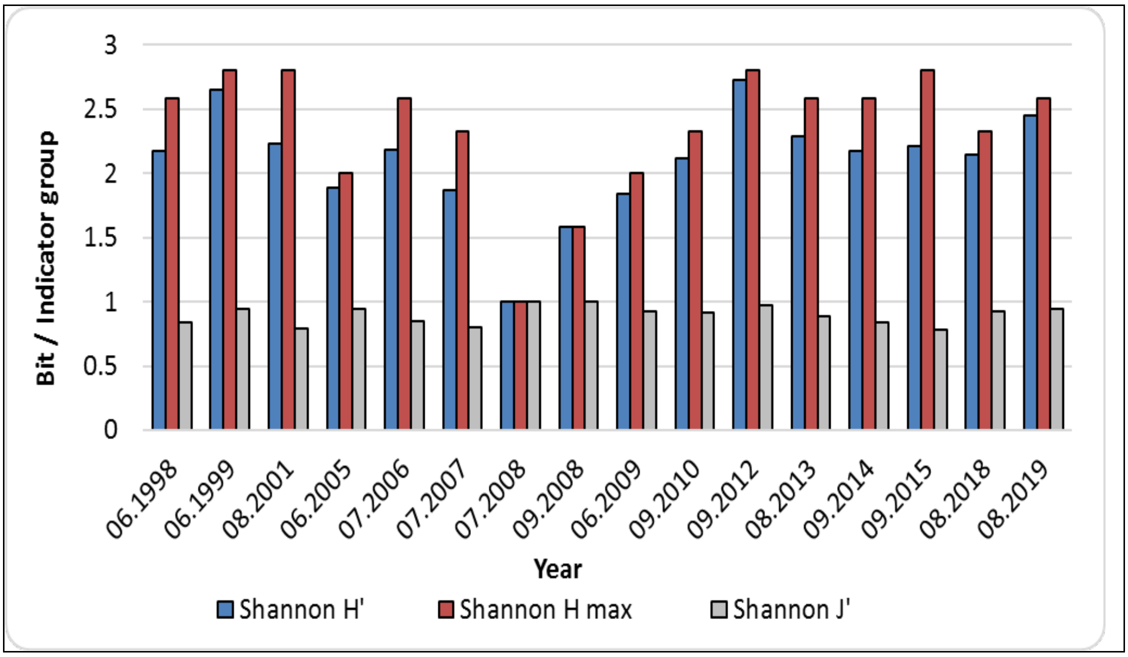

Figure 9: Dynamics of changes in the index of species diversity H, maximum index of diversity H max and evenness J of the wealth of indicator groups in the "sub-community" of indicator types.

The indicator of diversity adopted by us varied both on the number of indicator groups and the saturation of their species. So, from 2008 to 2012, the number of indicator groups increased from two to seven (Fig. 10a). Although, in 2013, the number of indicator species on average per indicator group, decreased (from 5.2 in 2013 to 1.8 in 2019), due to the high uniformity the diversity was quite high (Fig. 10b).

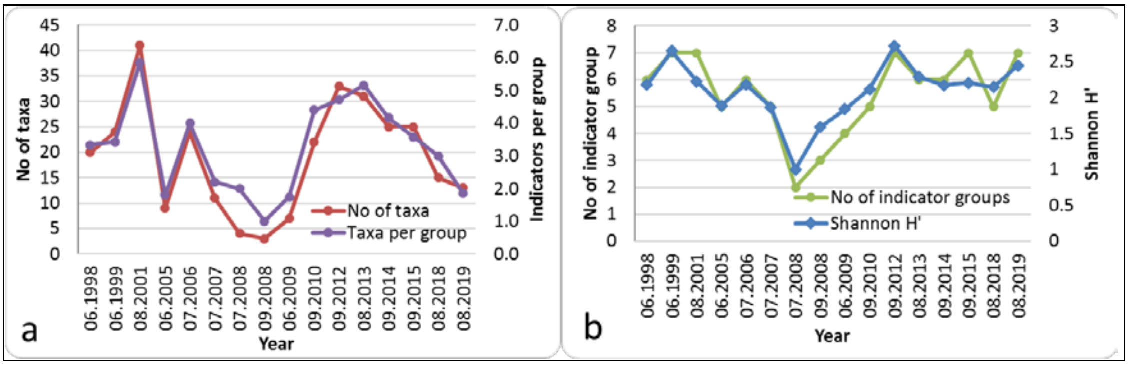

Figure 10: Dynamics of the number of indicator groups and species richness (a) and saturation of groups with indicator species (b) during the study period.

The graphs in figure 10 show that the number of species per group of trophic indicators repeats the species richness (a). At the same time, the Shannon index repeats the number of groups of trophic indicators (b). Moreover, in the third period, both of these pairs are in antiphase, which suggests that both for the structural properties of the pond ecosystem and for trophicity indicators, the key moment (Gumpinger et al., 2008) of cardinal changes is a decrease in the species richness of phytoplankton.

Earlier, we noted (Protasov et al., 2019) a close relationship between the distribution patterns of Shannon indices and species richness in algal communities relative to the trophic level of the water body. At the same time, excessive emphasis on the indices of species diversity (Pore et al., 2020) distracts the researcher's attention from a really important issue – trends in the trophicity of the reservoir, based on which important technical and administrative decisions are made. At the same time, the results of the current work reveal similar patterns in the dynamics of the species richness of algae and indicators of trophicity, presenting prospects for the development of new simple criteria (Dedić et al., 2020) for determining trends in change trophicity of a water body in a changing environment along with ecological modeling (Barinova, 2017), and which can be used for monitoring in future.

CONCLUSIONS

The KhNPP cooling pond's trophic status varied within wide limits during the entire study period on the background of an increase in the power plant's capacity. Reorganization of the ecosystem, benthos, and periphyton was observed, caused by invasion and mass development, and then partial elimination of the filter-feeding mollusk *D. polymorpha*. The range was very wide: between the first and seventh trophicity categories according to (Oksiyuk et al., 1994). In the process of these transformations, the composition and richness of trophic indicator species in phytoplankton changed. A kind of quasi-community of indicator species was formed and rebuilt. In the list of species throughout the study, the greatest richness was noted in the indicators of meso-eutrophic waters. Their representatives were most often part of the dominant phytoplankton complexes. At the same time, indicators of oligo-mesotrophic waters were constantly observed in the floristic spectrum. Hypertrophs were observed only at the first and third stages of research when the level of trophicity in terms of the abundance of algae was high (categories 4-7). In the long-term aspect, the dynamics of the taxonomic richness of the trophicity indicators coincided with the dynamics of the trophicity of the waters of the KhNPP.

Thus, the use of phytoplankton biological indication methods along with traditional hydrobiological research methods increases the representativeness of assessing the state of aquatic ecosystems. Based on bioindication, it was possible to establish the nature of deep restructuring in the technoecosystem, which was associated with a change in the operating mode of the power plant and the introduction of invasive species of aquatic organisms.

ACKNOWLEDGEMENTS

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PLANT LANDSCAPE AND MODELS OF FRENCH ATLANTIC ESTUARINE SYSTEMS. EXTENDED SUMMARY OF THE DOCTORAL THESIS

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KEYWORDS: Atlantic estuaries, ecological gradients, models, natural and semi-natural habitats, (syn)phytology, plant landscape.

ABSTRACT

The present study proposes a theoretical common model of environmental gradients and functioning of vegetation and Plant Landscape of the French Atlantic estuarine systems. This model offers a basis to improve classification and ecological studies of estuarine systems, and to helps the monitoring and assessment of land uses, land forms transformation and human impacts, thanks to the develop of a spatio-temporal predictive model based on actual and potential vegetation following a dynamico-catenal approach. In eight selected estuaries, fieldworks was undertook for a total of 98,315 ha highlighting two vegetation series and four geopermaseries, corresponding to 131 plant associations, 60 alliances, 43 orders, and 28 classes. The vegetation of three representative estuaries was mapped, for a total of 74,433 ha. A synthetic scheme of estuary vegetation landscape is proposed, integrating geographical and ecological gradients as well as geomorphologic forms.

RÉSUMÉ: Paysage végétal et modèles des systèmes estuariens atlantiques français. Résumé détaillé de la thèse de doctorat.

Cette étude réalise un modèle commun de fonctionnement et de gradients de la végétation et du paysage végétal des systèmes estuariens atlantiques français, afin de constituer une base pour améliorer leur classification et leurs études écologiques, et pour aider au suivi et à l'évaluation des utilisations des terres, de la transformation des formes de terrain et des impacts humains – en développant un modèle prédictif spatio-temporel basé sur la végétation réelle et potentielle en utilisant l'approche dynamico-caténale. Dans huit estuaires sélectionnés, des travaux de terrain ont été entrepris pour un total de 98.315 ha mettant en évidence deux séries de végétation et quatre géopermaseries, correspondant à 131 associations de plantes, 60 alliances, 43 ordres et 28 classes. La végétation de trois estuaires représentatifs a été cartographié pour un total de 74.433 ha. Un schéma du paysage végétal des estuaires est proposé, intégrant les gradients géographiques et écologiques ainsi que les formes géomorphologiques.

REZUMAT: Peisajul vegetal și modelele sistemelor de estuare din Atlanticul francez. Rezumatul extins al tezei de doctorat.

Acest studiu realizează un model teoretic comun al gradienților de mediu și de funcționare a vegetației și a peisajului vegetal al sistemelor de estuare din Atlanticul francez pentru a crea o bază pentru îmbunătățirea clasificării și a studiilor ecologice și pentru a ajuta la monitorizarea și evaluarea utilizărilor terenurilor, transformarea formelor de teren și impactul uman – dezvoltarea unui model predictiv spațio-temporal bazat pe vegetația reală și potențială utilizând abordarea dinamico-catenală. În opt estuare selectate, am întreprins lucrări de teren pentru 9.8315 ha, evidențiind două serii de vegetație și patru geopermaserii, care corespund la 131 asociații de plante, 60 alianțe, 43 de ordine și 28 de clase. Am cartografiat vegetația a trei estuare reprezentative pentru 74.433 ha. Este propusă o schemă sintetică a peisajului de vegetație de estuar, care integrează gradienți geografici și ecologici, precum și fome geomorfologice.

INTRODUCTION

Background

This text derives from and it represents an extended summary of the author PhD thesis, entitled "Plant landscape and models of French Atlantic estuarine systems" (Cianfaglione, 2018). It was funded by the French Ministry for Environment, as part of the national mapping program of natural and semi-natural habitats (CarHAB Project, convention number 2100992970) and it was conducted following a jointly supervised co-tutorship of PhD program between the University of Camerino (Italy) and the University of Western Brittany (France). The University of Camerino co-financed the place and the PhD course through a ministerial competition won by the candidate with a public competition. The PhD thesis was defended in December 2018, in Brest (France) under the Eurolabel (Doctor Europaeus) conditions, an additional certification to PhD title for having respected the conditions of the Confederation of Conferences of Rectors of EU countries, implemented by the European University Association (EUA). This PhD thesis was evaluated in the research activity carried out for the deliverance of the Young Researcher Award with participation grant at the "7th Aquatic Biodiversity International Conference" Sibiu, Romania (September 25th to 28th, 2019).

In papers that rely on secondary research, the definitions, concepts, principles and methodology sections would provide the necessary background or history for understanding the discussion to come. An overwiew of the available literature more specifically synthesizes information from a variety of significant sources related to the major point of this paper.

Introduction to the research

All European big river basins including their direct contact areas with seas and oceans are lately under a constant habitats and biodiversity change (Bănăduc et al., 2020; Tockner et al., 2021) reason for which needs permanent high scientific research focus and efforts, based on special on site adapted/designated research methods. Europe has a long-documented tradition in vegetation science and cartography, particularly following the establishment of Josias Braun-Blanquet's International Mediterranean and Alpine Geobotany Station (SIGMA) in the early 20th century (van Der Maarel, 1975; Pignatti, 1995; Pirola, 1999; Cristea et al., 2016; Géhu, 2004, 2006; Ubaldi, 2012) a research center founded by De Leeuw W. C. and Combes R. initiative, and diriged by Braun-Blanquet from its foundation in 1930, until its disappearance in 1980 (Géhu, 2010a, b; 2011). Meanwhile, the 1992 European Habitat-Fauna and Flora Directive has drawn attention to habitats of community interest, which require the development of knowledge in the areas of habitat distribution and mapping (Clergeau and Blanc, 2013). As part of the 2011-2020 National Biodiversity Strategy, the French Ministry of the Environment launched in 2011 a national terrestrial habitat mapping program entitled "National Mapping of Natural and Semi Natural Terrestrial Habitats" (CarHAB), in collaboration with various French institutional and academic structures (*), consequently the CarHAB project was established to produce a 1:25 000 vegetation map of France, following the approaches and concepts of phytosociology and landscape phytosociology (Dynamico-catenal Plant Sociology).

Estuaries have been selected as study areas of the CarHAB program to better understand their originality in terms of flora and dynamic trajectories of vegetation, linked to the landscape, β-biodiversity, use of land and water.

Estuaries represent a very important system for human uses (Borja et al., 2012; Day et al., 2012; Thrush et al., 2013), and they are very important for their biodiversity issues. Estuaries are commonly considered very rich in nutrients (Middelburg and Herman, 2007) and consequently rich in species, very productive in biomass and as important sources of ecosystem services (Muchiut et al., 2008). Generally, these environments are considered of very high importance also following “Birds” and “Habitats” EU directives together within the “Ramsar Convention”. National and local administrations improved these directives and conventions by laws, regulations, restrictions, prohibitions and actions – following the different national or local realities, peculiarities and risks. In general, estuarine environments are characterized by high water dynamics and sometimes even violent tides, with frequent variation of the salinity fronts that depend on the daily, seasonal, occasional cycles and extreme events of tides, and on the aquifers dynamics from the catchment areas carried out by rivers (Romaña, 1994).

Estuaries may have undergone very important changes over the centuries due to human pressure (Kestner, 1966; Kragtwijk et al., 2004; Verger, 2005; van Proosdij et al., 2009; Sawtschuk and Bioret., 2012; Di Pietro et al., 2017; Le Dez et al., 2017a, b).

These changes may have created a set of semi-natural and artificial ecosystems in detriment of natural ecosystems, and they may have limited or compromised the primitive functionality of estuary systems and services, changing the physical and chemical quality of the water, tampering the hydraulic functioning, the species composition, the geomorphology and the landscape forms. For that reason, estuaries generally represent a complex of natural and semi-natural habitats, developing from oceans (or seas) to fresh water (bottom-up gradient), and from the lowest to highest water levels, including exceptional flood level where the alluvial plain can be flooded during extreme events (minor-major bed gradient) (**).

A river mouth is the part (the point) of a river or an estuary, that flows into a water body (e.g.: another river, a lake, reservoir, sea, or ocean). At the river mouth the water characteristic changes in some way. The main changes are on water flow conditions, causing changes in currents and related physical, chemical and biological characteristics, together with the erosion and sediment deposition dynamic. In common language, the “river mouth” word can be generically used to denote any geomorphologic type of estuary i.e.: “Bouches du Rhône” – where the Rhone River final portion is anastomized (multiple channel) delta type; and “Embouchures de la Loire” – where the Loire River final portion is from a single channel type.

An estuary corresponds to the river portion where the effect of the sea (or ocean) in which it flows is noticeable (Fig. 1). It concerns the entire portion of the river where the water is salty, brackish and freshwatery. Ocean and sea are here used as synonyms.

In 1967 Pritchard D. W., considered great specialist in estuaries (Romaña, 1994) proposed a definition of them based on scientific considerations: an estuary is a confined body of water with a free connection to the open sea and which seawater is measurably diluted with fresh waters drained in the watershed. It is interesting to note that the word “tide” was not mentioned because some estuaries are not under the influence of tide cycles. Tides determine the tidal estuaries, being the main dynamic factor of the estuarine cycles and related variations. For that, tidal estuaries are more variable in time and space systems. Estuaries body of water are in any case transversally confined in the estuarine bed and longitudinally confined in the area of where the upriver waters are influenced by the sea waters (Fig. 2). Tidal estuaries are in general characterized by: longer surfaces, following the highest tide level, and because in the upper side the freshwater front is influenced by the seawaters following the tide level. This estuarine freshwater portion is also commonly known “dynamical tide portion”, while the other downstream portion is commonly known as “salty tide portion” (Guo et al., 2015; Perales-Valdivia et al., 2018).

The estuarine system could be subdivided in salinity portions following the average water salinity concentration – following the international thalassic series of the “World Ocean Atlas, 2009”, from the downstream to upstream portions (Fig. 3).

Salty water domain:
– Euhaline (mixoeuhaline) zone – more than 30 psu;
– Polyhaline zone – between 30 and 18 psu.
Brackish water domain:
– Mesohaline zone – between 18 and 5 psu;
– Oligohaline zone – between 5 and 0.5 psu.
Freshwater domain:
– under 0.5 psu.

Psu is Practical Salinity Unit, based on water conductivity (salinity); equivalent of grams of salt (NaCl) per kg of water (g/kg); or salt grams per liter of water (g/l). psu could ben be expressed as “ppt (part per thousand)”, or using dimensionless numbers, or just followed by the “‰”, or by word “salinity (s)” (Lewis, 1980; Mantyla, 1987).

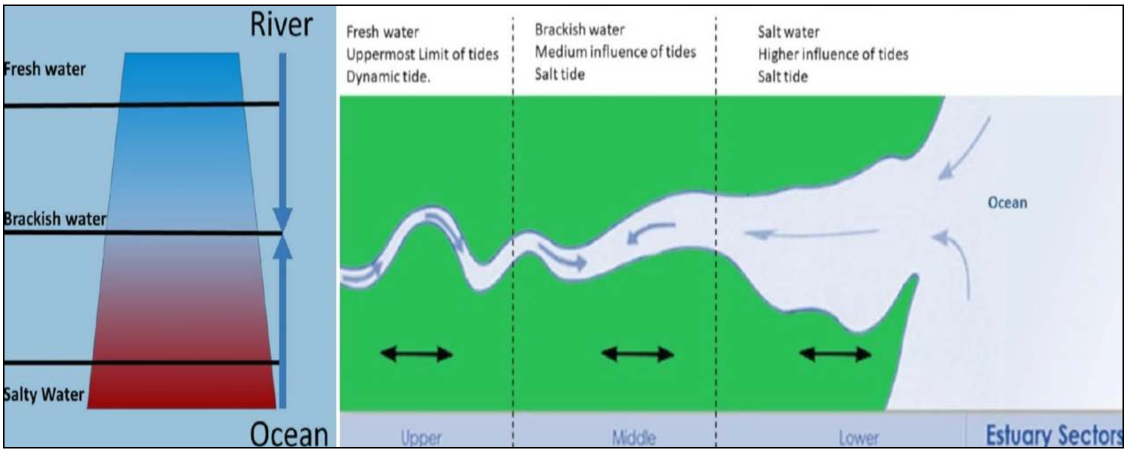

Figure 1: The general salt-freshwater gradient in estuaries follows the gradient between ocean and river conditions.

By comparison, generally the average ocean salinity is around 35 psu. The limit on agriculture irrigation is normally fixed on 2 psu and the limit for drinking waters commonly is 0.1 psu.

Tides cycles influence salinity zones extension and could shift them along the riverbed. Salty tides are located where the effect of the sea in estuaries is strongest. In the inner estuarine zone, the effect of sea is lesser, only freshwater is present but still under tides influence: the dynamic tides.

Estuarine systems could be classified following the tidal dynamics in:
– Macrotidal, undergoing significant tidal ranges (over four meters);
– Microtidal, undergoing lesser tidal ranges;
– Non tidal, not influenced or under negligible tidal influence.

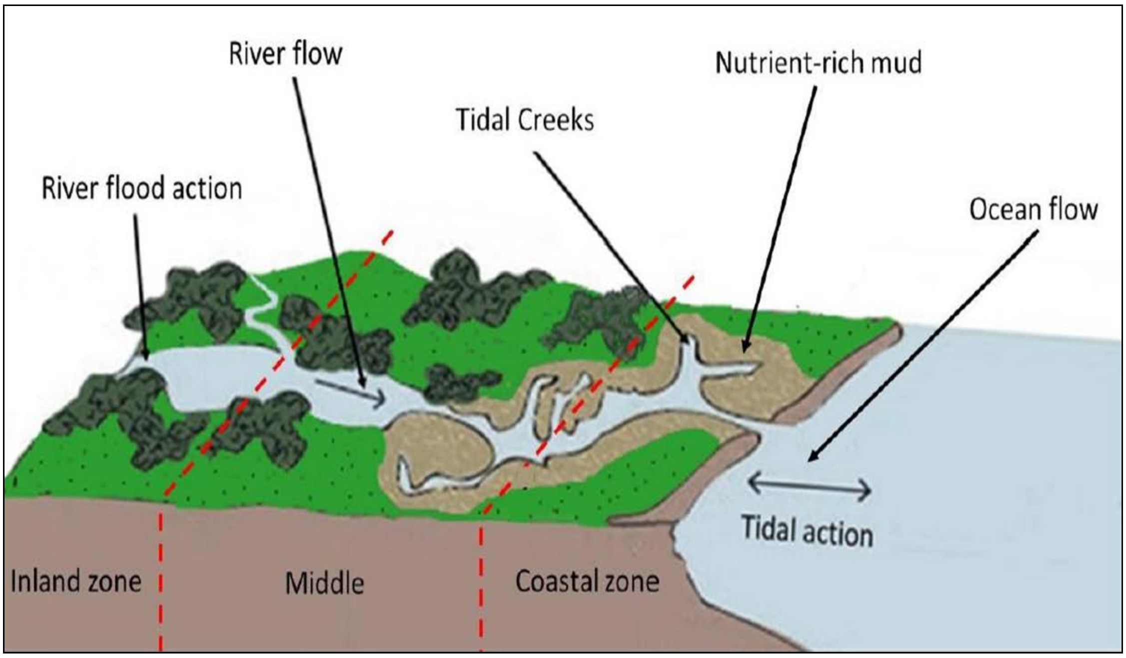

Figure 2: General geomorphologic variation between inner and coastal estuary portions.

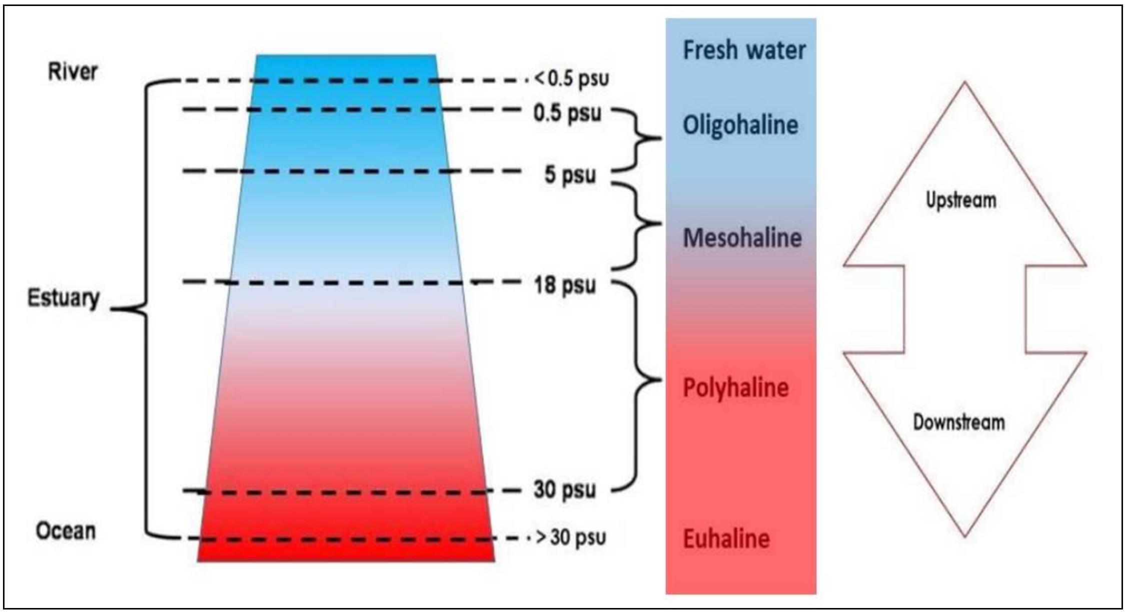

Figure 3: Estuarine up-down stream salinity gradient and related ecological sectors; psu corresponds to one part of NaCL per thousand parts of water.

MATERIAL AND METHODS

Research questions and objectives

This work is aimed to develop a spatial-temporal predictive model based on the current and potential vegetation of estuaries, following a dinamico-catenal approach. This approach aims to represent three levels of organization of the vegetation: communities' organisation (associations), dynamic trends (series), and landscapes (geoseries).

The main research questions are the followings. Which geographical and ecological characteristics influence the vegetation patterns in the estuaries? How to classify estuaries according to vegetation characteristics (traits, distribution, and diversity) and their models? It is possible to define a generic common model of ecological gradients and landscapes plants from estuaries? The cartography process is performed to evaluate surfaces from tessellar units (sigmeta) and catenal units (geosigmeta).

This raises some additional questions about the potential and current vegetation. How can secondary communities help to characterize estuarine vegetation series? To what extent the current vegetation communities are in balance with the natural or artificial dynamics? This thesis also aims to study ecological and geographic systems in order to deepen knowledge of vegetation and ecosystems, in order to develop a synphyitosociological and cartographic methodology of the vegetation of the French Atlantic estuary systems.

General concepts and definitions

Phytosociology or simply plant sociology study the groups of plant species that usually grow together (phytocoenois, synusiae, plant communities, or phytoassociations) (Rivas-Martínez, 1976; Béguin et al., 1979; Tüxen, 1979; Géhu and Rivas-Martínez, 1981; Schwabe, 1989; Gillet et al., 1991; Theurillat, 1992a, b; Lazare, 2009; Biondi et al., 2011). The basic unit of studies in classical phytosociology is the plant association which constitutes a homogeneous community of plants in a homogeneous environmental unit. The plant association (or phytoassociation) is a plant community in equilibrium with the environment, characterized by a specific ecology, floristic composition, and aspect. This allows considering each plant association as original phenomena from a physiognomic, floristic, ecological, dynamic, and historical point of view (Tüxen, 1973, 1978; Falinski, 1986, 1998, 1999; Falinski and Pedrotti, 1990). Phytosociology organises plant communities in syntaxonomic units (syntaxa), which likely the taxonomical ranks are hierarchically organized at various levels. In plant associations, progressive dynamics are related to primary or secondary successions. The dynamics, on the other hand, are negative when they are related to phenomena of regression and degeneration. They are stable when they are related to fluctuation (anthropogenic or natural). In the vegetation series, the positive dynamics are oriented towards successions, passing from the current state to one with presumably higher in environmental balance (increasing both the structure complexity and of accumulated biomass). Conversely, negative dynamics tend to move away to this balance, reversing these characteristics.

Plant associations constitute the first level analysis of the plant landscape. Synphythosociology (or phytosociology of the landscape) includes the study of all plant associations in the landscape (Guinochet, 1973; Géhu and Rivas-Martínez, 1981; Géhu, 1991; De Foucault, 1984; Weber et al., 2000; Dengler et al., 2008; Dengler, 2017). Landscape phytosociology focuses on the description and classification of vegetation series in an ordered system, looking for a standard hierarchical system. By its holistic nature, this integrative system is useful for developing tools for monitoring ecosystems, conservation measures, functionality, habitats assessment, natural heritage, and biodiversity threats (Pedrotti, 2013; Cristea et al., 2016).

In the field of the land management, it is possible to measure the status of the environment, evaluating the threats relying on the degree (impact) of land uses, following the degree of artificiality or naturalness of the landscape. The landscape phytosociology allows to integrate the vegetation dynamics by describing the trajectories of the series vegetation. Since the 1970s, the novelty has been characterized by a greater and increasing integration effort of geographic and ecological data (with landscapes, land use and other environmental data) followed by the creation of a large set of based on vegetation thematic maps. Classic integrated phytosociological studies correspond to the integration in a spatial-temporal way of the vegetation features (integrated phytosociological maps). Another possible integration type is the ecological integration, considering the integration with other thematisms (e.g.: environmental, social, agronomic, geographic, geological, soil, climate, and fauna) (Pedrotti, 2013; Cristea et al., 2016). The integration of these themes recalls, among other things, the definition of "geoarchitecture", a term used by the architect Le Corbusier at the beginning of the 20th century (Petrilli, 2006). Concept inspired in some way by some eminent scholars like Maestro Martino (Martino de' Rossi), Anthelme Brillat-Savarin, Hannah Glasse, Pellegrino Artusi, about Gastronomy. In fact, in a broader sense, the term Gastronomy, meaning it as the study of the relationship between culture and food in an interdisciplinary science that involves biology, agronomy, anthropology, history, philosophy, psychology, and sociology. Resuming, it is possible to distinguish some subtypes of phytosociological maps: maps of real vegetation/syntaxonomic units; and maps of potential vegetation/climatic syntaxonomic units). The integration of these types of vegetation maps corresponds to the classical integrated maps of vegetation, where the vegetation is integrated in time and space, and the current vegetation is represented within the potential vegetation colour shades. Ecological integrated vegetation maps are integrated with other thematic aspects (soil, geology, etc.). Geosynphytosociological maps (geosigmetal maps) correspond to the vegetation complexes maps.

From a morphological point of view, an estuary is the portion of a river where the effects of the sea (or ocean) are remarkable. The mouth is the part of an estuary that flows into the sea. In estuaries, the main environmental factors are due to the conditions of the flows and the chemical, physical, and biological properties of the water. Variations in water flow determine the dynamics of sedimentation and erosion, as well as variations in salinity. Tidal estuaries are typically characterized by their larger surfaces, according to the highest possible tide levels (Gibson, 1934; Pritchard, 1955; Cameron and Pritchard, 1963; Guilcher et al. 1982; Wells, 1995; Gnanadesikan, 1999; Valle-Levinson, 2010; Mann et al., 2013).

The further downstream estuary portion is characterised by salty water, and influenced by salinity tide, while the portion located further upstream, with fresh water, they correspond to the dynamic tide. The dynamics of estuaries are influenced by the seasonal cycles linked to the floods caused by the tides (downstream) and the inflow of water from the catchment area (upstream). The beds, meanders, swamps, banks, and terraces of estuaries are always subject to the dynamics of the currents that can reshape them (Hansen and Rattray, 1966; Owen and Odd, 1972; Lambiase, 1980; Amos and Mosher, 1985; Shi et al., 1995; Strang and Fernando, 2001; Orton and Kineke, 2001). In all estuaries, the bed, meanders, banks, and terraces are constantly reshaped by the water flows cycles; by continued or alternative filling/erosion of materials; by different water levels and different salinity values, by suspensions coming from river or from the sea, creating a "permanently unstable" area. This dynamism is reflected in unstable (stably-unstable) environments, subject to recurrent or occasional disturbances that could affect all biological expressions, including vegetation, and in meantime they could reshape the landforms and the hydrology, consequently making these systems as "plastic" environments.

From a geographical, geomorphological, and ecological point of view, the estuaries represent a multiple gradient between inland (riverine) and coastal (marine) systems. They represent a transition from the salty environment that are more exposed to sea winds, towards freshwater environments, more sheltered and less mild. In large estuaries, the influence of rivers is more pronounced due to the larger and therefore more impacting river bodies. In smaller estuaries, the influence of the sea is dominant to the point to consider them like a bay, a gulf, a marina: a bend of the sea. (Romaña, 1994; Verger, 2005)

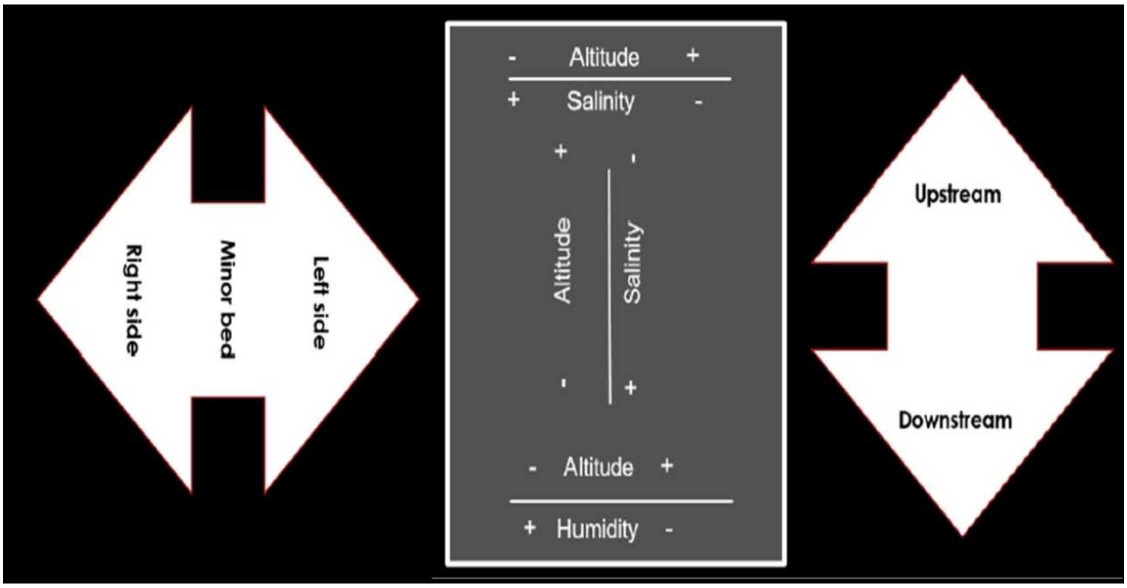

Figure 4: Schematization of estuarine geographical gradients and directions.

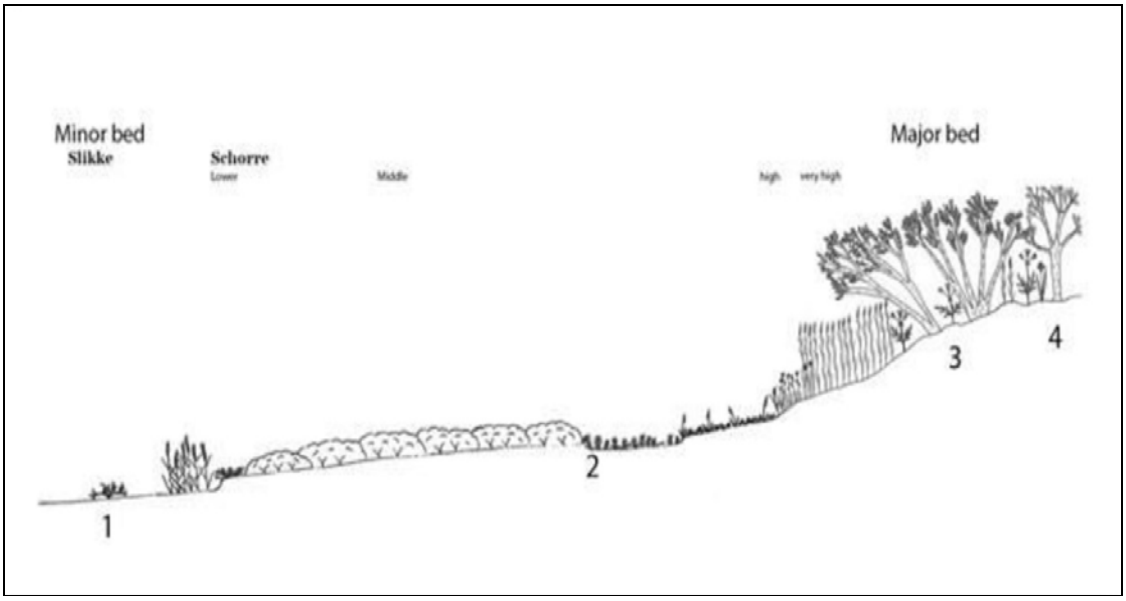

Figure 5: An example of complete phanerophyte gradient per geomorphological position, in salty estuarine portion. Vegetation is divided as expected from literature: from 1 to 2 non woody (permaseries) vegetation; to 3 to 4 woody vegetation (holoseries).

Figure 6: Aulne Estuary lower portion. The salt mud and meadows community, from glasswort, up to *Halimione portulacoides* coenoses, on salt mud tidal creeks.

Figure 7: Laïta Estuary middle portion. From minor to major riverbed: the reed bed community (in large sense); *Salix atrocinerea* marshy forests (lower forest); and *Fraxinus excelsior* forests (upper forest). The zonal forests is characterised by *Fagus sylvatica*, out of the estuary.

Figure 8: Laïta Estuary, St. Maurice. The contact between salt mud and meadows community (*Elymus repens* and *E. athericus* grasslands) and mesic forests community (*Fraxinus excelsior* and *Quercus robur*); on sandy-mud salt tidal creeks. At the bottom, the estuarine macroalgal tidal community.

Study area

The study area corresponds to the French Atlantic coast, located between the Basque Country (Iberian-French border) and Flanders (Franco-Belgian border), characterized by an oceanic climate (Fig. 9).

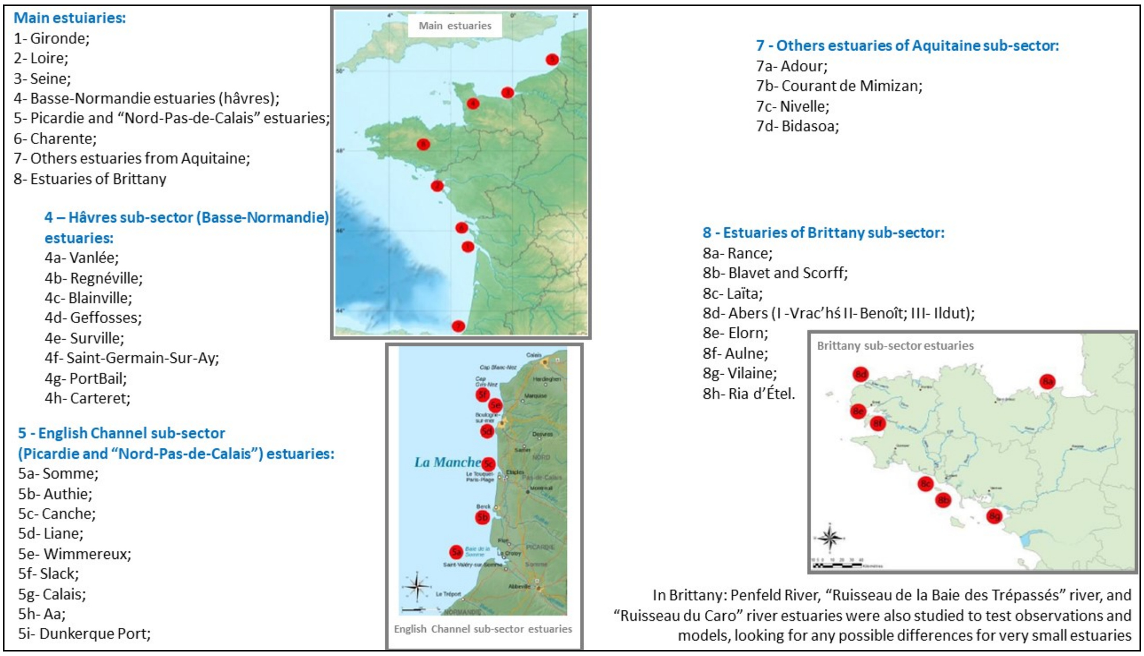

Figure 9: Estuaries sectors of study.

Among the largest estuaries studied are: Gironde, Loire, Seine, and Charente. Among others from Basse-Normandie (Hâvres) are: Vanlée, Regnéville, Blainville, Geffosses, Surville, Saint-Germain-Sur-Ay, PortBail and Carteret. Among the estuaries of Picardy and the Nord-Pas de Calais are: Somme, Authie, Canche, Liane, Wimmereux, Slack, Calais, Aa, and Port of Dunkerque. Among the other estuaries of Aquitaine are: Adour, Courant de Mimizan, Nivelle and Bidasoa. Among the estuaries of Brittany are: Rance, Blavet and Scorff, Laïta, Abers (I-Vrac'h, II-Benoit, III-Ildut), Elorn, Aulne, Vilaine, and Ria d'Étel.

Data analysis

The vegetation series were named after the head-series association, while the geoseries were named after the most representative head-series association. For the secondary facies, we tried to identify potential vegetation. Consequently, semi-natural and artificial formations have been aggregated with head series formations into their relative series.

The preliminary work was carried out on all estuaries based on bibliography, aerial photos, topographic maps, maps of the intertidal zone, thematic maps related to vegetation, maps of habitats, land use, and protected areas), allowing us to summarize the available data on biotic and abiotic factors; and also to define a first ecological characterization, a first model of the estuary system and to create a first database to have initial elements of hypothesis, reflection and discussion about it. Particular attention was given to the characterization of vegetation and its cartography, as well as the observation of the role of ecological gradients, the dynamics of vegetation and the understanding of the anthropogenic pressure exerted.

A selection of estuaries was carried out to carry out field surveys, to develop the typology and cartography of the vegetation series and geoseries. The phytosociological and geo-reliefs were carried out to identify the different series, geoseries, and geopermaseries, to describe the distribution of vegetation in the landscape, and possibly highlight any synendemic elements or, conversely, any similarities (invariant elements) between estuaries.

The data cartographic processing has allowed us to develop a spatial model that allows us to represent the general organization of the estuary vegetation based on the associated ecological gradients. Not always has been possible to describe all the trajectories and dynamics of vegetation, due to the lack of historical data or because the land use is so marked on large surfaces to the point of altering the expression of vegetation or the shapes of the landscape and hence the potential of vegetation (drainage, erosion, deforestation, desertification, loss of natural species, introduction of exotic species). The map of potential vegetation (represented by series, geoseries, and geopermaseries of vegetation) was integrated with the symphi-sociological and phytosociological surveys (real vegetation) describing the composition of the various mapped units. Special cases can be represented by symbols on the cards or described. The vegetation maps were created using the QGIS software (version 2.18.14).

Umbrothermic, climatic, and bioclimatic analyses were performed using data from the MeteoFrance and WorldClim databases, with the aim of framing the estuaries and analysing the climatic micro-variations in the estuaries.

RESULTS AND DISCUSSION

The main factors that characterize estuaries and their ecological gradients are the salinity and the water content of the substrate (sediments/soil) (Cianfaglione, 2018). Other physical factors can determine differences, peculiarities or exceptions: substrate size, slope, sea winds, microclimatic variations, human impact. Each estuary is an original system, due to a unique combination of its geographical, ecological, uses history and dynamic characteristics, combined with present and past human impact. In estuaries, ecological gradients follow geographic and morphological variations in two directions: longitudinal (from valley to mountain) and transverse (from minor to major bed). In both cases, we go from lower topographical levels to higher levels, consequently the salinity decreases, as does the soil moisture content. Following the direction of the topographical levels, the higher you go, the more you can find a common tendency in both directions regarding the expression of the vegetation (from marshes and salty meadows to the forests of greater ash and English oak). In the two directions (longitudinal and transverse) the influence of the tides tends to be less important further upstream, while, the precipitations (with the water table) increase their footprint. The transverse topographic gradient (minor-major bed) corresponds to a gradient of decreasing humidity (or flooding) and similarly also happens for salinity. Following these variations, we can found the following geomorphological compartments (Fig. 5): main channel, Slikke, Schorre and alluvial plain (Verger F., 1995; Géhu J.-M., 2009a, b)

In Slikke level (mudflats) we find a mud layer exposed at the tidal fringe, with very changing water level and salty conditions especially in the medium estuary. Here we can find non vegetalised mud or algal communities (micro and marco algal formations, compised the Maerl – or rhodolith, a coralline-like formation of red algae, found occasionally in less muddy and stonyest (pebbles) substrate. In the innermost portions of the estuary (freshwater portions) these communities are replaced by the lowest most freshwater amphibious plant communities (i.e. *Apitum nodiflorum, Berula erecta, Veronica beccabunga,* etc.).

In the Schorre level we can find a saltmarshes (tidal marsh), sited in the upper coastal intertidal zone between land and open saltwater or brackish water that is regularly flooded by the tides. It is dominated by dense stands of salt-tolerant plants such as herbs, grasses, or low shrubs (Adam, 1990; Woodroffe, 2002). In the innermost freshwater parts of the estuary these communities are replaced by uppermost freshwater amphibian vegetation (i.e. sedges and reeds) and by annual summer plant communities (i.e. *Poligonum* and *Bidens* species).

In the alluvial plain we can find the largest riverbed portion where forests can develops from riverine, to marshy and mesic types. In this level the human activities are wider (agriculture, livestock pastures, urbanisation, and industrial zones). Topography or soil differences (slope, drainage, frequency of floods, and the level of the groundwater) here can favour one or another potential vegetation, until reed-beds and others non-forest marshy/riverine communities. At this level, in upper topographical levels, floods can be annual, with very long frequencies (even centuries or millennia) or occasional (extreme events). The alluvial plain in the more coastal portion is more subject to winds and salt spray that could disadvantage the formation of tall forests, in favour of dwarf forest and bushes.

Under normal conditions, on this level, soft wood forest communities develops, dominated by ash trees (*F. excelsior* and *F. angustifolia*) mixed with more hygrophilous species (willows, poplars and alder species), up to them forests increasingly become rich in hardwood species –then mixed with more mesophilic species (*Acer* sp. pl., *Ulmus* sp. pl., *Prunus* sp. pl., *Betula* sp. pl. and *Quercus robur*) until they become very rich in *Q. robur*. In extreme cases, it is possible to find also *Q. petraea, Q. cerris* and *Castanea sativa* presences mixed in the forest communities (in ecotonal conditions with non azonal forests). In more drained and thermophilic ecotonal conditions, also conifer trees could be found (in particular *Pinus pinaster*) and also *Quercus ilex*. About shrub formations (Prunetalia) in more drained conditions (upper topographic levels, or in sandier soils) we increasingly find the presence of *Ulex Europaeus* in the thicket. In more thermic coastal condition we can find an increasingly presence of *Ligustrum vulgare* or other coastal species of *Ulex* (dwarf thicket). Under tiny soils on acid substrate (or decalcified soils) we can found *Erica* species and *Cyitssus scoparius* in the thicket. In marshy and riverine condition the shrubland is composed by *Salix* species that (more rarely) are accompanied by the *Frangula alnus* species (in more fresh watery condition) and *Rubus caesius* (frequently remplaced by its hybrids) at same level, but in more drained conditions, we can find *Euonimus europaeus*.

According to the longitudinal topographic gradient, (coast to inland) three salinity compartments can be distinguished from the mouth upstream: salt, brackish, and fresh water.

Estuaries can be defined as ecosystems, but at the same time also as complexes of ecosystems characterized by fluid ecotones, with boundaries delimited in time and space (Fig. 4). The behaviour of an estuary varies greatly depending on the season, location, tidal strength, river flow, rainfall, wind, and deep-sea currents. The expression of estuary biodiversity is complex due to the presence of characteristics that coexist even if they could appear to be antagonistic (for example the influence of salt water and fresh water on the same surface, or the alternation of drought and aquatic conditions, sediment deposition and erosion, etc.). This ecological complexity induces a certain complexity of the habitats and therefore of the vegetation. Consequently, estuarine gradients can be highly variable and multidirectional, reflecting the complexity of each of these systems. The presence of species, plant communities and vegetation limits can be roughly defined by analyses over time and based on water bodies, taking the main channel as a reference (Figs. 5-8). As primary producers in the ecosystem, plants and plant communities are particularly sensitive to the phenomena that characterize the environment, and due to their physiological and biological characteristics they are considered good bio-indicators (sometimes known as macrophytes) especially for aquatic and mesic environments (as in the case of estuaries). In fact, the study of vegetation allows the short-term characterization of the environment and the monitoring of global changes in the long term, because plants are closely linked to the expression of biodiversity and therefore to environmental conditions, functioning as bio-indicators (Sender et al., 2014, 2017).

Out of a total of 36 identified estuaries, eight were selected for phytosociological and synphyto-sociological research (Charente, Loire, Vilaine Etel, Blavet-Scorff, Laïta, Aulne, and Elorn). The field work involved a 98,315 ha surface (Fig. 10). The data analysis and phytosociological synrelevés highlight two series and four geopermaseries, corresponding to 131 associations, 60 alliances, 43 orders, and 28 phytosociological classes. Three estuaries were selected to build the vegetation mapping and geoseries (Loire, Laïta, and Aulne). 74,433 ha were mapped, equal to two series and four vegetation geopermaseries. The phytosociological analysis does not claim to be exhaustive. In the estuaries, from the mouth to the freshwater portion, some variations and exceptions relating to the local geomorphology can be distinguished. The main variation follows the confinement of estuaries and the associated continuity (lateral, longitudinal, and vertical). In fact, the more the estuaries are of the confined type, the less the sequences of the vegetation series are evident (the series and geoseries tend to be more linear, discontinuous, nuanced, and thin), until they no longer allow the expression of one or more series, influencing the plant communities richness and the transgression. Considering that the floodplain is the largest floodable area, the problems of confinement and continuity therefore reflect on the human impact, as a result of artificial embankments, dams, drainages, reclamation, and backfilling. These changes block or affect hydrodynamics and geomorphology, with consequent exceptions related to vegetation expression.

The elaboration of phytosociological and synphytosociological tables, alongside the elaboration of vegetation maps, allowed us to validate and refine the initial hypothesis of ecological zoning in estuaries and to adapt it to series, geoseries, and geopermaseries, according to the cartographic principle of generalization.

In the saltier areas, from the minor to the major bed, the marshes vegetation and salt meadows (*Atriplici prostratae-Elymeto atherici* geopermasigmetum) are installed, succeeded by the marshy willows to *Salix atrocinerea* (forests of *Salix atrocinerea* geosigmetum), in addition the *Fraxinus excelsior* forests (*Fraxinus excelsior* forest geosigmetum). Upstream, *Salix atrocinerea* tends to be replaced by *Salix fragilis* (*Saliceto fragilis* sigmetum) and further upstream by *Salix alba* (*Saliceto albae* sigmetum). In the estuary minor bed, the vegetation can express well in the most sheltered or residual conditions; in linear or punctual form, due to strong currents and changes in the water fronts. Due to these characteristics and the possible mixed accessions of fresh water at various levels, we have simplified the cartography of the aquatic vegetation in the Lemneto minoris geopermasigmetum. It has included the aquatic vegetation of the pools, the meandering springs, floodplains, and rivulets, including all the primary aquatic vegetation. Three vegetation subgroups can be distinguished (depending on the rather salty, brackish or freshwater character). Vertical continuity and related natural exceptions influence the expression of vegetation. For example, it is worth mentioning the influence of fresh water natural accesses in saline habitats, or the possibility of marshy vegetation in the greater bed or of humid meadows and marshes with little or no salt, which in summer dry up, being able to show a certain outcrop of salt during the dry season (salinizing).

In the saline part, geomorphology and hydrodynamics influence the expression of the vegetation based on the type of substrate and the morphological type of the mouth. The relative variations in the granulometry of the substrate depend on its stability (balance between sedimentation, and erosion). If the balance between deposition and erosion is not strong enough to continuously reshape the surface, the vegetation can install more easily; the mud can also settle between the pebbles and the sand, promoting the installation of the plant community linked to marshes and wet saline parts. The influence (transgression and contacts) of the vegetation of the sands creates a variant of this community that is enriched with species typical of the beaches and dunes. The same phenomenon occurs in the presence of rocky outcrops or overhangs of earth and related species. If the deposits move, there may be an almost total absence of vegetation, scattered and less developed specimens, fragments of vegetation influenced by more stable deposits or by accessions of fresh water, as noted in the estuaries of the Loire, the Ria d’Etel, the Laïta, the Blavet-Scorff, and the Vilaine.

If the river is very open to the sea, or if the tidal flow is clearly greater than that of the river, the estuary behaves more like a sea bay (this is the case of Étel); the vegetation linked to salty waters can be more easily observed and the oligo to mesohaline Schoenoplectus tabernaemontani formations appear only punctually. In areas disturbed by human activities, due to deforestation and different uses, large surfaces may not express a seed. In other cases there has been a change in the vegetation series (displacement) upstream or downstream, following a change in the flood or salinity front, factors which can also cause the death of some species or the degeneration and regression of communities plants (Loire and Charente). In other cases, in salty or brackish areas, due to dams that prevent or slow down the rise of the salinity front, a marked presence of *Alnus glutionsa* can be noted, replacing forests with *Salix atrocinerea* (in more swampy conditions) or even *Fraxinus excelsior* forests (in less swampy conditions). This phenomenon has been observed in the lower part of the Erdre in the Loire Estuary and near the Folgoat chapel (Landévennec), near the old tide mill, in the Aulne Estuary. Similarly, reed beds and other herbaceous formations of fresh water can be found in the estuaries of Ria d’Étel and Laïta, in areas of salinity, but no longer subject to salt as they are located upstream of the lateral dams. In the Vilaine Estuary, upstream of the Arzal Dam, there is now a freshwater vegetation in the minor bed, in a former halophilous area. The Guily Glaz Dam, built in the Aulne Estuary to limit the impact of floods on the watershed, limits the expansion of water in the oligoaline zone, reducing the surfaces and the expression of vegetation linked to dynamic tides. The displacement of the willow series (*Salix fragilis* and *Salix atrocinerea*) to both banks of the Loire, between Saint-Nazaire, Nantes, and Donges is observed as a result of the artificial accumulation of sediments after the channel deepening into the estuary for channelling due to navigation (Figs. 10-13).

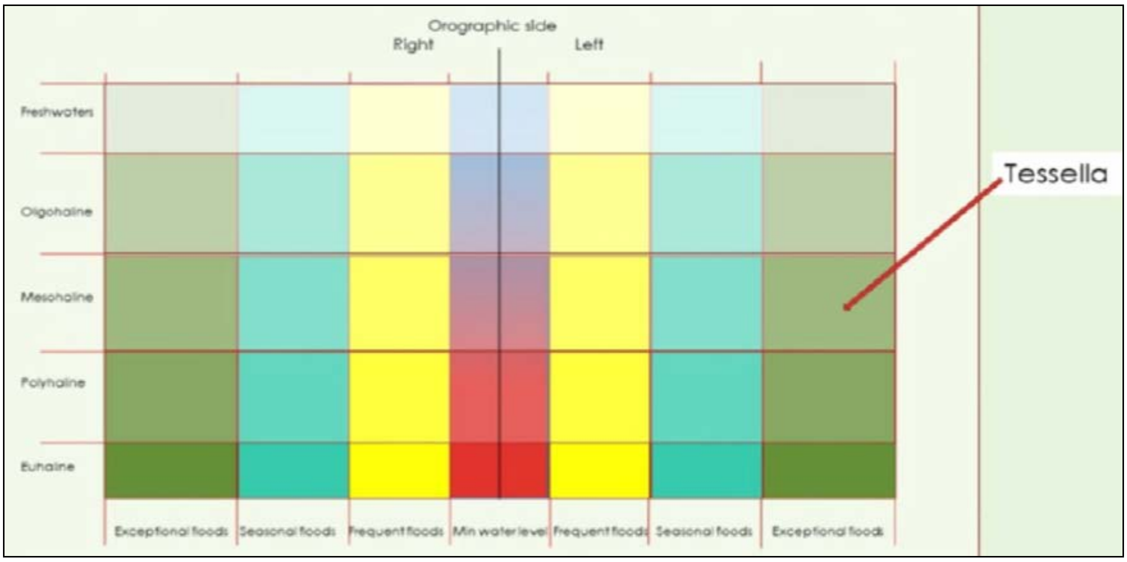

Figure 10: Theoretical square grid system of the expected ecological compartments distribution of estuaries, obtained crossing floods, and salt levels.

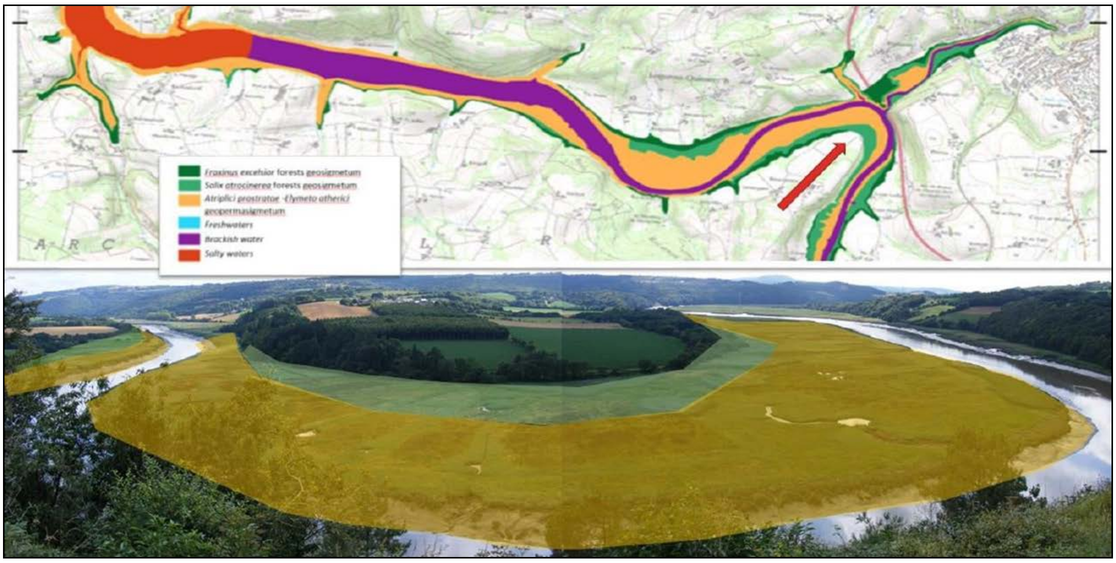

Figure 11: Plant map spatialization example of serial complexes in brackish water portion of Aulne Estuary. Down, in detail is represented the point indicated in the cartography with the red arrow. The zonation from minor to major riverbed is: acquatic environments (riverbed and pools), salt marshes and meadows (*Atriplici prostratae-Elymeto atherici* geopermasigmetum) brackish variant, *Salix atrocinerea* sigmetum, and *Fraxnius excelsior* forests geosigmetum.

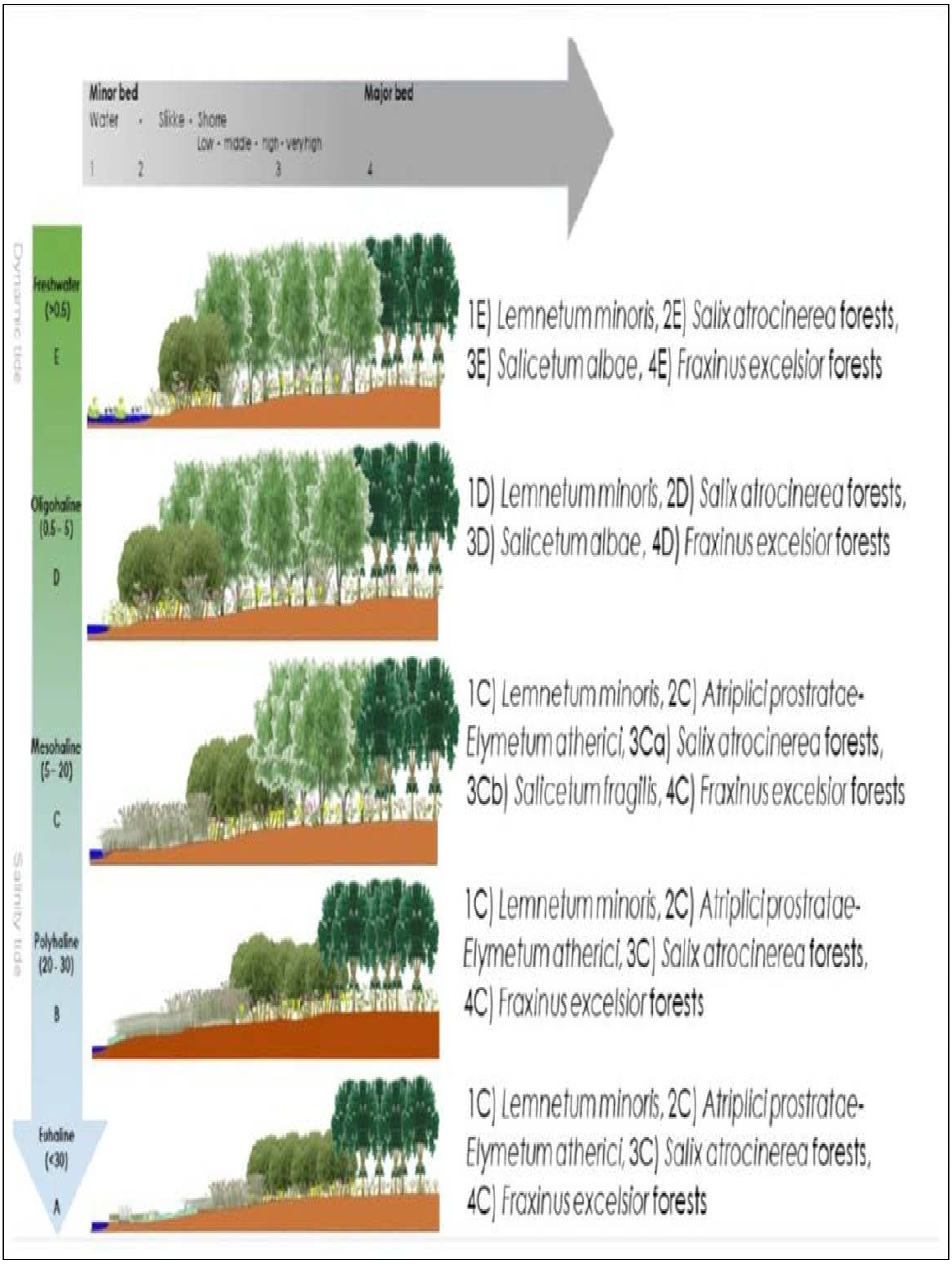

Figure 12: Plant association general transect model per Up-Down and Left-right ecological transect for salinity sector.

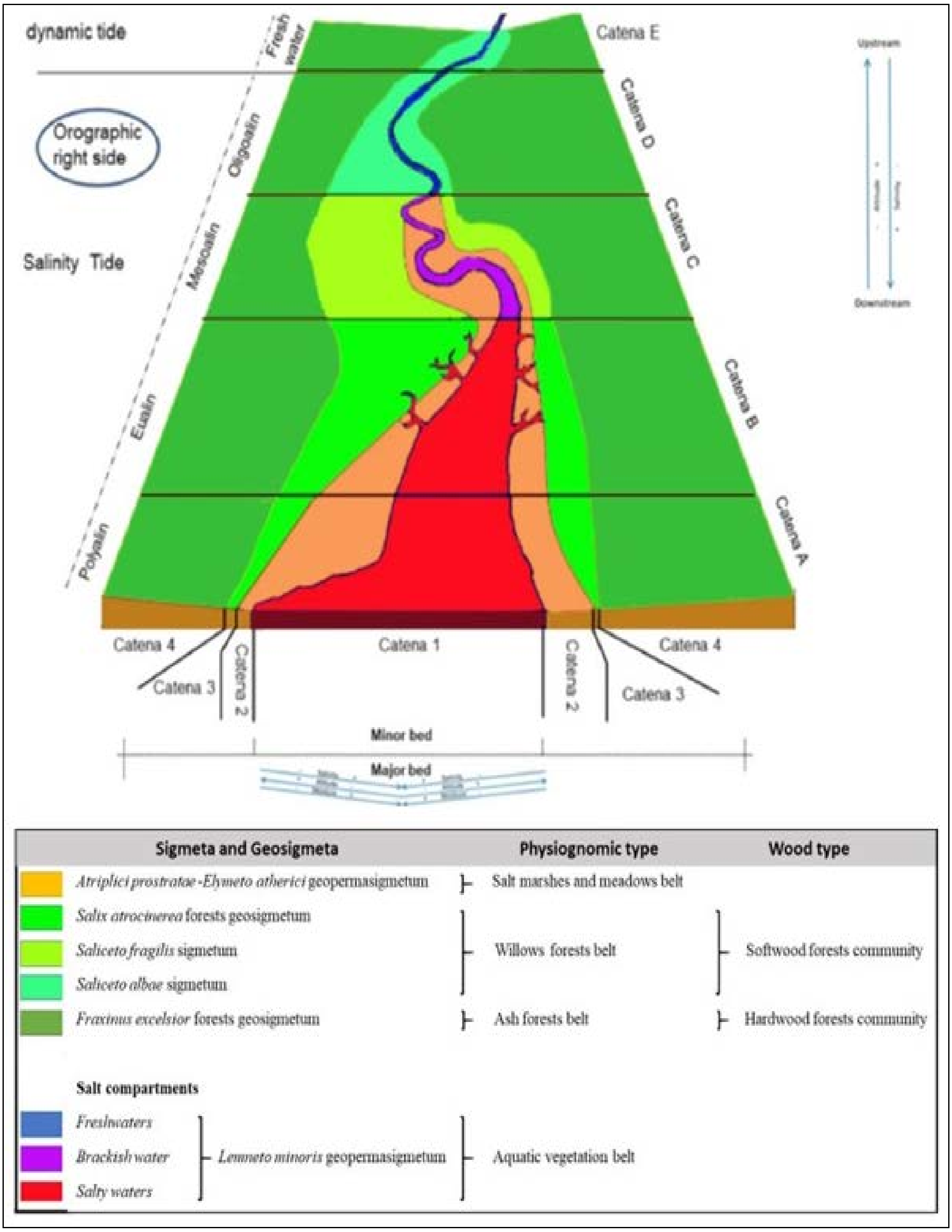

Figure 13: Theoretical series/catenas scheme
of an estuary after our synphytosociological elaboration.

CONCLUSIONS

As part of the CarHAB program, this research allowed to propose a first phytosociological and serial typology, a cartography methodology and model characterization (general and tidal estuaries) on the distribution and organization of the vegetation of the French Atlantic estuaries. Studied estuaries resulted exposed to a wide range of different human impacts. The results and the employed research methodology elements can be used on a small and large scale and can be applicable to other estuaries.

A perspective to be developed concerns the inductive acquisition of data in the field, mobilizing tools to measure ecological gradients (salinity, pH, humidity), to produce quantitative models that allow to search for mathematical correlations with the deductive models already produced and apply them to variations in the vegetation, detectable manually in the field or by remote sensing. The implementation of diachronic monitoring of vegetation would complete the knowledge of floristics, β-biodiversity, syntaxonomics, and the chorology of estuarine vegetation. It would also be interesting to correlate the data on the distribution of vegetation with the monitoring of the presence of microorganisms, plankton, and variations in biomass productivity. On the test sites, it would be interesting to give each set of vegetation the opportunity to freely express its natural dynamics for applications related to habitat management and conservation, in order to better understand the potential of the plant landscape and optimize the methodologies for evaluating the human impact, mobilizing the concepts of naturalness, artificialization and resilience. A research perspective, already launched under the CarHAB program, concerns the use of ecological white funds and to facilitate tissue divisions. Recently, the ISTHME laboratory of the University of Saint-Etienne organized a test to identify the most relevant indicators to be modelled in the context of the spatial delineation of vegetation and other research carried out within the CarHAB project. This makes it possible to identify ecological reference points that could facilitate the recognition of vegetation limits and try to automate the work techniques as much as possible. Another perspective concerns the refinement and resolution of vegetation cartography and synphysociology through digital skills, using computer programs, satellite images and remote sensing, to provide more quantitative data and develop the comparison with qualitative data so as to develop further applications for land management.

Our work mainly focuses on environments and habitats of international importance (“Natura 2000” habitat and the Ramsar Convention). The same habitat could be represented by associations of plants with different ecological values, which indicate different degrees of artificialization and rarity. For this reason, more in-depth phytosociological and synphysociological research could allow to better understand the evolution and evaluate the natural heritage, based not only on the presence of species, but also on plant associations, and on the series of vegetation.

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HOST SELECTIVITY OF *NEROCILA ORBIGNYI* (GUERIN-MENEVILLE, 1832) (ISOPODA, CYMOTHOIDAE) WITH A RECORD OF A NEW HOST FROM THE SEA OF MARMARA (TURKEY)

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ABSTRACT

Nerocila orbignyi (Isopoda, Cymothoidae) is reported for the first time on *Mugil cephalus* Linnaeus, 1758 (Pisces, Mugilidae) from Bandırma Bay (the Sea of Marmara, Turkey) during 2020. This paper aims to present the morphological characters of male of *N. orbignyi* from Turkey. Hosts infested with *N. orbignyi* are commented according to taxonomical status (order, families), ecological behaviours (habitat selections, feeding habits, school-solitary), morphological characters (scale types) according to current records. It may be said that *N. orbignyi* has been reported more frequently on fish belonging to the Perciformes order and Mugilidae and Sparidae families. It may also be said that this parasite selects also the fishes with carnivorous, demersal, schools, and migratory character.

RÉSUMÉ: Sélectivité de l'hôte de *Nerocila orbignyi* (Guerin-Meneville, 1832) (Isopoda, Cymothoidae) avec un enregistrement d'un nouvel hôte de la mer de Marmara (Turquie).

Nerocila orbignyi (Isopoda, Cymothoidae) est signalée pour la première fois sur *Mugil cephalus* Linnaeus, 1758 (Poissons, Mugilidae) sur Bandırma Bay (la mer de Marmara, Turquie) au cours de 2020. L'article vise à présenter les caractères morphologiques du mâle de *N. orbignyi* de Turquie. Les hôtes infestés par *N. orbignyi* sont commentés selon leur statut taxonomique (ordre, familles), leurs comportements écologiques (choix de l'habitat, habitudes alimentaires, leurs caractères morphologiques (types d'échelle) selon les enregistrements actuels. On peut dire que *N. orbignyi* a été signalé plus fréquemment que les poissons appartenant à l'ordre des Perciformes et aux familles des Mugilidae et des Sparidae. On peut également dire que ce parasite sélectionne également les poisons en bancs en bancs et à caractère carnivore, démersal, et migrateour.

REZUMAT: Selectivitatea gazdei *Nerocila orbignyi* (Guerin-Meneville, 1832) (Isopoda, Cymothoidae) cu înregistrarea unei noi gazde din Marea Marmara (Turcia).

Nerocila orbignyi (Isopoda, Cymothoidae) este raportată pentru prima dată pe *Mugil cephalus* Linnaeus, 1758 (Pești, Mugilidae) din Golful Bandırma (Marea Marmara, Turcia) în 2020. Lucrarea își propune să prezinte caracterele morfologice ale masculului de *N. orbignyi* din Turcia. Gazdele infestate cu *N. orbignyi* sunt descrise în funcție de încadrarea taxonomică (ordin, familie), comportamentul ecologice (selecția habitatelor, obiceiurile de hrănire, independența față de banc), caracterele morfologice (tipurile de solzi) conform înregistrărilor actuale. Se poate spune că *N. orbignyi* a fost raportată mai frecvent pe peștii aparținând ordinului Perciformes și familiilor Mugilidae și Sparidae. Se poate spune, de asemenea, că acest parazit selectează și peștii cu caracter carnivor, demersal, social și migrator.

INTRODUCTION

Fish parasites are important groups of biodiversity. Parasites are in balance with host fish in the natural environment. However, parasites can be harmful due to changes in environmental conditions such as intensive stocking, temperature, ph, etc., in fish farms. Fish parasites can even lead to mass mortalities on fish farms (Northcott et al., 1997; Öktener and Ünal, 2020). Sometimes, parasites can become active for various reasons and cause mass mortalities in natural environments. For example, *Haplosporidium pinnae* Catanese et al., 2018 caused the mass mortality in endangered *Pinna nobilis* (Linnaeus 1758) fan mussels from the Mediterranean Sea (Panarese et al., 2019). It is known that there are 257 fish species from the Sea of Marmara (Bilecenoğlu et al. 2014). However, there are not many studies on parasite diversity in fish.

Cymothoidae (Crustacea) are ectoparasitic isopods especially on the skin, bucal cavity, gill cavity, fins of hosts belonging to different marine, freshwater and brackish teleost fish (Trilles, 1994). Although Cymothoids are typically reported from teleost fish, there are some unusual associations such as sponges (Monod, 1933), jellyfish (Haswell, 1880), crustaceans (Lemos de Castro and Gomes Corrêa, 1982), chondrichthyans (Moreira and Sadowsky, 1978), amphibians (Stadler, 1972), snakes (Saravanakumar et al., 2012). While there are many reports of cymothoids from wild fishes, there are also reports from fish farms and aquaculture systems (Bragoni et al., 1983, 1984; Mladineo, 2002; Horton and Okamura, 2003; Čolak et al., 2018).

The cymothoid diversity of fishes should be more deeply investigated to better understand the biology of them. The present study aims to report a new host record for *Nerocila orbignyi* from Turkey. In addition, hosts of *Nerocila orbignyi* are examined according to family characteristics, habitat selections, feeding habits.

MATERIAL AND METHODS

109 individuals of *Mugil cephalus* Linnaeus, 1758 were collected by hand fishing rod from Bandırma Bay, the Sea of Marmara of Turkey during 2020. Parasites were fixed in 70% ethanol. Parasites were dissected using a Wild M5 stereo microscope. The dissected parts were mounted on slides in a glycerin-gelatine mounting medium. The appendages were drawn with the aid of a camera lucida (Olympus BH-DA). The photos were taken with the aid of Canon camera (EOS 1100D) attached to the microscope. Measurements were taken in millimeter (mm) with a micrometric program (Pro-way). Scientific names, synonyms were checked with the WoRMS Editorial Board (2020). The information of feeding habits, habitat characteristics of the host were prepared according to Froese and Pauly (2019). Identifications and comparisons of parasites were performed according to Trilles (1975), and Bruce (1987).

RESULTS AND DISCUSSION

Isopoda Latreille, 1817
Cymothoidae Leach, 1818
Nerocila Leach, 1818
Nerocila orbignyi (Guérin-Méneville, 1832) (Figs. 1-3)

Figure 1: *Nerocila orbignyi*, male.

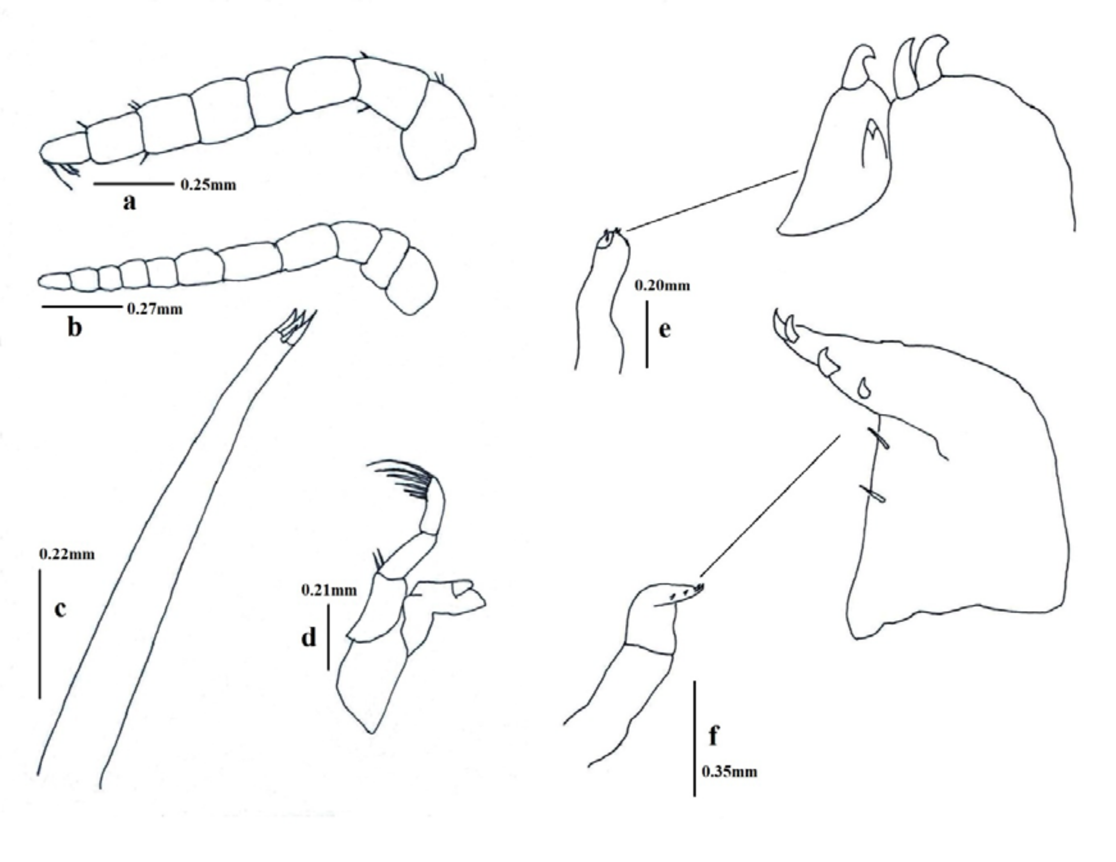

Figure 2: a) antennula, b) antenna, c) maxillula, d) mandible, e) maxilla, f) maxilliped.

Number of examined fish 109; number of infested fish eight; prevalence 7.33%; mean intensity 1; infestation site on host on ventral and pectoral fins.

Male morphological characteristics: body length varies from 6.8 to 9.5 mm. Cephalon 0.5 times longer than wide, visible from dorsal view. Body three times as long as greatest width. Pereon longest at pereonite 1, shortest at pereonite 4. Pereon widest at pereonite 5, most narrow at pereonite 1. Eyes big, facets distinct, 0.2 times width of head. Coxal plates of pereonites not visible in dorsal view. All pleonites visible in dorsal view. Pleon longest at pereonite 5, shortest at pereonite 1. Pleon widest at pereonite 1, most narrow at pereonite 5. Pleon 1 and 2 not overlapped by pereonite 7. Pleotelson 0.85 times as long as anterior width. Pleotelson not wider than pereonite 7 and pleonite 5. Pleotelson longer than width. Antennula (Fig. 2a) comprising eight articles; extending to posterior margin of eye. Antenna (Fig. 2.b) comprising 11 articles, extending to anterior margin of pereonite 1. Antenna sligthly longer than antennula. Mandibular process (Fig. 2d) without simple setae. Third article of mandible palp sligthly shorter than others, article 3 with six setae; article 2 with two setae on lateral margin. Maxillula (Fig. 2c) with four terminal setae, one long, one short, two setae similar in length. Maxilla (Fig. 2e) mesial lobe with two robust setae, lateral lobe with two recurved setae. Maxilliped (Fig. 2f) comprising three articles, article 3 with 4 recurved robust setae.

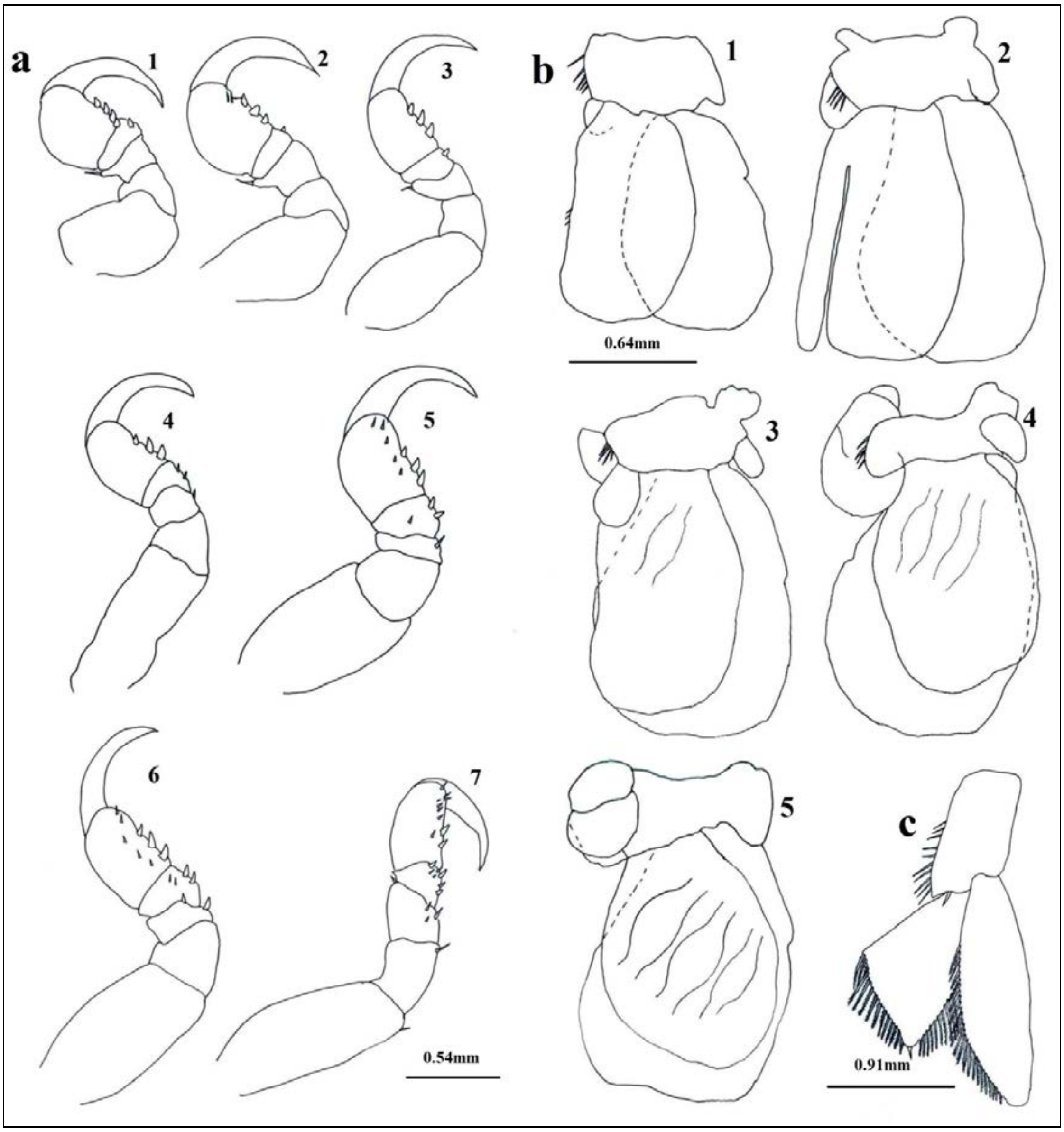

Figure 3: a) Pereopods 1-7, b) pleopods 1-5, c) uropod.

Pereopods 1-3 (Fig. 3a) similar in size, slightly smaller than pereopods 4-7. Three big spines on posterior margin of propodus of pereopods 2-6; four spines on posterior margin of propodus of pereopod 1; two spines on posterior margin of propodus of pereopods 7. Besides, five spines on medial side of propodus of pereopods 5-6; eight spines with pereopod 7. One big spine on posterior margin of carpus of pereopods 1-3; two big spines on posterior margin of carpus of pereopods 4-6; five big spines posterior margin of carpus of pereopod 7. Small spines on medial side of carpus of pereopod 5-7. One spine of posterior margin of merus of pereopods 4-5; two spines posterior margin of merus of pereopods 6-7. Besides, one spine on anterior margin of merus of pereopods 1-3, 7. One spine on posterior margin of ischium and basis of pereopod 7. Pleopods (Fig. 3b) slightly decreasing in length. Pleopod 2 appendix masculina the same length as length of endopod. Peduncles of pleopods 1-4 with coupling hooks. Pleopod 1 exopod 1.4 times as long as wide, lateral and mesial margin slightly rounded, distally broadly rounded; endopod 1.6 times as long as wide, lateral margin staright, distally broadly rounded, mesial margin rounded; peduncle 1.8 times as wide as long. Exopod of uropod (Fig. 3c) longer than endopod; endopod extending beyond pleotelson posterior margin.

Eight genus belonging to the family Cymothoidae (Crustaceca, Isopoda) were reported from the Mediterranean such as *Anilocra*, *Ceratothoa*, *Elthusa*, *Emetha*, *Idusa*, *Livoneca*, *Mothocya*, and *Nerocila* (Trilles, 1997; Castello et al., 2020). Forty-two species were listed by The World Register of Marine Species (WoRMS, 2020) in the genus *Nerocila*. Four species (*Nerocila acuminata*, *Nerocila bivittata*, *Nerocila orbignyi*, and *Nerocila milesensis*) were reported from Turkish waters (Öktener and Trilles, 2004; Er and Kayış, 2015; Öktener et al., 2020).

Nerocila orbignyi is a parasite frequently reported from the body surfaces and fins of fish. It has been reported from North Atlantic Ocean, Mediterranean Sea, Adriatic Sea (Trilles 1994). It is associated with Actinopterygii and Elasmobranchii (Tab. 1).

Table 1: The hosts of *Nerocila orbignyi* with synonyms.

Nerocila orbignyi (Guérin-Méneville, 1832) with synonyms	Host fish species (synonyms)	Order, family of host	Locality	References
	Chimaera sp.	Chimaeriformes, Chimaeridae.	Warrnambool, Victoria	Hale (1926)
	Callorhinchus milii	Chimaeriformes, Callorhinchidae.	Tasmania, off Storm Bay	Hale (1940)
	Chelon auratus (syn. *Mugil auratus*)	Mugiliformes, Mugilidae.	Thau and Vic-Mireval ponds, and Lake Patria in Italy	Trilles (1961, 1962, 1964a, b, 1968)
	Mugil cephalus	Mugiliformes, Mugilidae.	Thau and Vic-Mireval ponds, and Lake Patria in Italy	Trilles (1961, 1962, 1964a, b, 1968)
	Chelon ramada (syn. *Mugil capito*)	Mugiliformes, Mugilidae.	Thau and Vic-Mireval ponds, and Lake Patria in Italy	Trilles (1962, 1964a, b, 1968)
	Chelon labrosus (syn. *Mugil chelo*)	Mugiliformes, Mugilidae.	Thau and Vic-Mireval ponds, and Lake Patria in Italy	Trilles (1962, 1964a, b, 1968)
	Dicentrarchus labrax (syn. *Labrax lupus*)	Perciformes, Moronidae.	Thau and Vic-Mireval ponds, and Lake Patria in Italy	Trilles (1962, 1964a, b, 1968)

Table 1 (continued): The hosts of *Nerocila orbignyi* with synonyms.

	Host fish species (synonyms)	Order, family of host	Locality	References
Nerocila orbignyi (Guérin-Méneville, 1832) with synonyms	*Platichthys flesus* (syn. *Pleuronectes flesus*, *Flesus passer*)	Pleuronectiformes, Pleuronectidae.	Thau and Vic-Mireval ponds, and Lake Patria in Italy	Trilles (1962, 1964a, b, 1968)
	Oreochromis spilurus (syn. *Tilapia galilea*)	Perciformes, Cichlidae.	Brackish lake in Egypt	Wunder (1962)
	Salmo trutta	Salmoniformes, Salmonidae.	–	Scott (1964)
	Syphonostomes	–	–	Fain-Maurel (1966)
	Mugilidae	Mugiliformes, Mugilidae.	–	Fain-Maurel (1966)
	Argyrozona argyrozona	Perciformes, Sparidae.	Table, False, Algoa, Senegal, North Africa	Kensley (1978)
	Pterogymnus laniarius	Perciformes, Sparidae.	Table, False, Algoa, Senegal, North Africa	Kensley (1978)
	Rhabdosargus globiceps	Perciformes, Sparidae.	Table, False, Algoa, Senegal, North Africa	Kensley (1978)
	Synaptura sp.	Pleuronectiformes, Soleidae.	Table, False, Algoa, Senegal, North Africa	Kensley (1978)
	Thyrsites atun	Perciformes, Gempylidae.	Table, False, Algoa, Senegal, N. Africa	Kensley (1978)
	Chelon auratus (syn. *Mugil auratus*)	Mugiliformes, Mugilidae.	Gulf of Marseille	Berner (1969)
	Chelon ramada (syn. *Mugil capito*)	Mugiliformes, Mugilidae.	Gulf of Marseille	Berner (1969)
	Chelon labrosus (syn. *Mugil chelo*)	Mugiliformes, Mugilidae.	Gulf of Marseille	Berner (1969)
	Rhombosolea plebeia	Pleuronectiformes, Rhombosoleidae.	the Avon heathcote estuary	Webb (1973)
	Rhombosolea leporina	Pleuronectiformes, Rhombosoleidae.	the Avon heathcote estuary	Webb (1973)
	Chelon auratus (syn. *Mugil auratus*)	Mugiliformes, Mugilidae.	Tunis Lake, Tunisia	Trilles and Raibaut (1973)
	Mugil cephalus	Mugiliformes, Mugilidae.	Gulf of Tunis	Trilles and Raibaut (1973)
	Chelon ramada (syn. *Mugil capito*)	Mugiliformes, Mugilidae.	Ichkeul Lake, Tunisia	Trilles and Raibaut (1973)

Table 1 (continued): The hosts of *Nerocila orbignyi* with synonyms.

	Host fish species (synonyms)	Order, family of host	Locality	References
Nerocila orbignyi (Guérin-Méneville, 1832) with synonyms	*Chelon labrosus* (syn. *Mugil labrosus*)	Mugiliformes, Mugilidae.	Tunis Lake, Tunisia	Trilles and Raibaut (1973)
	Alosa fallax	Clupeiformes, Clupeidae.	Tunisia	Trilles and Raibaut (1973)
	Alosa fallax (syn. *Alosa fallax nilotica*)	Clupeiformes, Clupeidae.	Tunisia	Trilles and Raibaut (1973)
	Chelon auratus (syn. *Mugil auratus*)	Mugiliformes, Mugilidae.	Royan (lower Charante), Gulf of Gascogne	Trilles (1975)
	Mugil cephalus	Mugiliformes, Mugilidae.	Royan (lower Charante), Gulf of Gascogne	Trilles (1975)
	Chelon ramada (syn. *Mugil capito*)	Mugiliformes, Mugilidae.	Royan (lower Charante), Gulf of Gascogne	Trilles (1975)
	Chelon labrosus (syn. *Mugil chelo*)	Mugiliformes, Mugilidae.	Royan (Charante), Gulf of Gascogne	Trilles (1975)
	Platichthys flesus (syn. *Pleuronectes flesus*, *Flesus passer*)	Pleuronectiformes, Pleuronectidae.	Royan (lower Charante), Gulf of Gascogne	Trilles (1975)
	Dicentrarchus labrax (syn. *Labrax lupus*)	Perciformes, Moronidae.	Royan (lower Charante), Gulf of Gascogne	Trilles (1975)
	Halobatrachus didactylus (syn. *Batrachoides didactylus*)	Batrachoidiformes, Batrachoididae.	Temara-isthme, Rabat, Morocco	Dollfus and Trilles (1976)
	Solea senegalensis	Pleuronectiformes, Soleidae.	Rabat, Morocco	Dollfus and Trilles (1976)
	Dicentrarchus labrax	Perciformes, Moronidae.	the pond Diana (Corsica)	Bragoni et al. (1983)
	Dicentrarchus labrax	Perciformes, Moronidae.	the pond Diana (Corsica)	Bragoni et al. (1984)
	Pleuronectidae and Soleidae	Pleuronectiformes.		Rokicki (1985)
	Chelon saliens (syn. *Liza saliens*)	Mugiliformes, Mugilidae.	Montenegro	Trilles et al. (1989)
	Chelon auratus (syn. *Liza aurata*)	Mugiliformes, Mugilidae.	Montenegro	Trilles et al. (1989)

Table 1 (continued): The hosts of *Nerocila orbignyi* with synonyms.

	Host fish species (synonyms)	Order, family of host	Locality	References
Nerocila orbignyi (Guérin-Méneville, 1832) with synonyms	*Chelon ramada* (syn. *Liza ramada)*	Mugiliformes, Mugilidae.	Montenegro	Trilles et al. (1989)
	Chelon labrosus	Mugiliformes, Mugilidae.	Montenegro	Trilles et al. (1989)
	Lophius budegassa	Lophiiformes, Lophiidae.	Montenegro	Trilles et al. (1989)
	Belone belone	Beloniformes, Belonidae.	Courtmascsherry Bay	Dorman and Holmes (1991)
	Prionotus sp.	Scorpaeniformes, Triglidae.	Amazonas, Brazil	Thatcher (1995)
	Merlangius merlangus	Gadiformes, Gadidae.	The Severn Estuary, Bristol Channel	Potter et al. (1989) (1988)
	Chelon ramada (syn. *Liza ramada*)	Mugiliformes, Mugilidae.	Ghar El Melh, Tunisia	Charfi-Cheikhrouha et al. (2000)
	Chelon saliens (syn. *Liza saliens*)	Mugiliformes, Mugilidae.	Bizerte, Tunisia	Charfi-Cheikhrouha et al. (2000)
	Chelon auratus (syn. *Liza aurata*)	Mugiliformes, Mugilidae.	Ghar El Melh, Tunisia	Charfi-Cheikhrouha et al. (2000)
	Chelon labrosus	Mugiliformes, Mugilidae.	Sfax, Tunisia	Charfi-Cheikhrouha et al. (2000)
	Dicentrarchus labrax	Perciformes, Moronidae.	Ghar El Melh, Tunisia	Charfi-Cheikhrouha et al. (2000)
	Solea solea	Pleuronectiformes, Soleidae.	Sfax, Tunisia	Charfi-Cheikhrouha et al. (2000)
	Serranus scriba	Perciformes, Serranidae.	Sfax, Tunisia	Charfi-Cheikhrouha et al. (2000)
	Diplodus annularis	Perciformes, Sparidae.	Sfax, Tunisia	Charfi-Cheikhrouha et al. (2000)
	Arripis trutta	Perciformes, Arripidae.	New Zealand	Hine et al. (2000)
	Dicentrarchus labrax	Perciformes, Moronidae.	Aegean Sea, Turkey	Horton and Okamura (2001)
	Chelon auratus (syn. *Liza aurata*)	Mugiliformes, Mugilidae.	Mistras Lagoon, Sardinia	Merella and Garippa (2001)
	Seriola dumerili	Perciformes, Carangidae.	Mazarrón (Murcia)	Montero (2001)
	Chelon auratus (syn. *Liza aurata*)	Mugiliformes, Mugilidae.	Black Sea	Öktener and Trilles (2004)
	Halobatrachus didactylus	Batrachoidiformes, Batrachoididae.	Portuguese coast Guadiana, Tagus, Sado, Olha˜o and Tavira coastal areas	Marques et al. (2005)

Table 1 (continued): The hosts of *Nerocila orbignyi* with synonyms.

	Host fish species (synonyms)	Order, family of host	Locality	References
Nerocila orbignyi (Guérin-Méneville, 1832) with synonyms	*Mugil cephalus*	Mugiliformes, Mugilidae.	Béjaïa, Soummam Oued, Algeria	Ramdane et al. (2007)
	Symphodus tinca (*Crenilabrus pavo*)	Perciformes, Labridae.	Gulf of Béjaïa, Algeria	Ramdane et al. (2007)
	Symphodus tinca (*Crenilabrus pavo*)	Perciformes, Labridae.	Gulf of Jijel, Algeria	Ramdane et al. (2007)
	Trigla lyra	Scorpaeniformes, Triglidae.	Gulf of Béjaïa, Algeria	Ramdane et al. (2007)
	Platichthys flesus	Pleuronectiformes, Pleuronectidae.	North-Central Portuguese Coast	Cavaleiro and Santos (2007)
	Scorpaena porcus	Scorpaeniformes, Scorpaenidae.	Adriatic Sea	Ferri et al. (2008)
	Monochirus hispidus	Pleuronectiformes, Soleidae.	Northeast Atlantic	Marques et al. (2009)
	Solea solea	Pleuronectiformes, Soleidae.	Pazar Coast, Turkey, Black Sea	Kayış and Ceylan (2011)
	Chelidonichthys capensis	Scorpaeniformes, Triglidae.	South Africa	Hadfield et al. (2013)
	Moolgarda seheli	Mugiliformes, Mugilidae.	Red Sea, Yemen	Al-Zubaidy and Mhaisen (2013)
	Chelon auratus (syn. *Liza aurata*)	Mugiliformes, Mugilidae.	Red Sea, Yemen	Al-Zubaidy and Mhaisen (2013)
	Serranus cabrilla	Perciformes, Serranidae.	Samandağ, Turkey, Mediterranean	Özcan et al. (2015)
	Belone belone (syn. *Belone b. gracilis*)	Beloniformes, Belonidae.	Tunisia	Châari et al. (2015)
	Chelon ramada (syn. *Mugil capito*)	Mugiliformes, Mugilidae.	Qaroun Lake, Egypt	Shaheen et al. (2017)
	Solea solea	Pleuronectiformes, Soleidae.	Qaroun Lake, Egypt	Shaheen et al. (2017)
	Coptodon zillii (syn. *Tilapia zilli*)	Perciformes, Cichlidae.	Qaroun Lake, Egypt	Shaheen et al. (2017)
	Chelon ramada (syn. *Mugil capito*)	Mugiliformes, Mugilidae.	Qaroun Lake, Egypt	Mahmoud et al. (2017)
	Liza carinata	Mugiliformes, Mugilidae.	Qaroun Lake, Egypt	Mahmoud et al. (2017)
	Coptodon zillii (syn. *Tilapia zilli*)	Perciformes, Cichlidae.	Qaroun Lake, Egypt	Mahmoud et al. (2017)
	Scomber scombrus	Perciformes, Scombridae.	Swanage, UK waters	Horton and Baillie (2019)
	Clupea harengus	Clupeiformes, Clupeidae.	Southampton, UK waters	Horton and Baillie (2019)
	Chelon labrosus	Mugiliformes, Mugilidae.	Newlyn harbour, UK waters	Horton and Baillie (2019)

Table 1 (continued): The hosts of *Nerocila orbignyi* with synonyms.

	Host fish species (synonyms)	Order, family of host	Locality	References
Nerocila orbignyi (Guérin-Méneville, 1832) with synonyms	*Solea solea*	Pleuronectiformes, Soleidae.	Sinop, Turkey, Black Sea	Güven and Öztürk (2019)
	Salmo salar	Salmoniformes, Salmonidae.	Tasmania, Australia	González et al. (2019)
	Callorhynchus milii	Chimaeriformes, Callorhinchidae.	Bass Strait, Nutgrove Beach, Derwent Estuary	Bruce (1987)
	Pseudocaranx dentex	Perciformes, Carangidae.	Southern Western Australia, Walpole	Bruce (1987)
	Dactyloptena orientalis	Scorpaeniformes, Dactylopteridae.	South Coast, Tasmania	Bruce (1987)
	Girella tricuspidata	Perciformes, Girellidae.	Lake Illawarra, New South Wales, Australia	Bruce (1987)
	Mola mola	Tetraodontiforms, Molidae.	Off New South Wales, Australia	Bruce (1987)
	Mugillidae sp.	Mugiliformes, Mugilidae.	Port Hacking, New S. Wales, Australia	Bruce (1987)
	Platycephalidae sp.	Scorpaeniformes, Platycephalidae.	Victoria	Bruce (1987)
	Pomatomus saltatrix	Perciformes, Pomatomidae.	Nornalup, Western Australia	Bruce (1987)
	Sillago bassensis	Perciformes, Sillaginidae.	FrederickHenryBay, Storm Bay, Tasmania	Bruce (1987)
	Acanthopagrus butcheri	Perciformes, Sparidae.	The Coorong, South Australia	Bruce (1987)
	Pagrus auratus (syn. *Chrysophrys auratus, Pagrosomus auritus*)	Perciformes, Sparidae.	Sydney, New South Wales, Palm Beach, Broken Bay, Little Jerusalem Bay, Hawkesbury River	Bruce (1987)
	Chelidonichthys kumu	Scorpaeniformes, Triglidae.	Southern Western Australia, Walpole	Bruce (1987)
	Mugil cephalus	Mugiliformes, Mugilidae.	Israel	Paperna and Overstreet (1981)
	Dicentrarchus labrax	Perciformes, Moronidae.	Black Sea	Kayış et al. (2017)
	Chelon auratus (syn. *Liza aurata*)	Mugiliformes, Mugilidae.	Black Sea	Kayış et al. (2017)
	Serranus cabrilla	Perciformes, Serranidae.	Black Sea	Kayış et al. (2017)
	Solea solea	Pleuronectiformes, Soleidae.	Black Sea	Kayış et al. (2017)

Table 1 (continued): The hosts of *Nerocila orbignyi* with synonyms.

	Host Fish Species (synonyms)	Order, Family of Host	Locality	References
Synonym as *Nerocila maculata* H. Milne Edwards, 1840	Unknown	Unknown	Castellon, Spain	Balcells (1953)
	Raja sp.	Rajiformes, Rajidae	the Croisic vicinity, France	Trilles (1975)
	Trisopterus capelanus (syn. *Gadus capelanus*)	Gadiformes, Gadidae	Algeria	Dollfus and Trilles (1976)
	Unknown	Unknown	Province de Bou Haroun, Algeria	Dollfus and Trilles (1976)
	Rostroraja alba (syn. *Raja alba*)	Rajiformes, Rajidae	Casablanca, Morocco	Dollfus and Trilles (1976)
	Unknown	Unknown	Turkey, Spain, Yougoslavie	Trilles (1977)
	Raja clavata	Rajiformes, Rajidae	Yougoslavie	Trilles (1977)
	Chelon labrosus (syn. *Crenimugil labrosus*)	Mugiliformes, Mugilidae	The Island of Texel	Trilles (1977)
	Unknown	Unknown	Naples, Genova	Trilles (1977)
	Chelon labrosus (syn. *Crenimugil labrosus*)	Mugiliformes, Mugilidae	Wadden Sea	Holthuis (1978)
	Chelon labrosus (syn. *Crenimugil labrosus*)	Mugiliformes, Mugilidae	The Island of Texel	Adema and Huwae (1982)
	Trisopterus minutus	Gadiformes, Gadidae	Montenegro	Trilles et al. (1989)
	Trachinus draco	Perciformes, Trachinidae	Montenegro	Trilles et al. (1989)
	Pagellus acarne	Perciformes, Sparidae	Gulf of Béjaïa, Algeria	Ramdane et al. (2007)

The host fish of *Nerocila orbignyi* are examined according to their order; 22 (38%) of 58 host species belong to Perciformes; 14 species (14%) to Mugiliformes and Pleuronectiformes; 22 species (38%) to different fish families (Fig. 4).

According to their families, the parasite appears to be more frequently reported from two families; Mugilidae and Sparidae with seven species (Fig. 5).

According to habitat selections; 24 (42%) of 58 host fish species are demersal; 15 species (26%) are benthopelagic, seven species (12%) are pelagic-neritic, six species (10%) are reef-associated, three species (5%) are bathydemersal, three species (5%) are pelagic-oceanic (Fig. 6). It seems that *Nerocila orbignyi* clearly prefers demersal fish than pelagic fish. Luque et al. (2010) and Brusca (1981) verified the occurrence of higher parasite species on demersal fishes in their studies.

According to feeding habits; 44 species (76%) of 58 host fish species are carnivorous; 12 species (21%) are omnivorous; two species (3%) are herbivorous (Fig. 7). *Nerocila orbignyi* appears to prefer carnivorous fish rather than omnivorous and herbivorous fish.

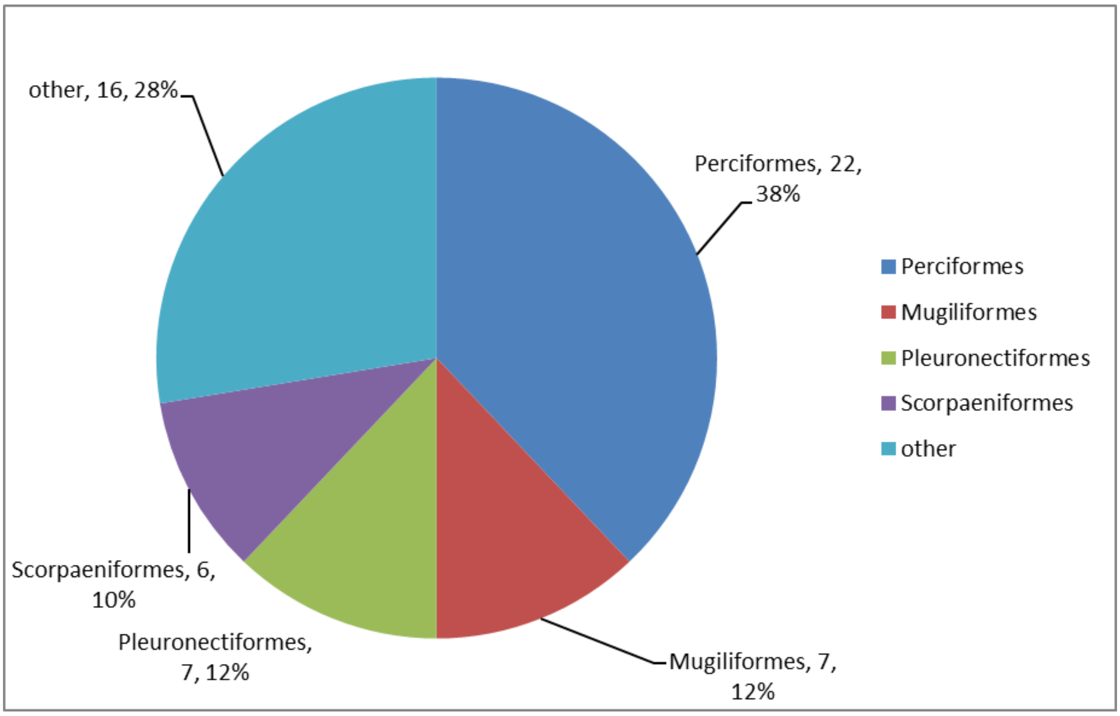

Figure 4: The host reported with *Nerocila orbignyi* according to their order.

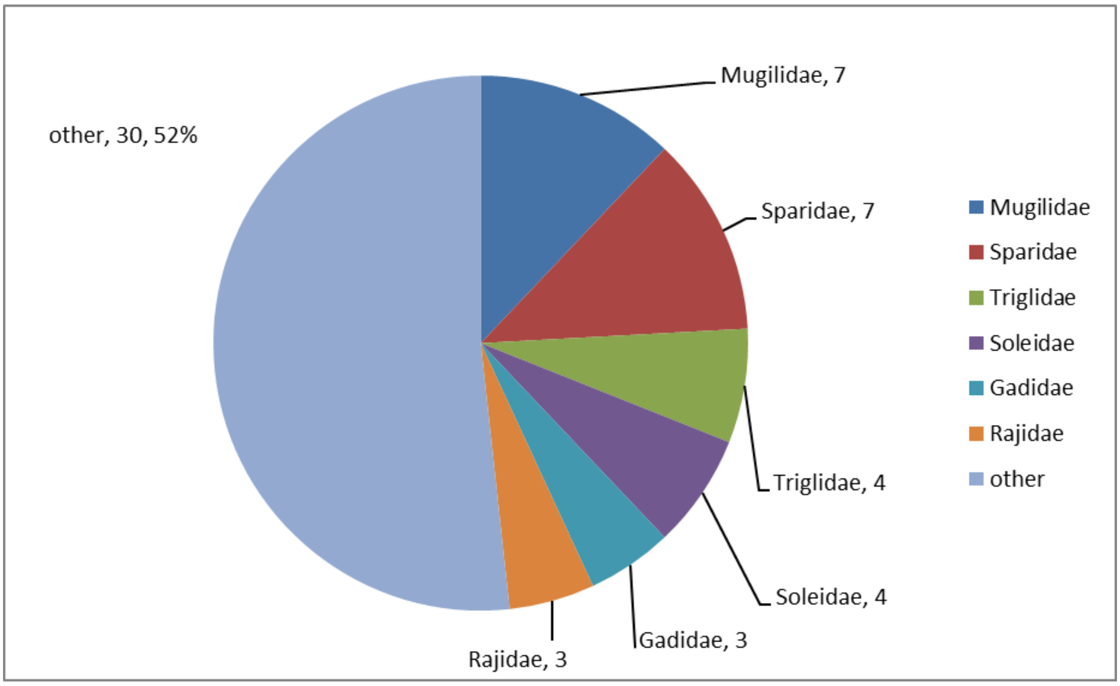

Figure 5: The host reported with *Nerocila orbignyi* according to their family.

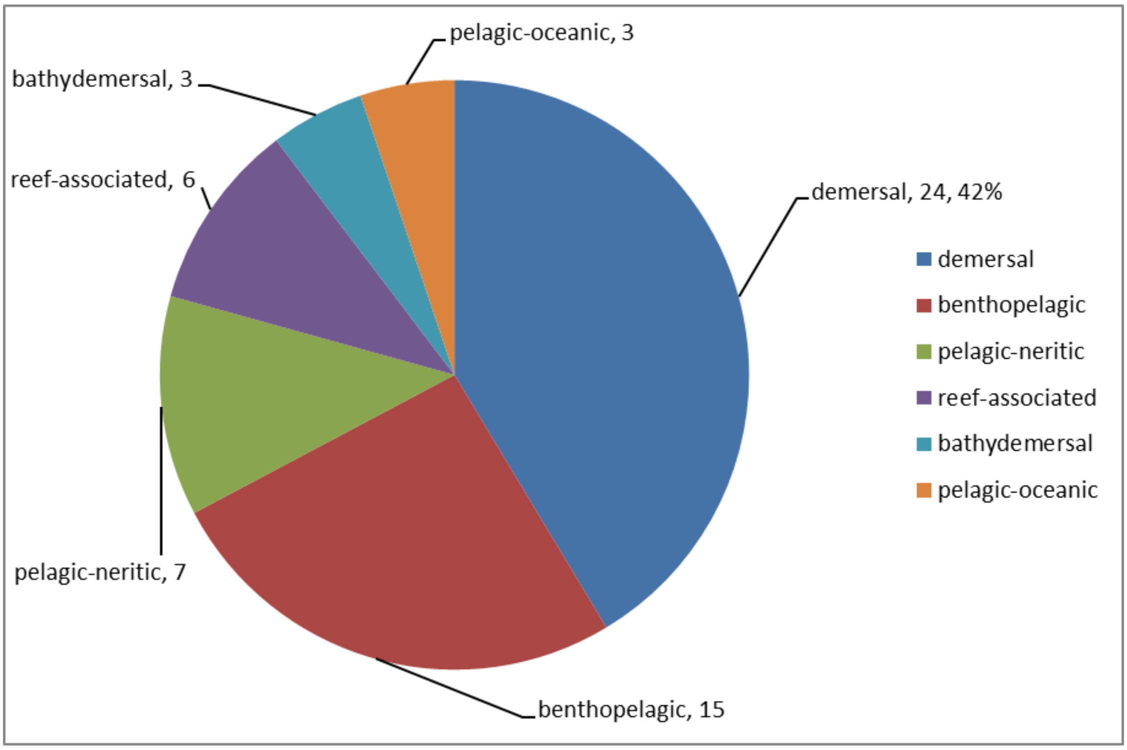

Figure 6: The host reported with *Nerocila orbignyi* according to habitat selections.

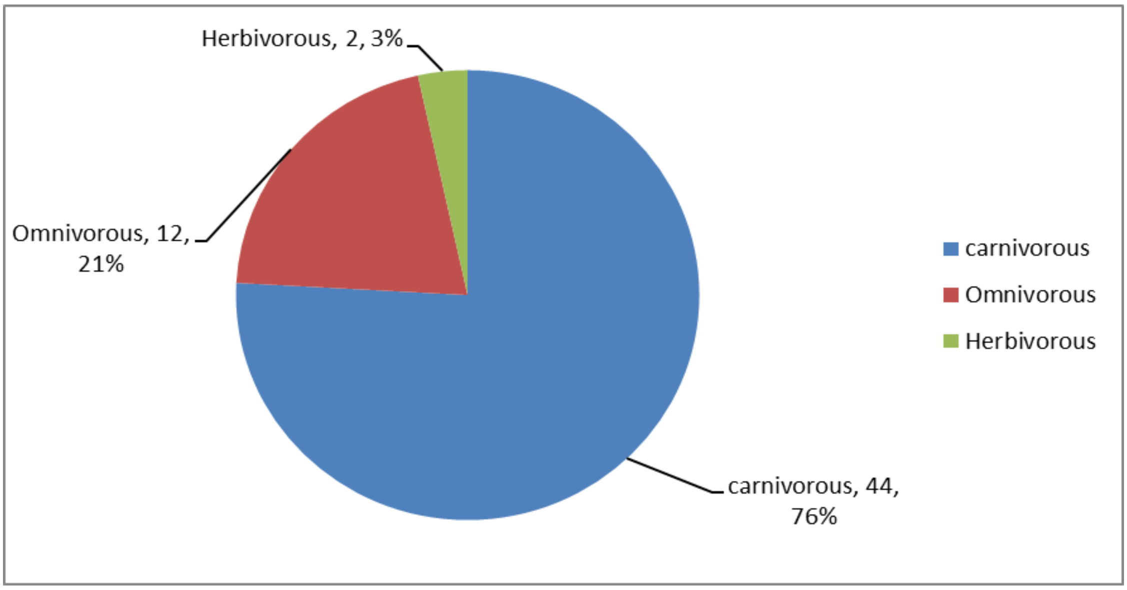

Figure 7: The host reported with *Nerocila orbignyi* according to feeding habits.

According to their solitary/schools; 33 (57%) of 58 host fish species are schooling, 25 species (43%) are solitary (Fig. 8). Although there is not much difference, it may be argued that *Nerocila orbignyi* is reported more frequently than fish that form a school. Luque et al. (2014) indicated that fish parasites prefer fish that form more schools than solitary fish especially ectoparasites. Brusca (1981) determined preferred hosts of *Nerocila acuminata* are schooling fishes.

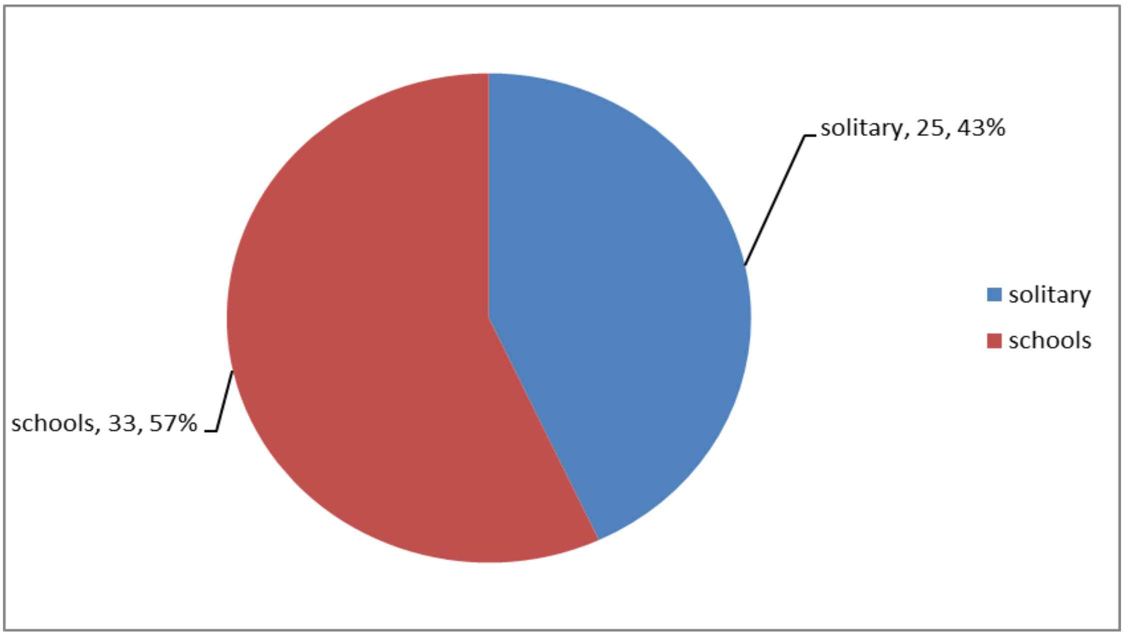

Figure 8: The host reported with *Nerocila orbignyi* according to solitary/schools.

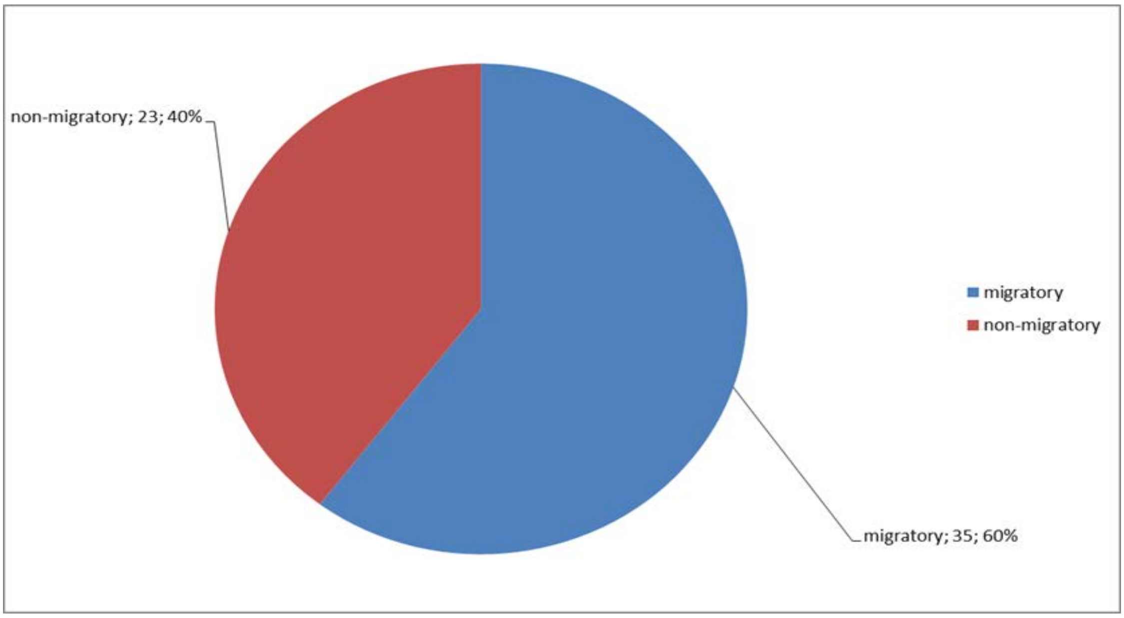

Figure 9: The host reported with *Nerocila orbignyi* according to migratory/non-migratory.

According to migratory/non-migratory; 35 species (60%) of 58 host fish species are migratory; 23 species (40%) to non-migratory. (Fig. 9). Fryer (1966) and Welicky and Sikkel (2015) founded that diurnal movements and nocturnal migrations of fish has an important role for the most settlement of parasite.

According to their scale types; 27 (46%) of 58 host fish species are cycloid; 26 species (45%) ctenoid; five species (9%) with placoid (Fig. 10).

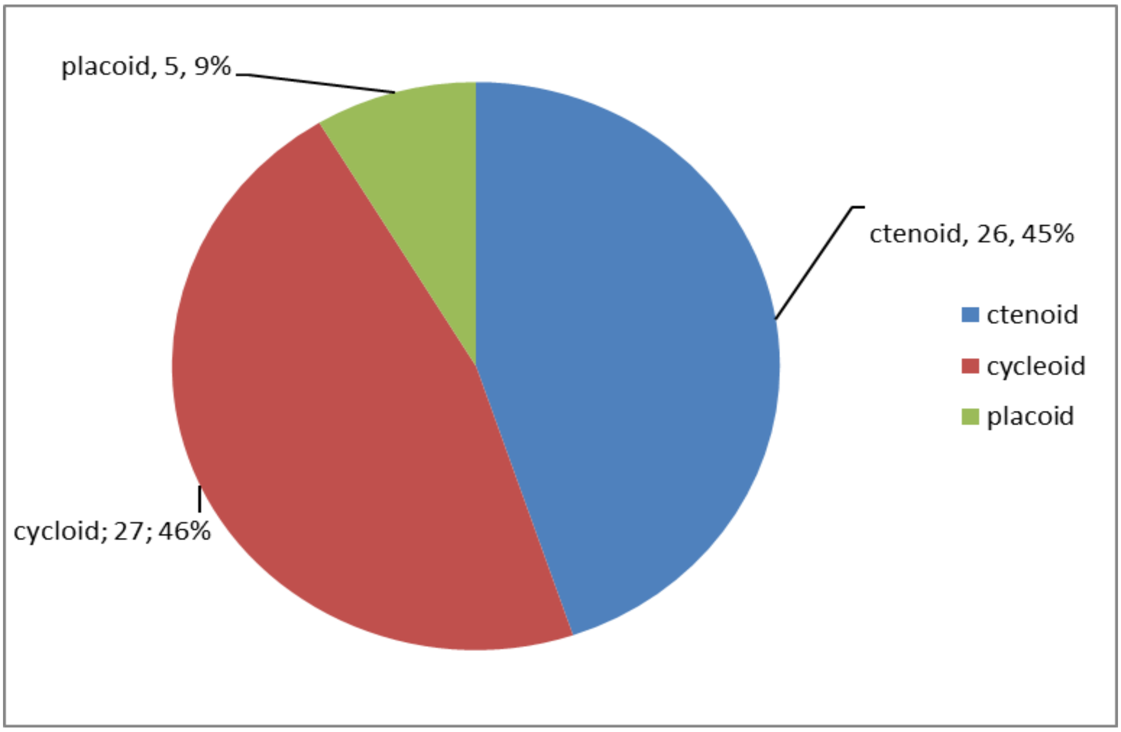

Figure 10: The host reported with *Nerocila orbignyi* according to scale type.

It may be said that *Nerocila orbignyi* has been reported more frequently than fish belonging to the Perciformes order and Mugilidae and Sparidae families. It may also be said that this parasite selects also the fishes with carnivorous, demersal, schools, and migratory character.

CONCLUSIONS

Cymothoids are an important group of parasites reported in fish. *Nerocila* is also a highly reported genus among Cymothoidae. It is a genus that is reported only from the body surface and fins in fish. Articles about cymothoid parasites are mostly in the form of reports and not much information is given about their morphology. The aim of this study is to give the updated morphology of *Nerocila orbignyi* and to provide comparison opportunities for those working on this subject. In addition, there is not much work on the host and host properties of cymothoid parasites. In this article, it is aimed to examine the host selectivity by mentioning both the morphology and ecology of the hosts of *Nerocila orbignyi*.

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INDIVIDUAL SERUM TRIIODOTHYRONINE AND THYROXINE LEVELS IN SEVEN FRESHWATER FISH SPECIES

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ABSTRACT

The thyroid hormones (THs) play an important role in the regulation of the rate of metabolism, affect the growth and function of different systems in the organism. The aim of this study was to assess serum concentration of total triiodothyronine (T3), total thyroxine (T4) as well as T3/T4 ratio in serum from healthy fresh water fish from Salmonidae, Acipenseridae, Cyprinidae, and Clariidae families to determine species-specific reference intervals. Mean concentrations of T3 and T4 levels varied significantly among fish. Finally, the test results show clear differences in the serum concentration of the T3 and T4 and give new insight into the thyroid hormones reference values in some commercial fresh water fish species.

RÉSUMÉ: Taux sériques individuels de triiodothyronine et de thyroxine dans quatre familles de poissons d'eau douce.

Les hormones thyroïdiennes (TH) jouent un rôle important dans la régulation du taux de métabolisme, affectent la croissance et le fonctionnement des différents systèmes de l'organisme. Le but de cette étude était d'évaluer la concentration sérique de la triiodothyronine totale (T3), de la thyroxine totale (T4) ainsi que le rapport T3/T4 dans le sérum des poissons d'eau douce sains d'Salmonidae, Acipenseridae, Cyprinidae, and Clariidae afin de déterminer les intervalles de référence spécifiques à chaque espèce. Les concentrations moyennes des niveaux de T3 et T4 ont varié significative parmi les poissons. Enfin, les résultats des tests montrent de nettes différences dans la concentration sérique de la T3 et T4, et donnent un nouvel aperçu des valeurs de référence des hormones thyroïdiennes chez certaines espèces commerciales de poissons d'eau douce.

REZUMAT: Nivelurile serice individuale de triiodotironă și tiroxină în patru familii de pești de apă dulce.

Hormonii tiroidieni (TH) joacă un rol important în reglarea ratei metabolismului, afectând creșterea și funcționarea diferitelor sisteme din organism. Scopul acestui studiu a fost de a evalua concentrația serică de triiodotironină totală (T3), tiroxină totală (T4), precum și raportul T3/T4 în ser de pește sănătos de apă dulce de la Salmonidae, Acipenseridae, Cyprinidae şi Clariidae, a determina intervalele de referință specifice speciei. Concentrațiile medii ale nivelurilor T3 și T4 au variat semnificativ în rândul peștilor. În cele din urmă, rezultatele testelor arată diferenţe clare în concentrația serică a T3 și T4 și oferă o nouă perspectivă asupra valorilor de referință ale hormonilor tiroidieni la unele specii comerciale de pești de apă dulce.

INTRODUCTION

The levels for some enzymes, hormones, and ions can be used as indicators of health for different animal species as well as fish. Endocrine parameters can be useful as indicators for physiological and pathological processes in the body of fish. The major hormonal determinations carried out on the fish are for cortisol, progesterone, insulin, and thyroxine (Labarrère et al., 2013). The pro-hormone thyroxine (T4) and small amount of the biologically active hormone triiodothyronine (T3) are synthesized by the thyroid follicles (Krassas et al., 2007). The liver is the major organ responsible for conversion of thyroxine to triiodothyronine, synthesis of thyroid binding globulin (TBG), as well as release of T3 and T4 into the circulation (Neto and Zantut-Wittmann, 2016).

Despite over a decade of research, the role of the thyroid hormones in fish is still not fully understood, because the diffuse structure of the thyroid glands making it more difficult to study (van de Pol et al., 2017; Campinho, 2019). They also, have unique characteristics and functions due to diversity in fish anatomy, habitat, and life cycle (Deal and Volkoff, 2020). Furthermore, some studies have reported positive effects of thyroid hormones to improve hatching, post-embryonic growth, and larval survival (Stepien and Huttner, 2019; Deal and Volkoff, 2020). Also, thyroid hormones play a significant role in almost all physiological processes in the body (i.e. metabolic process, bone remodeling, cardiac function, mental state, and brain development) (Singh et al., 2014; Gavrilă and Hollenberg, 2019). Therefore, a better understanding of function and structure of thyroid hormones can provide valuable information to improve the knowledge about the freshwater fish species physiology.

The present study aimed to establish referent values of total triiodothyronine and total thyroxine, using as model some typical representatives of four freshwater fish families (Salmonidae, Acipenseridae, Cyprinidae, and Clariidae).

An additional purpose of this work is to add the information in the existing database which is used to monitor fish health.

MATERIAL AND METHODS

The study was done in the spring season (April, 2019) on fish individuals belonging to Salmonidae, Acipenseridae, Cyprinidae, and Clariidae families. Totally 120 fish (12 fish individuals per species) for analyses were collected from different fish production systems, as follows Brown trout-*Salmo trutta fario* Linnaeus, 1758 and Rainbow trout-*Oncorhynchus mykiss* (Walbaum, 1792) – concrete tanks and net cages; Common carp-*Cyprinus carpio* Linnaeus, 1758 – ponds and net cages; Russian sturgeon-*Acipenser gueldenstaedtii* Brandt and Ratzeburg, 1833, Siberian sturgeon-*Acipenser baerii* Brandt, 1869, and hybrids – net cages only and African catfish-*Clarias gariepinus* (Burchell, 1822), recirculation system.

Blood samples were drawn from the vena caudalis using a needle (20G). The collected samples (approx. one ml) have been centrifuged at 3,000 rpm for five minutes (Ohaus FC5515, Ohaus Corp., USA) at room temperature. After coagulation, the obtained serum was immediately separated and it was stored at –20°C until analysis. Total triiodothyronine and total thyroxine analyses were conducted with Elisa analyser, HumaReader HS (Human GmbH, Wiesbaden, Germany) and its measurement Elisa kit (Monobind, Inc., USA).

Descriptive statistical analyses for calculating the means and the standard error of the mean were performed using the StatSoft Statistica v.10 software (StatSoft Inc., USA, 2002). All the results obtained were expressed as the mean ± standard error (SE).

RESULTS AND DISCUSSION

A study of species-specific differences in total triiodothyronine and total thyroxine in representatives of four fish families could help future scientists assess the health of the fish. The acquired results are shown in figures 1-3.

The variations were observed in the serum levels of both thyroid hormones in all studied species. Data regarding level of total triiodothyronine (Fig. 1) show obvious differences between families and individual species the biggest being between *Clarias gariepinus* (0.806 ng/ml) and *Acipenser gueldenstaedtii* (4.49 ng/ml). Median total thyroxine concentrations were highest in sturgeon species and show major differences against the other species as follow: *Salmo trutta fario* (1.31 ± 0.09 μg/dL); common carp (1.80 ± 0.23 μg/dL) and *Clarias gariepinus* (1.67 ± 0.16 μg/dL) and non differences between acipenserids (*Acipenser baerii* – 3.15 μg/dL and *Acipenser gueldenstaedtii* – 5.33 μg/dL). Furthermore, to individual levels for T3 and T4, ratios of T3/T4 concentrations were calculated for each species. Determined ratios of T3/T4 were around 0.6 in a majority of studied species whereas in *Salmo trutta fario* and *Cyprinus carpio* were 1.45 and 1.44, respectively.

The study was conducted in spring season because the thyroid hormones activity increased significantly from January to April and decreased significantly during autumn and early winter from October to December according to decrease of water temperature. Not only the season and water temperature have a severe impact on hormone activity but also important are biotic factors such as health condition, husbandry of fish, feed and technology system, environment. By hormones fish can adapt to constantly changing environment. Like other vertebrates, teleost fish also use the hypothalamic-pituitary-thyroid (HPT) axis to regulate their metabolism. The central nervous system, provoked by the diverse environment, regulates the homeostasis of thyroid hormones. In vertebrates the follicles are aggregated into one or two thyroid glands while in teleost fish, thyroid gland is scattered elements (follicles) around the ventral aorta. In them, thyrotropin-releasing hormone (TRH) stimulates the anterior pituitary to synthesize and secrete the thyroid-stimulating hormone (TSH), but there is an assumption that TRH is not a major TSH-releasing factor in fish (Cortés et al., 2014). Also, TSH take part in formation and production of thyroid hormones which are 3, 3’, 5-Triiodo-L-thyronine (triiodothyronine, T3), and L-thyroxine (thyroxine, T4) which have negative feedback regulating effect on TSH (Fig. 4). The thyroid gland is the only endocrine organ with such an extracellular store (follicular) where T3 and T4 are stored (Qu et al., 2016).

Thyroid function in fish has been investigated mainly on teleost fish of the class Actinopterygii, subclass Chondrosteii which include order Acipenseriformes to this the sturgeons belong (Plohman et al., 2002). Most early studies of sturgeon thyroid were on *Acipenser stellatus* and *Acipenser gueldenstaedtii* (McKenzie et al., 2007). Authors observed much higher percentages of free T4 and T3 present in sturgeon plasma than in *Oncorhynchus mykiss* used like a model for comparing. Plohman et al., (2002) also observed significant differences in thyroid hormone concentrations in blood plasma and tissues during immature-phase and spawning-phase of lake sturgeon-*Acipenser fulvescens* compared with some teleost fish. Authors had proposed that in the sturgeon, manufacture of triiodothyronine is main determined of releasing process in peripheral tissues. Indeed, the comparison of the results shows that the levels of thyroxine in *Acipenser gueldenstaedtii* and *Acipenser baerii* were much higher than other fish species subject to this study. It should also be noted that the concentration of triiodothyronine in *Acipenser gueldenstaedtii* was highest in current study.

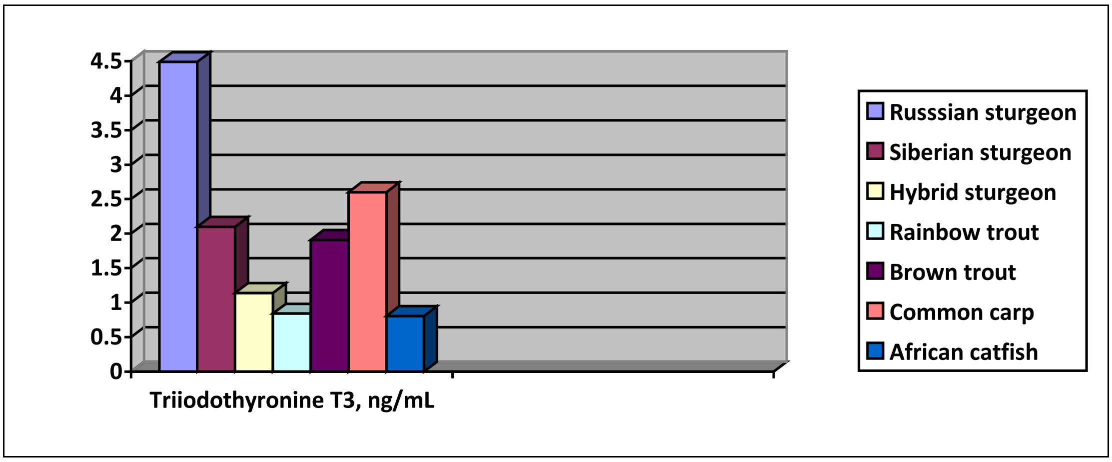

Figure 1: Levels of triiodothyronine (T3) ng/mL
of representatives of Salmonidae, Acipenseridae, Cyprinidae, and Clariidae family.

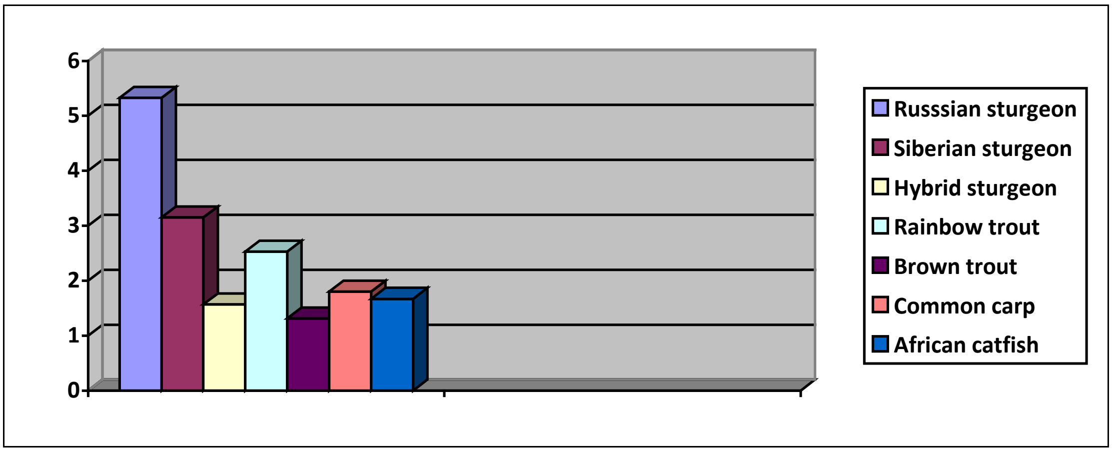

Figure 2: Levels of Thyroxine (T4) mcg/dL
of representatives of Salmonidae, Acipenseridae, Cyprinidae, and Clariidae family.

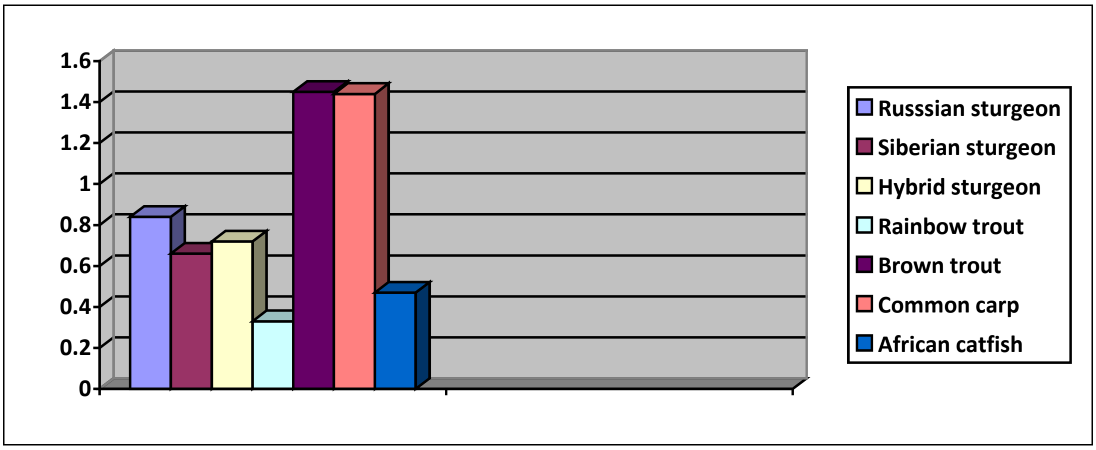

Figure 3: Levels of T3/T4 ration
of representatives of Salmonidae, Acipenseridae, Cyprinidae, and Clariidae family.

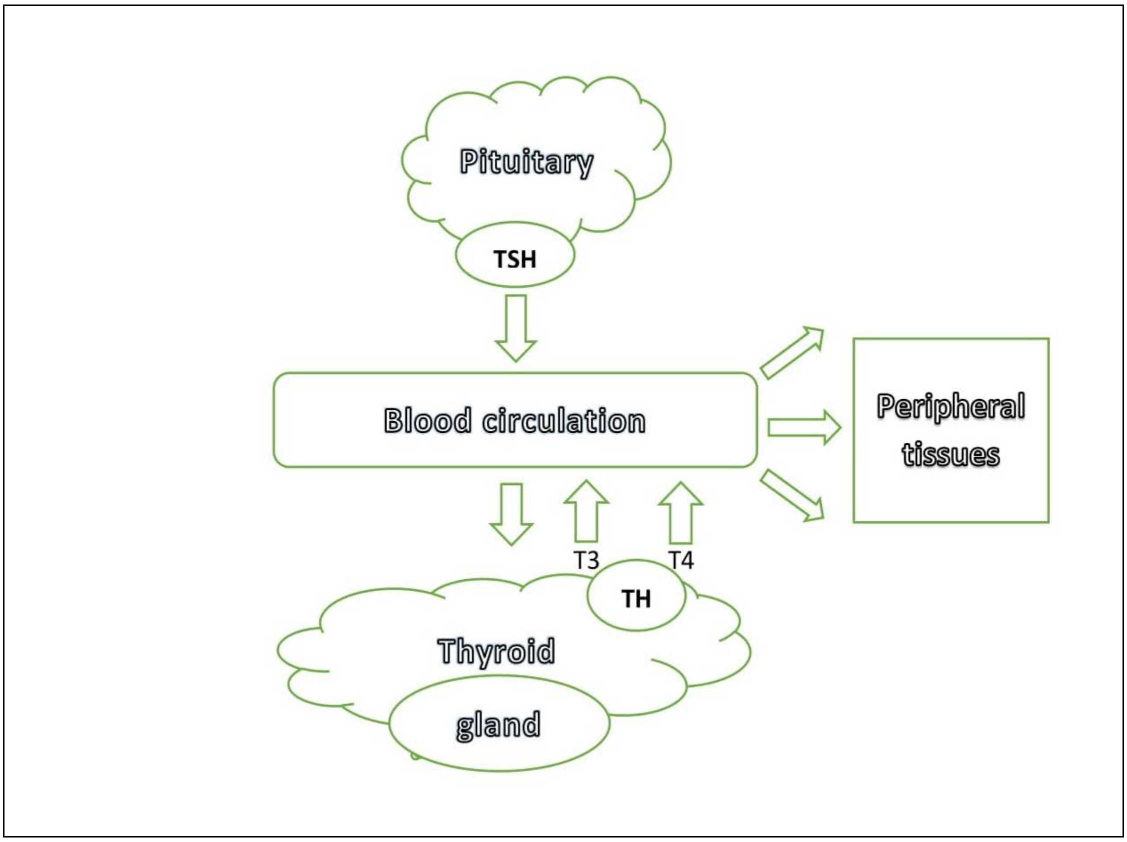

Figure 4: The classic pathways
of thyroid hormone metabolism.

According to the obtained results by Gomez et al. (1997) in *Oncorhynchus mykiss* the baseline levels of T3 are 2.2 ± 0.2 ng/ml, as well as the average daily T3 concentration is 2.6 ± 0.2 ng/ml (range 0.6 to 7.1 ng/ml) which were not close to the values obtained by us. The authors reveal a high degree of variability in the magnitude of T4 peaks (range 0.8 to 12.7 ng/ml) and the average daily T3/T4 = 0.5 while in our study the ratio is lower (0.33). Authors based its conclusions on absolute plasma T3 and T4 concentrations that fluctuations of T3/T4 ratio depend on the type of observations and on the time scale. Their results support theory of separate regulation of T3 and T4 production under normal physiological conditions. Recognising the limitations of our analysis, we attributed the low levels of T3 to feed. *Oncorhynchus mykiss* fed a high-fat diet reduced plasma T3 level, while the same diet resulted in high plasma T4 level and hence to reduce T3/T4 ratio.

The study therefore established that mean T4 concentration in *Cyprinus carpio* was 1.80 µg/dl, which was similar to levels in cyprinid fish reported by Dogru et al. (2016). In terms of T3, the levels indicated by the same authors were much higher than our results. The results of the current study generally were similar to results observed in studies by Dapeng et al. (2008) conducted with healthy crucian carp-*Carassius auratus* (Linnaeus, 1758), where the triiodothyronine concentration in the blood is 1.84 ng/ml and thyroxine 11.08 ng/ml. In the current study, where *Cyprinus carpio* under growth in net cages and ponds conditions, it can be concluded that season and spawning period that the cause of the variation in TH levels.

The results revealed significant differences when *Clarias gariepinus* were compared with other fish species. In a *Clarias gariepinus* the values were lowest in comparison to another in the study. The T3 concentrations determined in current study were close to the mean values reported by Ahmed et al. (2015) (1.58 ng/ml), as well as were the similar (0.54 ng/ml) reported by Suchiang and Gupta (2011) for summer period.

Additionally, we have to take into account the fact that the cause of the differences in blood parameters could be species-specific variations, different environmental conditions and health status (Nicula et al., 2010).

CONCLUSIONS

The present study was designed to determine serum thyroid hormone concentrations in fish species which belong to four families and represent important species for aquaculture. It can be concluded that contributes to detailed description of the mean levels of triiodothyronine and thyroxine in seven freshwater fishes during the spring season. However, the data are insufficient, and more research is needed to complete the hormonal profile and identified relationships with other hormones and different conditions.

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PREDATION BY THE NONNATIVE RAINBOW TROUT, *ONCORHYNCHUS MYKISS* (WALBAUM, 1792), ON THE NATIVE BIOTA FROM FRESHWATER ENVIRONMENT OF THE CENTRAL ANDES (ARGENTINA)

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KEYWORDS: Andes, *Oncorhynchus mykiss*, rainbow trout, predation, native biota.

ABSTRACT

This study aimed to examine the impact of the nonnative rainbow trout *Oncorhynchus mykiss* on the native biota that inhabits freshwater environments of the central Andes, Argentina. To assess the predation pressure on native Andean vertebrates and invertebrates, the stomach contents were taken from rainbow trout caught at three Andean sites. Results showed that the major prey items were the native torrent catfish *Hatcheria macraei* (100% in diet), Elmidae coleopterans (23%), and the native crab *Aegla affinis* (38%) in the rainbow trout stomachs collected from Cipolletti Dam (North zone), Yaucha River (Middle zone), and Vaina Stream (South zone), respectively. This preliminary study exhibits the predation pressure of the rainbow trout on native Andean species and suggests that policies are necessary to control the release of fry of this exotic salmonid in the Andes region.

RESUMEN: Depredación de la trucha arcoíris, *Oncorhynchus mykiss*, sobre la biota nativa de ambientes de agua dulce de los Andes centrales (Argentina).

Este estudio tuvo como objetivo examinar el impacto de la trucha arcoíris, *Oncorhynchus mykiss*, sobre la biota nativa que habita en ambientes de agua dulce de los Andes centrales, Argentina. Para abordar esto, se tomó el contenido estomacal de truchas arcoíris capturadas en tres sitios para evaluar la presión de depredación sobre los vertebrados e invertebrados andinos nativos. Los resultados mostraron que las principales presas fueron el bagre nativo *Hatcheria macraei* (100% en la dieta), los coleópteros Elmidae (23%) y el cangrejo nativo *Aegla affinis* (38%) presente en los estómagos de las truchas arcoíris capturadas en el dique Cipolletti (zona Norte), el Río Yaucha (zona Intermedia) y el Arroyo Vaina (zona Sur), respectivamente. Este estudio preliminar muestra la presión de depredación de la trucha arcoíris sobre las especies nativas andinas y sugiere que se apliquen políticas de control para la liberación de alevines de este salmónido exótico en Andes centrales.

REZUMAT: Prădătorismul păstrăvului curcubeu non-nativ, *Oncorhynchus mykiss*, asupra biotei native din mediul dulcicol din Anzii centrali (Argentina).

Acest studiu a avut ca scop examinarea impactului păstrăvului curcubeu non-nativ *Oncorhynchus mykiss* asupra biotei native care populează mediile dulcicole din Anzii centrali, Argentina. Pentru atingerea acestui scop, a fost prelevat conținutul stomacal de la indivizii de păstrăv curcubeu capturați în trei situri andine pentru a evalua presiunea de prădător asupra vertebratelor și nevertebratelor andine native. Rezultatele au arătat că principalele specii pradă au fost somnul nativ *Hatcheria macraei* (100% în dietă), coleoptere din familia Elmidae (23%) și crabul nativ *Aegla affinis* (38%) găsite în stomacurile indivizilor de păstrăv curcubeu colectați de la barajul Cipolletti (zona de nord), râul Yaucha (zona de mijloc) și respectiv pârâul Vaina (zona de sud). Acest studiu preliminar prezintă presiunea de prădător a păstrăvului curcubeu asupra speciilor native andine și sugerează că sunt necesare reglementări pentru a controla eliberarea alevinilor acestui salmonid exotic în Anzii Centrali.

INTRODUCTION

Invasive fish species continue to be a leading threat to the structure and function of aquatic ecosystems worldwide (Rypel, 2014; Gubiani et al., 2018). In addition to their inherent negative impacts on native fauna, the monetary cost of invasive species across six developed nations is an estimated 335 billion US dollars per year (Rypel, 2014). Significant emphasis has been placed on predicting invasions and understanding why certain invasive species are successful (Lusk et al., 2010). According to the literature, the irrational introduction of exotic fish species usually produces strong ecological imbalances, due to the lack of specific predators in the aquatic environment (Lusk et al., 2010; Rypel, 2014; Gubiani et al., 2018).

The ichthyofauna of the Andes fits perfectly into this general pattern, since the phenotypic plasticity and voracity of salmonids, especially rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792), allows them to quickly adapt and colonize new environments. The rainbow trout are thus able to displace native species through predation and competitive exclusion (Figueroa et al., 2010; Zarco et al. 2020).

Along the river basins of the central Andes region in Argentina, the rainbow trout, a fish species native to North America, has been successfully introduced due to its recreational and gastronomic relevance (Ríos et al., 2019). This salmonid is a voracious top predator fish (Alvear et al., 2007; Di Prinzio et al., 2013; Ríos et al., 2015), considered as one of the 100 most harmful invasive exotic species in the world (Global Invasive Species Database, 2020). It is known that fry mainly feed on invertebrates that occupy low levels of the food web (Molineri, 2008), while adult trout incorporate other fish, amphibians and macrocrustaceans into their diet (Alvear et al., 2007; Di Prinzio et al., 2013; Ríos et al., 2015). This potentially negative impact on the native biota, identifies the rainbow trout as an invasive fish that could cause pernicious and irreversible consequences on the biodiversity of the central Andes' freshwater environments. Furthermore, given the migratory behaviour of these salmonids, they may reach areas where rainbow trout were previously absent and thus increase the detrimental effect on native populations (Zarco et al., 2020).

Rainbow trout, a well known competitor for food for native fishes around the world (McLennan and MacMillan, 1984; Lucas, 2008; Kruzhylina and Didenko, 2011) were initially introduced to the Mendoza Province in the central Andes region, Argentina, in 1957 (Villanueva and Roig, 1995). The tasks of official introduction of this salmonid coming from San Carlos de Bariloche (Argentinean Patagonia) to Mendoza were carried out through procedures made in the hatchery El Manzano (Villanueva and Roig, 1995), located in the middle zone of the central Andes region. Specifically, these procedures include incubating, rearing, and stocking fry. Since 1957 to date, release of fry takes place regularly in several rivers and streams within the Mendoza Province of the central Andes (Secretaria de Ambiente, 2013).

This study aimed to examine the potential impact of the nonnative rainbow trout on the native Andean biota and assessed the plausible implications for the biodiversity of freshwater environments of the central Andes region. Due to the sampling limitations (e.g., difficult access to high elevation mountain sites), the sample sizes in this study were relatively low. However, our results add new information to the scarce data on the effect of a voracious predator on native freshwater biota and can be taken as an indicative baseline for the central Andes region.

MATERIAL AND METHODS

Georeferenced sampling sites, the number of individuals captured, and the fish morphometry of rainbow trout are detailed in table 1. The captures were made in freshwater environments corresponding to the North, Middle and South zones of the central Andes region. All fish specimens were adults and caught during the Austral autumn (April to June) in 2014 by using conventional fishing with artificial lures according to our research authorization (permission issued by the Direction of Renewable Natural Resources of the Government of Mendoza, research permit #659). Immediately after capture and sacrifice, fish were transported in coolers with ice to the laboratory, where the specimens were weighed (0.01 g) and sized before dissection. The length of the fish was measured from the front-tip of the mouth to the end of the caudal fin (total length).

Table 1: Sampling sites and fish morphometry of rainbow trout (*Oncorhynchus mykiss*) from central Andes.

Sites	Zone	Latitude	Longitude	Altitude (m.a.s.l.)	N	Total weight (g)	Total length (cm)
Cipolletti Dam	North	–33.0519	68.9396	1009	3	335 ± 20.2	28.7 ± 0.75
Yaucha River	Middle	–34.2458	69.3260	1873	6	198 ± 6.81	25.7 ± 0.42
Vaina Stream	South	–35.9329	70.0419	1689	7	282 ± 22.8	27.8 ± 0.90

Specifically, the rainbow trout were caught in the Cipolletti Dam (n = 3) belonging to the Mendoza River basin (North zone), in the Yaucha River (n = 6) of the Tunuyán River basin (Middle zone), and in the Vaina Stream (n = 7) belonging to the Rio Grande basin (South zone). Because rainbow trout and the native torrent catfish *Hatcheria macraei*, (Trichomycteridae) (Girard, 1855) are sympatric species in the Mendoza River basin (Villanueva and Roig, 1995), several specimens of *H. macraei* were collected from the Cipolletti Dam, to morphologically compare them with the semi-digested fish found in the stomachs of the three rainbow trout caught from this site. This procedure allowed a correct taxonomic classification.

The dissection of each specimen was performed with a scalpel and surgical scissors. The content of the excised stomachs was conserved in ethanol:water (70:30) individually for each specimen for the subsequent identification of the prey items. All the fish detailed here were processed and conditioned in the same way prior to the diet analysis. The contents of each stomach were examined in the Entomology Laboratory of IADIZA (Argentine Institute for Arid Zones Research) by using a binocular magnifying glass and systematic keys (Domínguez and Fernández, 2009). The arthropods and fish present were taxonomically identified and the diet was estimated according to the study site. The occurrence of each item consumed by each individual was calculated, differentiating by site. The quantity of each prey item present in the individualized stomachs of the trout was expressed as the percentage of said prey item in relation to the total number of prey contained in each stomach.

RESULTS AND DISCUSSION

The analysis of the stomachs of the rainbow trout from the Cipolletti Dam (North zone), showed that 100% of the diet was composed only by the native fish species *Hatcheria macraei* (Fig. 1).

Figure 1: Stomach content of rainbow trout (n = 3) from Cipolletti Dam. The three stomachs analyzed contained only the native fish *Hatcheria macraei* (100% in diet).

The stomachs of the Yaucha River (Middle zone) trout contained a great diversity of food items, however, the dominant prey (23%) were the beetles of the Elmidae family (Fig. 2).

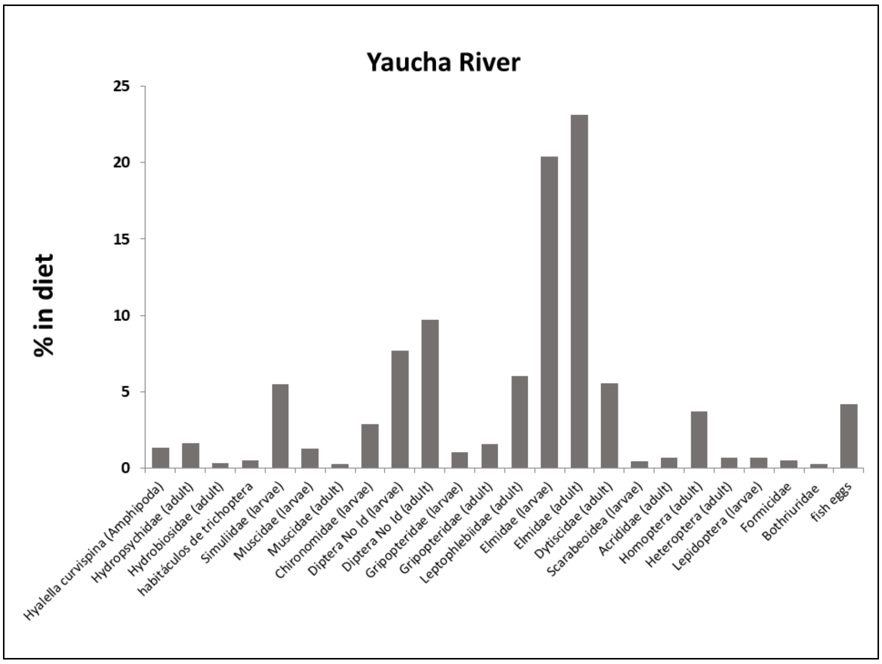

Figure 2: Food items in the stomachs of rainbow trout (n = 6) from the Yaucha River.

The trout from Vaina Stream (South zone), contained 38% of the river crab *Aegla affinis* Schmitt, 1942 in their stomachs, being their major prey item (Fig. 3).

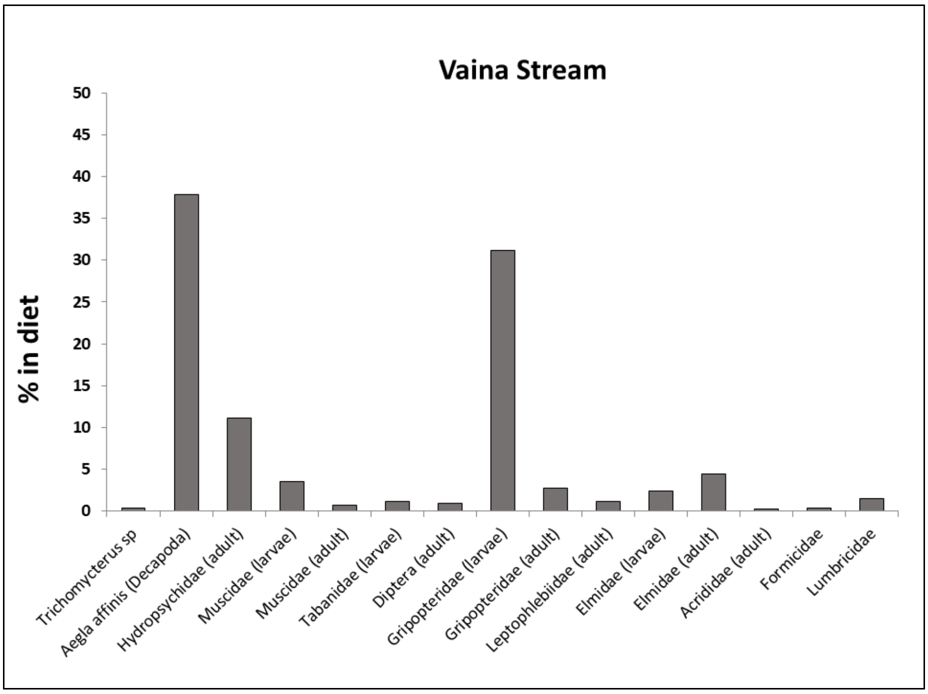

Figure 3: Food items in the stomachs of rainbow trout (n = 7) from Vaina Stream.

CONCLUSIONS

This preliminary study showed the negative impact of an exotic fish on native biota such as the fish *Hatcheria macraei* and the river crab *Aegla affinis* Schmitt, 1942 from the central Andes region.

The synergistic effects of introducing an exotic predator with previous stressors are unknown, but could be detrimental to native fish populations, amphibians (Zarco et al., 2020), as well as macrocrustaceans (Vigliano et al., 2009). Recently, Zarco et al. (2020) reported for the first time, the predation of rainbow trout on the critically endangered Pehuenche Spiny-chest Frog *Alsodes pehuenche* Cei, 1976, an endemic species from the central Andes region, highlighting an additional factor in the decline of populations of this frog species.

Critical actions are necessary to prevent the entrance of rainbow trout into rivers and streams where trout are still absent, and to avoid an increase in trout density in the freshwater environments of the central Andes region. Policies are needed to control the culture and release of trout in Andean rivers and streams.

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A SHORT REVIEW ON THE BIOLOGICAL CHARACTERISTICS OF THE SPECIES *ESOX LUCIUS*, LINNAEUS, 1758 IN CASPIAN SEA BASIN (IRAN)

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KEYWORDS: Northern Pike, Caspian Sea basin, biology.

ABSTRACT

The *Esox* genus belongs to the family Esocidae. It is a freshwater fish that can be found in different parts of Europe, Asia, and North America. The Northern Pike, is a carnivorous fish, member of the only remaining genus of the Esocidae. This fish prefers to lead a solitary life due to the disadvantages of the presence of individuals of the same species which compete for food resources and territory. Waiting for a suitable situation to catch prey is a favoured hunting method, which means this specific species is a lie-in-wait predator. The elongated body and the broad snout are the most striking features used for the identification of this species. This lie-in-wait carnivorous predator mostly feeds on invertebrates and fishes. The species spawns annually. The special living conditions of this species and their endangered environment have made it necessary to avoid any acts that can affect their life quality.

ZUSAMMENFASSUNG: Eine kurze Überprüfung der biologischen Merkmale des Hechtes *Esox lucius*, Linnaeus 1758 im Becken des Kaspischen Meeres (Iran).

Esox, eine gattung aus der familie der Esocidae, ist ein süßwasserfisch, der in verschiedenen teilen Europas, Asiens und Nordamerikas vorkommt. Seine arten werden hecht genannt und in akademischen studien als *Esox lucius* bezeichnet. Der hecht ist ein fleischfressender fisch und gehört zur einzigen verbliebenen gattung der Esocidae. Dieser fisch zieht es vor, allein zu leben, da die gleichen arten wie die gegenseitigen nahrungsressourcen und das territorium die nachteile aufweisen, die zu unterschiedlichen herausforderungen führen können. Das warten auf eine geeignete situation, um die beute zu jagen, ist ein häufiges verhalten, was bedeutet, dass diese spezielle art ein raubtier ist, das auf der lauer liegt. Langer körper und breite schnauze sind merkmale und eigenschaften dieses fisches, die einen unterschied deutlich machen.

REZUMAT: O scurtă revizuire asupra caracteristicilor biologice ale speciei *Esox lucius* Linnaeus, 1758, în bazinul Mării Caspice (Iran).

Genul Esox aparține familiei Esocidae, fiind reprezentat de pești de apă dulce răspândiți în diverse părți ale Europei, Asiei și Americii de Nord. Știuca este un pește carnivor, membru al singurului gen existent în familia Esocidae. Peștele duce o viață solitară, date fiind dezavantajele prezenței indivizilor din aceeași specie în ceea ce privește competiția pentru hrană și teritoriu. Obișnuiește să aștepte momentul oportun pentru atacarea prăzii, fiind un prădător de ambuscadă. Corpul alungit și rostrul larg sunt trăsăturile distinctive folosite pentru identificarea speciei. Hrana principală o reprezintă nevertebratele și peștii. Specia depune icre anual. Condițiile de viață deosebite și mediul de viață aflat într-un echilibru precar fac acest pește foarte vulnerabil față de acțiunile ce i-ar putea afecta calitatea vieții.

INTRODUCTION

The fish species of economic and ecological value and their habitats are generally threatened all over the world (Forouhar Vajargah et al., 2019; Kar and Khynriam, 2020; Reynaldo de la Cruz et al., 2020; Curtean-Bănăduc et al., 2020; Scheuerell et al., 2020; Koster et al., 2020), new, updated and variable research about them being highly needed for proposals of better management practices.

Esox lucius is considered a fish species of economic and ecological importance (Sattari, 2020).

The wide distribution and special behaviour of this fish have led to much research in the field of nutrition, physiology, behaviour, and habitat (Sattari, 2020).

The present research is a short review of information obtained from various researches and provides essential information about the behaviour and biological characteristics of this fish, especially in the Caspian Sea basin. Specific information relating to the Anzali wetlands, connected environments, and ecological problems, associated with these areas are provided.

The Northern Pike is a fish of the order Esociformes. *Esox lucius* Linnaeus, 1758 was firstly introduced from Europe (Coad, 2016). This fish is one of the widely distributed species that can be found in most of the aquatic ecosystems (Rodger, 1991).

The pikes can be found in the fresh waters of the northern hemisphere. Their size can vary from medium to large (40-50 cm up to 1.4 m).

In a single genus, *Esox*, seven species are recognized, in Iran, the species *Esox lucius* Linaeus exists (Coad, 1987; Eschmeyer and Fong, 2016).

Morphology

Elongated body, big partly scaled head, broad snout, huge mouth which covers half of the head, with many large and sharp teeth, convex upper jaw and a dorsal fin which is in front of the anal fin are the characteristics of this fish (Berg, 1948) (Figs. 1 and 2).

Figure 1: *Esox lucius* Linnaeus, 1758 (Coad, 2016).

The dorsal fin has 15 to 19 rays that can be divided into six to 10 branched and 13 to 18 unbranched rays. In addition, 12 to 16 anal rays, 11 to 17 pectoral rays and seven to 13 rays can be seen. Lateral line scales can be counted from 105 to 148. (Coad, 2016)

Colour

Generally, the skin is olive-green with light yellow spots which is darker on the back and becomes lighter and eventually fades over the belly. Yellow to white spots can be seen on the sides. Scales can also be recognized from the golden tips. Wavey head and golden or yellow eyes are noticeable. All fins, except pectoral and pelvic, are green, yellow, orange or red with the exception of black or dusky to orange spots (Coad, 2016).

Figure 2: *Esox lucius* Linnaeus, 1758, head (Coad, 2016).

Habitat

E. lucius can be seen in various parts of Northern Hemisphere such as Europe, North America, and Asia including Iran (Sattari, 2020).

This lie-in-wait predator lives solitarily and prefers to live in any stagnant or slow flowing water such as marshes, ponds, lagoons, etc. *E. lucius* can also be seen only in the lower reaches of rivers (Sattari, 2020). The Siah Keshim protected wetland, a part of the Anzali Wetlands (Fig. 3) in northern Iran, Caspian Sea basin, is known as one of the habitats of the *E. lucius* (Riazi, 1996). The Amir Kalayeh, Anzali, and Boojagh wetlands (all from the Caspian Sea basin, north of Iran) are habitats for *E. lucius* as well.

The Siah Keshim aquatic ecosystem is located in the south-west of the Anzali wetlands and has been designated as a protected area since 1968 due to its value as a shelter for migratory birds. The Siah Keshim land area spans from Mahruzeh in the North, the Anzali wetlands, and Siah Darvishan River in the East, Ziabar and Mazaranmahale villages, and Southern farms of Vishka in the West, and Laksar in the South. (Asri and Eftekhari, 2002)

Geologically, this wetland is very young, and its climate is influenced by the sea-mountain system. The rainfall is very high, with little annual change and the temperature fluctuations almost constant. (Asri and Eftekhari, 2002)

The average annual rainfall of the area is 1,686.5 mm, the average maximum temperature of the hottest month of the year is 33.9C° and the average minimum temperature of the coldest month of the year is –1.2C° and the average annual relative humidity is 85%. The dry season in this area is very brief and the area falls in the temperate climate. (Asri and Eftekhari, 2002)

In general, six main rivers flow into this lagoon which are, from south-west to north-east, the Gaz, Masouleh Roodkhaneh, Zagheh, Palangavar, Khalkii, and Morghak. There are also canals and drainage channels, the most important of which is Mahruzeh. (Asri and Eftekhari, 2002)

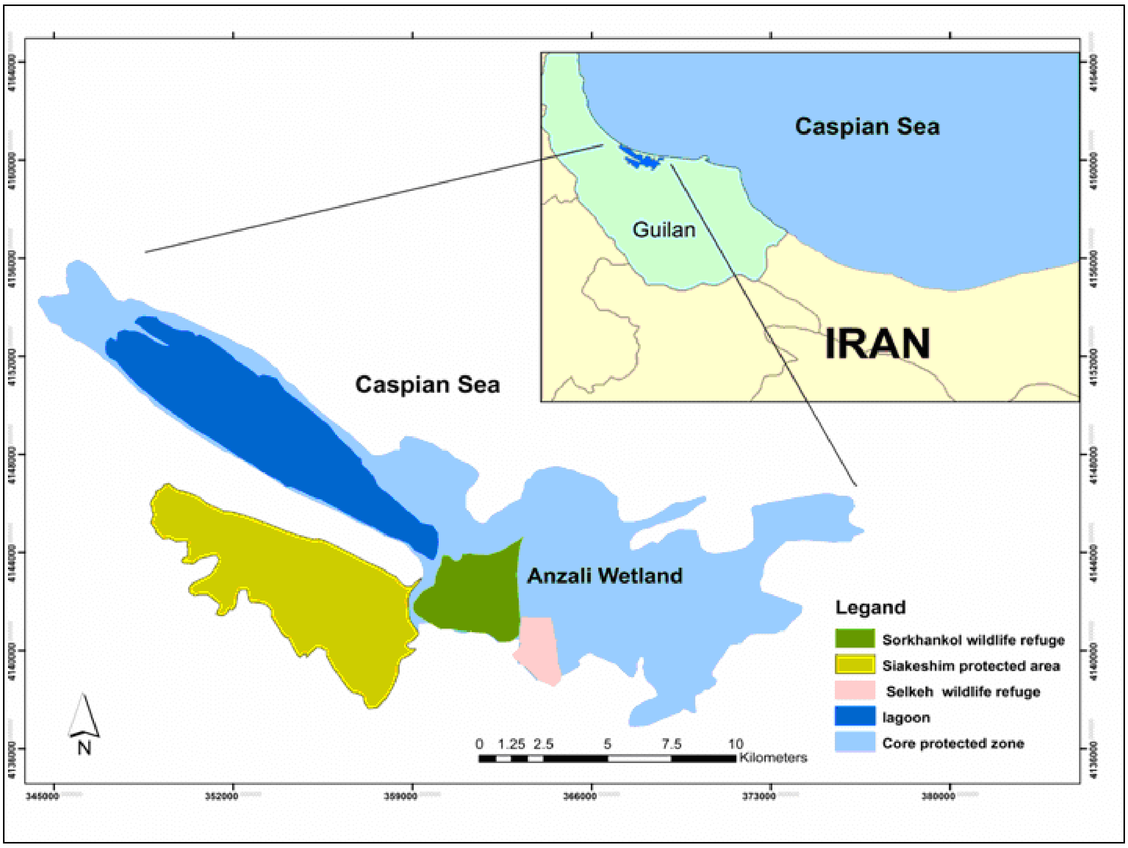

Figure 3: Anzali Wetland.

Anzali wetland

The Caspian Sea, the largest lake in the world (Forouhar Vajargah et al., 2018), is facing ecological problems such as discharge of industrial and agricultural effluents and growing urbanization in most riparian areas of the Caspian Sea (Sattari et al., 2020). As a connected environment, Anzali wetlands has similar ecological problems (Vesali Naseh et al., 2021).

Increasing anthropogenic activities such as overpopulation, industrial, and agricultural activities presence have led to a decrease in water quality of the Anzali wetlands (Nasirian, 2007).

At the southern end of the Caspian Sea, a globally important wetland is located, namely the Anzali Wetland, a suitable habitat to numerous aquatic and aquatic-dependent organisms including fishes, invertebrates, birds, etc. (Khosravi et al., 2011)

E. lucius or in local dialect, "Shook" (in Farsi), is an old native species of the Anzali wetlands that is still able to continue living and reproducing despite the fact that this wetland is facing different environmental problems. The pike is one of the most popular fish for sport fishing in the Guilan Province, North of Iran.

Food

E. lucius fingerlings prey on zooplanktons and insects, whereas adults prey on fish, mice, ducklings, and frogs. It is noticeable that both male and female stop eating during spawning (Orlova and Popova, 1976).

To be more specific, the results from research based on the *E. lucius* in Boojagh Wetland showed that the pike's diet includes 13 different types of food: among which dragonfly larvae (14%), pipefish (13.8%), and goby (13.4%), have the highest frequency percentage amongst all prey (Nezami et al., 2005).

Hunting

Their highly mobile eyes enable them to find prey in nearly any direction and their sighting grooves on the snout helps them to estimate depth and distance more effectively. A sudden explosion-like movement will lead to food capture. Fish with cylindrical bodies are preferred by *E. lucius* as they are easier to swallow. The whole process can be divided into eye movement towards the prey, turning the body to a suitable direction, chasing, attacking, capture, placing the head of the prey in mouth, and swallowing stages. Fish with one-third to one-half the length of the pike are normally picked. (Coad, 2016)

Reproduction

Evaluation and assessment of physiological condition and size is essential to artificial breeding and to providing the best growth condition for fish resource maintenance (Zaprudnova and Prozorovskaya, 1999).

Based on academic studies, it can be claimed that *E. lucius* has an annual winter spawning and that the gonadal development process happens through the spring. After spawning, gonads start developing again and in summer, yolk granules could be seen with a vacuole from spring. Furthermore, yolk production is complete in mid-autumn and spawning takes place in winter (Epler et al., 2008).

Threats and diseases

Many studies have proved a high level of infestation in pike. Research showed helminths were found within the ratio of 78.9% (Eslami et al., 1972). Encounter with the digenetic trematode, *Rhipidocotyle illense* (Ziegler, 1883), the nematode larva, *Eustrongylides excisus* Jägerskiöld, 1909, and *Acanthocephalus lucii* (Müller, 1776) was recorded (Mokhayer, 1976). The presence of *Eustrongylides excisus* was again reported in 2002 and 2004 (Sattari et al., 2020). This consistency is worthy of attention, noticing the fact that this parasite can damage muscle tissue thus making it an unlucrative commercial item (Coad, 2016). *Diplostomum spathaceum* Rudolphi, 1819, an eye parasite was also found in *E. lucius* (Barzegar et al., 2008)

In an examination on the pikes of the Amir Kalayeh wetlands in Guilan, Iran, the following parasites were recorded: *Eustrongylides excisus*, *Triaenophorus crassus* Forel, 1868, *Trichodina* sp. Ehrenberg, 1831, *Tetraonchus monenteron* (Wagener, 1857), *Diplostomum spatheceum*, *Lernaea* sp. Linnaeus, 1758, *Raphidascaris acus* (Bloch, 1779), *Camallanus lacustris* (Zoega, 1776), *Argulus* sp. Müller, 1785, and *Piscicola* sp. Blainville, 1818 (Khara et al., 2004). The piscivorous diet picked by the fish was suggested as the reason for this wide variety (Khara et al., 2004).

In light of the high economic and ecologic value, the blood parameters of the *E. lucius* were examined in a study in which 120 fish were tested for parasites. Their effects on blood parameters revealed that five of the 10 isolated parasites could affect blood parameters including *Rhipdocotyle illense*, *Corynosoma strumosum* (Rudolphi, 1802), *Diplostomum spathaceum*, *Tetraonchus monenteron*, *Eustrongylides exisus*, with the studied parameters being HCT, Hb, RBC, WBC, MCV, MCH, MCHC. (Jamalzade et al., 2014).

In addition, an analysis carried out in the Anzali wetlands showed the highest prevalence of the parasites in *E. lucius* was for *Eustrongylides exisus* (22.66%) and the lowest was for *Tricodina* sp. Ehrenberg, 1831 (3.33%) (Jamalzad et al., 2012).

The greatest average of infection severity was found for *Rhypdocotyle illense* (88.5%) and the minimum was reported to be for *Lernaea cyprinicea* (1.75%) (Jamalzad et al., 2012).

CONCLUSIONS

Esox lucius is an important fish to study from various aspects, including its evolution and the aquacultures which it is part of in different parts of the world. Its long olive-green body, predatory behaviour, fast movement and solitary living are known to be the most striking characteristics of this species. In addition,.

The fish is facing ecological problems in the Anzali wetlands, a famous habitat which is in the southern basin of the Caspian Sea, such as pollution that have been found in different studies and mentioned in this research.

The Northern Pike is a fish of biological importance that may need special protection in the near future due to the related problems. It can be understood that this species life conditions are changing in many ways, the Pasikhan River in Gilan, which was famous for its pikes, is an example of a river system where pike have almost vanished.

To conclude, the need for further research on this species is undeniable.

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IMPACT OF CHAOTIC URBANISATION ON BENGALURU'S (INDIA) URBAN AVIAN DIVERSITY

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KEYWORDS: bird fauna, ecology, Bengaluru, migrant species.

ABSTRACT

Bengaluru is facing the immediate threat of losing most of its native and migrant avian species due to urbanisation. In the current study, the most popular birding regions were identified; followed by the anthropogenic factors responsible for falling numbers of species. Finally, inferences were derived by analyzing the confluence of direct and indirect impacts. The study confirms instability in ecological and physiological factors, and postulates the need to monitor avian diversity, migratory behaviour, population sizes, distribution patterns, and conservation status.

RÉSUMÉ: Impact de l'urbanisation chaotique de la diversité aviaire urbaine du Bengaluru (Inde).

Le Bengaluru est confronté à la menace immédiate de perdre la plupart de ses espèces aviaires indigènes et migratrices en raison de l'urbanisation. Dans l'étude actuelle, des régions d'observation d'oiseaux les plus présents ont été identifiées, suivies par les facteurs anthropiques responsables de la baisse du nombre d'espèces. Enfin, des conclusions ont été tirées en analysant la confluence des impacts directs et indirects. L'étude confirme l'instabilité des facteurs écologiques et physiologiques, et postule la nécessité de surveiller la diversité aviaire, le comportement migratoire, la taille des populations, les schémas de distribution et l'état de conservation.

REZUMAT: Impactul urbanizării haotice asupra diversităţii avifaunistice din Bengaluru (India).

Bengaluru se confruntă cu amenințarea imediată a pierderii majorității speciilor de păsări native și migratoare din cauza urbanizării. În studiul de față, au fost identificate cele mai populare regiuni pentru păsări; urmate de factorii antropici responsabili de scăderea numărului de specii. În cele din urmă, interferențele au fost derivate prin analiza confluenței impacturilor directe și indirecte. Studiul confirmă instabilitatea factorilor ecologici și fiziologici și postulează necesitatea monitorizării diversității faunei ornitolgice, a comportamentului migrator, a dimensiunilor populației, a modelelor de distribuție și a stării de conservare.

INTRODUCTION

Birds are one of the most populous life forms on the planet that demonstrate amazing evolutionary adaptations. As an important part of most terrestrial ecosystems, birds play a vital role in the food chain and maintenance of ecological balance in several ways such as pollination. They inadvertently aid humans by enhancing agricultural yield, for example via pest/insect control in both pre and post-harvest stages. While *Passer domesticus* (Fig. 1), is highly effective against cabbageworms, tomato hornworms and leaf beetles, birds such as *Athene brama* (Fig. 2) prey on rats and mice that can otherwise cause huge losses on farms by eating stored grain. Greenwood (2004) has shown that their presence and absence hence serve as valuable bio-indicators for healthy global environment, and invariably indicate any change occurring within the system.

Figure 1: *Passer domesticus*.

Figure 2: *Athene brama*.

Figure 3: *Alcedo atthis*.

Figure 4: *Psittacula krameri*.

Figure 5: *Bubulcus ibis*.

Figure 6: *Dicaeum agile*.

MATERIAL AND METHODS

To accomplish the objectives of the study, the following sequential procedure was engaged upon. Firstly, the fifteen most popular birding regions of Bengaluru were identified and analysed for their land-use pattern. Secondly, major anthropogenic factors responsible for declining bird species numbers were identified via primary and secondary data collection. To understand this better, the major anthropogenically induced factors responsible for declining population of the bird and as specific to Bengaluru were brain-stormed and finally the inferences were arrived at. To accomplish this, the study focused on aspects connected to avian diversity, their migratory behaviour, population size, distribution pattern, and conservation status. Finally, the inferences were derived by analyzing the confluence of direct and indirect impacts of urbanisation. A sample checklist has been presented as table 1, which has been compiled by reviewing the website of biodiversity.org.

Table 1: Sample checklist for birds of Bengaluru (biodiversity.org).

Sl. No.	Scientific name	Order	Family	Common name	Field note
1.	*Francolinus pondicerianus*	Galliformes	Phasianidae	Grey Francolin, Grey Partridge	Breeding resident on outskirts
2.	*Cotumix coromandelica*	Galliformes	Phasianidae	Rain Quail, Common Breasted Quail	Rare
3.	*Cotumix cotumix*	Galliformes	Phasianidae	Common Quail	Rare
4.	*Perdicula asiatica*	Galliformes	Phasianidae	Jungle Bush Quail	Breeding resident on outskirts
5.	*Gallus sonneratti*	Galliformes	Phasianidae	Grey Jungle Fowl, Sonnerat's Jungle fowl	Breeding resident on outskirts
6.	*Pavo cristatus*	Galliformes	Phasianidae	Indian Peafowl, Blue Peafowl	Breeding resident on outskirts
7.	*Anser anser*	Anseriformes	Anatidae	Graylag Goose, Wild Goose	Rare
8.	*Serkidomis melanotos*	Anseriformes	Anatidae	Knob-Billed Duck, Comb Duck	Rare
9.	*Tumix suscitator*	Turniciformes	Turnicidae	Common Bustard Quail	Uncommon, only seen in Bannergatta and Kanakapura areas
10.	*Jynx torquilla*	Piciformes	Picidae	Eurasian Wryneck	Rare, in and around Gandhi K. V. K. Campus
11.	*Megalaima zeylanica*	Piciformes	Megalaimidae	Brown Headed Barbet, Large Green Barbet	Rare
12.	*Megalaima haemacephala*	Piciformes	Megalaimidae	Coppersmith Barbet, Crimson Breasted Barbet	Breeding Resident
13.	*Nyctyomis athertoni*	Coraciiformes	Meropidae	Blue Bearded Bee Eater	Rare, Bannerghatta Area
14.	*Pelargopsis capensis*	Coraciiformes	Halcyonidae	White Throated Kingfisher, White Breasted Kingfisher	Vagrant, Except in the Kaveri River valley area
15.	*Halcyon pileata*	Coraciiformes	Halcyonidae	Black Capped Kingfisher	Vagrant

Birding regions in Bengaluru, namely Badamanavarthi State Forest, Cubbon Park, Bannerghatta State Forest, Hesaraghatta Grasslands, Lalbagh Botanical Garden, Nandi Hills, Sangama Valley, etc., with typically diversified land-use patterns such as aquatic, barren land, scrub land, woodland, dryland, paddy, orchids, grassland, etc., support the natural habitat preference of both native and migratory birds.

Sadly, sightings of a few of these have become rare on account of various reasons, and are at risk of becoming listed as "threatened". After thorough field visits (primary data) and investigation of the existing literatures (secondary data), 37 species (comprising of 10 Orders and 18 Families) common to Bengaluru were found to be classified as rare, historic or vagrant. It was deduced that species such as *Alcedo atthis* (Fig. 3), *Francolinus pondicerianus, Perdix perdix, Gallus sonneratii, Psittacula eupatria, Megalaima haemacephala,* etc. are breeding residents. *Ardeotis nigriceps, Emberiza bruniceps, Columba elphinstonii,* etc., are now considered historic. As extracted from the portal of biodiversity.org; while the vagrant species included *Halcyon smyrnensis, Halcyon pileata, Merops leschenaultia,* etc., the rare species included and were not restricted to *Dicaeum agile* (Fig. 6), *Anser anser, Sarkidiornis melanotos, Nyctyornis athertoni, Phaenicophaeus leschenaultii, Coturnix coromandelica, Aerodramus unicolor,* etc. The transformation of the status of the once "resident birds" to being vagrant, historic, and rare is undoubtedly an outcome of Bengaluru's rampant urbanization. The negative trend of bird species status hence hints at the degeneration of Bengaluru's natural environment, as an inadvertent outcome of its rapid urbanisation (Deepak et al., 2017).

Bengaluru has grown in all directions due to the absence of pre-defined boundaries, with its spatial area increasing from 500 km^2. to 1,500 km^2 between 1972 city development plan to the present day (Krishna et al., 2007). Vijayalakshmi et al. (2015) have shown that this increase was made to accommodate the rapidly growing urban population and a real estate boom. Ravindran (1996) revealed that between 1945 to 1973 and between 1974 and 1980, the built-up area density of the city increased by over three times compared to expansion during the previous 33 years, and by two times in the seven years compared to that of the previous 28 years. This hints at the extremely rapid increase in human population even at the rural fringes of Bengaluru City.

A main observation to be made in this regard is that while the spatial growth of Bengaluru was increasing, so was the conurbation area; however, the existing land within the agricultural belt was also dwindling, as has been shown by Vijayalakshmi et al. (2015). When compared to conurbation/urban areas, village and agricultural sites provide more support to avian species in terms of reduced interference of humans, availability of food, suitable climate, etc. These developments eventually mean that as the city is pushing outwards for growth, it is putting more stress on the species in surrounding environments, for example by preventing the near-ground movement freedom of smaller birds such as Swifts. As more rural areas are replaced by urban spaces, the populations of many species are fast dwindling due to shortage of food and human interference.

Consequently, many species are forced to move to better areas of habitat, leading to clashes with native and migratory species for food, i.e., "survival of fittest". A classic example of Darwin's Theory is showcased in a common conflict (Fig. 7) between *Corvus splendens* and *Milvus migrans* in the skies of dump-sites (Fig. 8), yet another negative outcome of urbanization.

Figure 7: *Corvus splendens* and *Milvus migrans*.

Figure 8: Clashes for food in open dump sites.

The city's transition from garden city to garbage city has been near perfect with several parts of Bengaluru having huge garbage piles. Depending on the specific type of litter, it can affect birds through poisoning from toxic litter, by ingesting plastic litter that cannot be digested and which remains in the digestive tract therewith blocking the passage of food and eventually starving it to death, by injuring internal and external parts of body from sharp shards of glass or plastic while feeding in a dump site, by reducing populations due to threats from predators such as rats and feral cats and clashes among birds for food, by introducing ailments due to the unhygienic conditions, and by forcing birds to seek out less desirable areas with greater inter/intra species competition for necessary resources for nesting, feeding or shelter.

Since the late 1980's, Bengaluru's urbanisation has resulted in the conversion of vast expanses of its natural waste scrub lands into buidlings (Gopinath et al., 2014). As a result, the bird species dependent on scrub and shrub ecosystems are eventually driven away due to overcrowding in these spaces by humans.

The reduction in such spaces eventually causes a threat to natural habitats of both native and migratory species; especially birds which feed on smaller insects and worms. While the loss of habitat drives away some native species, the migration pattern gets altered for other species.

Figures 9 to 12 depicts the conversion of one such open-space into a residential enclave which also involves air pollution from burning; thereby forcing sensitive birds to shift nests that also impairs their feeding habits. This also forces them to move to greener pastures which might lead to further native competition and predator threats such as stray dogs and cats which prey upon eggs and hatchlings, hence decimating numbers. Other, indirect forms of urban predatory threat, is from invasive plant species like *Lantana* which invade the land space of indigenous plants, directly affecting the food availability and breeding habits of local bird populations.

Another urban problem creating physical threats to bird species is the increasingly popular concept of glass facades on high-rise buildings. The number of buildings in Bengaluru with glass exteriors is steadily on the rise. For a migratory bird or forest dwellers such as Indian Golden Oriole, glass is a bewilderingly new concept. As birds fly, they see the landscape reflected on glass facades, and by mistaking the reflection they try to fly right through the windows and crash into them. As divulged in a study carried out by Girish (2010), crashes at speeds over 30 miles per hour can result in brain damage, chipped beaks, internal injuries, all of which may eventually prove fatal. This has been observed also for birds that co-exist with humans in urban environs such as *Passer domesticus*, *Columba livia*, *Pycnonotus leucotis*, *Copsychus saularis*, etc.

Figure 9: Untouched natural cover.

Figure 10: Burning to remove weeds.

Figure 11: Construction initiation.

Figure 12: Wagtail scouring around debris.

The growth of high-rise buildings with glass facades in Bengaluru was an influence of western nations under the guise of information technology in the 1990s. This however also brought about another form of threat i.e., mobile radiation tower technology. In Bengaluru there are nearly ten thousand cell phone towers. Birds such as swans, sparrows, and pigeons are supposedly sensitive to magnetic radiation, as the microwaves can interfere with their sensors and confuse them while migrating, navigating, and hunting. As Bengaluru took on the identity of Electronic City, it lead to more population, human migration, change in lifestyle, and growth in transportation to cater to the growing human population needs.

Between 1980 to 2008, the number of vehicles registered in Bengaluru had grown from 0.68 to 2.2 million (Lokesh and Gopinath et al., 2017). Between 1998 to 2003, the annual petrol consumption for Bengaluru had increased by 41%, and for diesel in the same period it rose by 28% (Krishna et al., 2007). This meant that there was more risk of bird ailments and deaths due to increased automobile emissions for those species which remained in the urban/city area. Also, to accommodate the increasing count in vehicles and decongest traffic, the city has witnessed development of several arterial and peripheral ring roads that have been built on wetlands, thereby eliminating valuable habitats and sources of food and shelter.

After the completion of the new Bengaluru International Airport (B.I.A.), the Metro Rail is the latest infrastructure undertaken to improve connectivity. While B.I.A. spurred growth in North Bengaluru, the elevated expressway and six lanes to Hosur led to increase in more residential agglomerations in the vicinity of Electronic City. This created two more implications for birds: firstly forcing birds away from core areas, and secondly creating new threats to birds on the outskirts of city in the form of competition and scarcity of shelter/resources.

Figure 13: Hosur Road in the past *.

Figure 14: Hosur Road, in the present *.

This form of urban development also led to the increased construction of roads; resulting in razing of road-side vegetation which also removes several nesting grounds of migratory and native species. A classic example of transformation landscape for Hosur road in Bengaluru is highlighted in figures 13 and 14, clearly revealing the change in landscape from the past to the present after felling the trees that supported several bird species.

Another direct consequence of the urbanization driven transportation sector is the rising noise levels that have consistently violated environmental norms (Lokesh et al., 2017). Many plants rely on birds to distribute seeds and pollen, and noise pollution can hinder this process. Also birds communicate with each other with distinct calls, and communication plays a vital role during the brief mating period for birds such as *Eudynamys scolopacea*, *Acridotheres tristis*, *Pycnonotus melanicterus*, etc. In this context, in areas which are prone to excessive traffic/industrial noise and subject to conditions arising from daily anthropogenic activities namely construction, demolition, loudspeakers, and traffic noise; birds struggle to hear each other. A bird may exhaust itself calling for an entire day and still not find a mate, leading to population decline as an outcome of urban noise interference.

Potentially, in the absence of a strong alpha male, weaker offspring are produced or more male and female altercations can occur. Urbanisation also affects bird populations by interfering directly with food chains. For instance, frog populations have drastically reduced due to noise interference during their mating calls; and this impact birds such as *C. sinensis* and *M. intermedia* as they depend on frogs as a dietary staple. Automobile pollution also can severely impact insect population and diversity, thereby impacting the insectivorous birds.

A pivotal reason why Bengaluru area was a major spot for migratory birds and native species was its rich heritage of water-bodies such as “The Region of a thousand tanks” (Samana and Gopinath, 2012). About 4.8% of the geographical area in Bengaluru was once occupied by wetlands located near the rural fringes and outskirts of the city (**).

Unfortunately, most of these lakes have been encroached upon, or eutrophicated, or polluted with sewage. In the year 1930, there were about 937 lakes in Bengaluru, between 1930-2010 the numbers had shockingly dwindled by about 97% (Ramachandra and Uttam, 2008). Between 1970 and 1990, about 421 ha of water-cover was lost to development, (Gopinath et al., 2014) and urbanization had impacted not only the count but also the quality of water-bodies severely (Samana and Gopinath, 2012). This resulted in eutrophication, fish kills due to toxic sewage and its subsequent health impact on birds, competition among birds for decreasing fish populations and eventually death of lakes which impair the food-web.

As shared in the National daily “Deccan Herald”, migrant species also began to avoid water-holes such as in the case of Madiwala Lake which was once frequented by *Anas acuta* and *Anas clypeata*. Even the present remedial measures of lake restoration are not benevolent to birds, as the dredging action and placing of boulders and nets on edges disrupts the option of nesting on banks.

Another key reason why Bengaluru was a foremost spot for migratory birds and native species was its distinct green cover in the form of its tall tree canopies within the city and at Bannerghatta National Park (BNP). Trees of Bengaluru include African Tulip, Queen's Flower, Silver Oak, Eucalyptus, Acacia, etc. Unfortunately, most urban trees have been felled for road widening and the forest cover at BNP has shrunk to encroachments in the periphery, attributed to suburban development, illegal logging by communities, grazing animal population, and illegal stone mining in the region.

The act of afforestation and replacement with 1000's of saplings is a long-term solution, but does not address the imminent loss of tall trees and the support they have to many nesting bird species. The development of information technology corridors, multi national corporations, and the city's growth towards Whitefield and Electronic City has literally made inroads into the green belt and caused forest fragmentation. Fragmentation and unscientific afforestation harm many woodland birds by increasing their susceptibility to predation and nest parasitism (Cavitt and Martin, 2002).

Generally, when the green cover and water cover of a place are tampered with, it subsequently brings about local climate disturbance. The Earth's climate has witnessed a constant change. Consequently, while some bird species were able to adapt to these changes, others could not and naturally became extinct.

Nevertheless, the climatic shift presently experienced is human-induced with global warming occurring in an accelerated manner. Subsequently, it is tougher for several bird species survive. Birds generally migrate to find food which cannot be available at a place throughout the year, and a suitable place to breed.

However, climate change can disrupt bird preparations for migration; for instance, small birds eat frantically for several weeks before migrating to build up fat reserves. In this context, non-availability of food can weaken or delay migration; and climate change can hamper both availability and habitat quality/extent. When the size of a bird's habitat shrinks, the rate of extinction increases according to the specialization of that species' food and other needs. In this situation, smaller body size hinders survival. Small birds have more difficulty surviving the move from one ruined or overcrowded habitat to another. Erratic rains due to climate change in Bengaluru can result in non-uniform and irregular flowering patterns. This adversely affects plant pollination cycles, and thus the availability of seeds and pollen for local and migratory bird species.

All these factors lead to breeding failure, as all birds require optimum temperature for egg laying and incubation. Strong winds triggered by climate change have rendered many birds homeless as well. Many birds such as *Anas clypeata, Anas acuta,* etc. migrate over long distances, escaping harsh winters by flying southwards to India, resting and breeding in Bengaluru in locations such as Hebbal Lake, Lalbaugh, before migrating to other parts of world. However, urbanization is nowadays introducing localized climatic modifications such as "Urban Warming" (Gopinath et al., 2017).

Bengaluru city once was considered to have pleasant weather, which was even compared to that of London. However, under the localized influence of urban warming and the global phenomenon of global warming there has been a steep change in trend. In the last decade the temperature had been observed to go up by 1.8°C, above normal (Gopinath et al., 2017; Vrinda and Gopinath, 2018; Sachin et al., 2020). As Bengaluru continues to constantly expand, the elevated temperatures are anticipated to rise higher and contribute to regional climate change which will directly impact the migratory behavior of birds via shifting and shrinking their ranges.

Human attitude (or rather insensitivity) to birds is yet another major feature that influences their populations. Unethical bird photographers are particularly responsible for endangering the life of birds, especially migratory species. Several instances have already been reported from Hesaraghatta (Mike, 2009).

As tree-top habitats are reduced, birds have started making house-tops their homes. This action has irked human beings on account of their noise and droppings, leading to placing of nets and reducing sitting space at window sills to prevent their entry. Sadly, these measures trap birds, damaging their wings and their ability to fly. Another human action i.e., domestication and captive breeding (for example Parakeets used by Fake Astrologers) is a major threat to their right to freedom; which is causing them to deviate from their nature instincts of feeding, hunting, nest making, etc.

Also, the emergence of sky scrapers, elevated metros, and reducing trees have hindered their natural action of training the juvenile the flight and predation, as the human created interventions deprive them of freedom to fly without disruptions, which otherwise can lead them to head-on collisions, physical injuries and imminent death.

If industrial plumes from stacks are known to blind birds due to air pollution, the infamous kite flying festival with threads glued with glass pieces give a permanent scar to high flying birds such as *Milvus migrans, Haliastur indus,* etc. upon tangling, and even kill them mercilessly. Finally, even the nocturnal species such as owls are not spared from human recklessness as surplus artificial lighting in the night-time majorly creates havoc inter survival and feeding instincts.

CONCLUSIONS

Direct and indirect impacts as an outcome of human activities have constantly altered the natural landscape and influenced its environmental attributes, hence adding onto the ecological imbalance. Consequently these causes, independently and in synergy have become potential major threats for the survival of the native and migratory avian species of Bengaluru. While certain species have become rare due to inherent natural causes such as vulnerability, mating pattern, egg-laying pattern, prey preference, etc; certain others have become rare due to the reckless anthropogenic actions. Birds are extremely necessary for maintaining the ecological and environmental sustainability, and their absence hence would invariably impact the global biodiversity negatively.

This paper has discussed the consequences of rapid, extensive urbanisation in Bengaluru, India, on bird populations. Key anthropogenic effects on bird species include loss of habitat and nesting sites, degradation and pollution of habitat and food sources, creation of hazards such as roads and glass facades, and domestic anti-bird netting which damage or kill birds, and human induced urban warming and climate change which affect seasonal food and nesting site availability, amongst many other factors. These factors interact and multiply their effects on birds, with the result that many species once listed as frequent are now listed as rare or historic. This degradation in avian diversity and population indicates severe ecological damage, with consequences for human welfare, as well as the obvious issues facing the surviving bird species.

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IRREGULARLY MIGRATORY AND RARE WATERBIRD SPECIES WITHIN TWO REPRESENTATIVE WETLANDS FROM THE CENTRAL ROMANIA (SOUTH-EAST TRANSYLVANIA) BASED ON LONG TERM INVENTORY

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ABSTRACT

Waterbird species from the category of rare or irregular migratory, can have faunistical and conservative value, especially locally, but also regionally or nationally. This paper presents the results of long-term avifauna inventories (25 years) from two wetlands of importance for waterbirds, located in southeastern Transylvania, central Romania. 44 species of waterbirds from these phenological categories have been identified, some for the first time at national or regional level (Transylvania), others with a high number of individuals for the reference area or even records for Transylvania. Moreover, at least one of the species has bred sporadically here, as the only place inside the country and the second in Romania (*Ichthyaetus melanocephalus*), another is possibly breeding for several years (*Grus grus*).

RÉSUMÉ: Espèces d’oiseaux d’eau migrateurs irréguliers et rares dans deux zones humides représentatives du centre de la Roumanie (sud-est de la Transylvanie), sur la base d’un inventaire à long terme (1994-2020).

Les espèces d’oiseaux d’eau appartenant à la catégorie des migrateurs rares ou irréguliers, peuvent avoir une valeur faunistique et conservatrice, surtout au niveau local, mais aussi régional ou national. Cet article présente les résultats d’inventaires de l’avifaune à long terme (25 ans) des deux zones humides importantes pour les oiseaux d’eau, situées dans le sud-est de la Transylvanie, au centre de la Roumanie. 44 espèces d’oiseaux d’eau de ces catégories phénologiques ont été identifiées, certaines pour la première fois au niveau national ou régional (Transylvanie), d’autres avec un nombre élevé d’individus pour la zone de référence ou même des enregistrements pour la Transylvanie. En outre, au moins une des espèces s’est reproduite ici de façon sporadique, comme seul endroit du pays et comme deuxième en Roumanie (*Ichthyaetus melanocephalus*), une autre se reproduit peut-être depuis plusieurs années (*Grus grus*).

REZUMAT: Specii de păsări de apă rare și cu migrație neregulată din două zone umede reprezentative din centrul României (sud-estul Transilvaniei), conform inventarierii pe termen lung (1994-2020).

Speciile de păsări de apă din categoria celor rare sau a migratoarelor neregulate, pot avea valoare faunistică și conservativă mai ales pe plan local, dar și regional sau național. Lucrarea prezintă rezultatele inventarierilor avifaunistice de lungă durată (25 ani) din două zone umede de importață pentru păsările de apă, din sud-estul Transilvaniei, partea centrală a României. Au fost identificate 44 specii de păsări de apă din aceste categorii fenologice, unele fiind specii noi pentru avifauna țării sau pentru Transilvania, altele cu număr de exemplare ridicat pentru zona de referință sau prezentând numărul cel mai mare pentru Transilvania. Cel puțin una dintre specii a cuibărit neregulat aici, ca singurul loc din interiorul țării și al doilea din România (*Ichthyaetus melanocephalus*), iar o alta este posibil cuibăritoare de câțiva ani (*Grus grus*).

INTRODUCTION

Irregularly migratory and rare bird species can provide important faunistically and conservative information for a given territory, especially based on long-term inventory or monitoring.

In relation to a certain territory, irregularly migratory and also rare bird are species that:

– have usually been identified one-five times over a period of several years or;

– were not observed regularly (annually or almost annually) in one of the two migrations;

– from a quantitative point of view, they usually appear in small numbers (one individual or in small groups).

The definitions of phenological categories on the Rombird Data Base (******) were taken into account. We also considered the phenological status of these species at the reference territory level – central Romania, Transylvania.

Why is it important to inventory and centralize bird species in these categories in general or in a reference area?

a. Some of these species are expanding their breeding areas or starting to nest in new territories. An example from our study area is the Mediterranean Gull (*Ichthyaetus melanocephalus*), which appeared mainly during migration, irregularly and with a small number of individuals, but which sporadically formed small breeding colonies;

b. Other species may change their migration routes or wintering areas, or may use new routes or new wintering areas;

c. Some of them are species of Community interest (Annex I of the Birds Directive) or of different threat categories, such as: SPEC, European Threat Status (Tucker and Evans, 1997) and their occurrence on a territory/habitat may require, updating the standard forms of Natura 2000 sites and then assessing the conservation status of those species;

d. At least for some of them, there is a few data at the level of the reference area (i.e., Bârsa Depression, Brașov County and/or the center of Romania in our case). Any of their reports, especially on long-term observations, with appropriate data on distribution, resting or foraging habitat, or quantitative data are of such interest not only locally but also regionally or nationally, mainly with regard to Romanian bird's distribution maps;

e. From a quantitative point of view, observations on significant groups for the central part of Romania are important in the future, as the studied locations may become stop-over points for an increasing number of individuals;

f. All these situations definitely have practical implications in the conservation of species, populations, and specific habitats for nesting, feeding, resting. Depending on these observations and their analysis, additional conservation measures may be proposed at any time under the management plan of Natura 2000 Sites (i.e., ROSPA0037 in our case), which is an adaptive working tool.

This research focused on relevant man-made wetlands of south-east of Transylvania: Dumbrăviţa (including Dumbrăvița Fishing Complex Ramsar Site) and Rotbav Natura 2000 Site, Special Protection Area (ROSPA0037 Dumbrăviţa-Rotbav-Măgura Codlei) where observations were made on waterbirds for 25 years (1994-2020).

MATERIAL AND METHODS

The inventory was carried out on two main man-made wetlands within Dumbrăviţa-Rotbav-Măgura Codlei Natura 2000 Site (N 45º43'10" and E25º24'38"). These are situated at the internal curvature of Carpathians, in the Olt River Basin, a territory in the central side of Romania, Transylvania Province, the intracarpathian region, delimited by the Eastern Carpathians, the Southern Carpathians and, to the west, by the Apuseni Mountains (Fig. 1). The total area of Transylvania has 57.000 km². The study area is a man-made wetland, one of the most important concentration sites for water birds within Transylvania (Fig. 2). The construction of these artificial wetlands began in the 1970s and continued successively so that after 1985 there were almost all of these man-made wetlands.

The most important habitats for bird's resting and foraging are: deep and shallow water, emergent vegetation, submerged vegetation, willow thick, mud flats, etc. Depending on Ramsar Site wetland types the main such habitats, are: permanent freshwater marshes (Tp), freshwater tree-dominated wetlands (Xf), aquaculture ponds, reservoirs and seasonal/ intermittent freshwater marshes (Ts) (**). Some of these habitats (i.e. large waterbodies, mudflats, large areas of emergent vegetation), created by human intervention and by aquaculture management, are completely new compared to the initial ones. Obviously, the trophic source has diversified, especially after the beginning of the fish farming activity (Ionescu et al., 2020).

These kinds of man-made wetlands are recognized as very important or even "key" sites for many vulnerable, rare or endangered bird species and because of that Dumbrăviţa and Rotbav were designated as Important Bird Area (Papp and Fântână, 2008). The Natura 2000 Site has an official management plan comprising several concrete measures for the long-term conservation and maintenance of bird species and populations, in balance with sustainable fish farming (*********).

Regular or incidentals observations were made on waterbirds species.

In general, we applied the point transect method (Ionescu, 1999; Ionescu, 2002; Ionescu et al., 2008). Different types of binoculars (10x50, 10x45, etc.), scopes (x 20-60) and a professional camera were used during observations.

Some of these data were collected through different monitoring scheme or programs, such as:

Midwinter Count (***);

Global Shorebird Counting which takes place in September (****);

Inventory and monitoring of bird species/populations within the Natura 2000 Site (ROSPA 0037) management plan;

Having regard to the entire observation/inventory period (1994 to 2020), all months and phenological periods (migration, breeding, and wintering) have been completed, but not with a regular observation pressure over the whole period;

The electronic databases were consulted – the online species lists (******, *******, ********). From these databases there were extracted for the studied area all the data related to the species from the targeted categories.

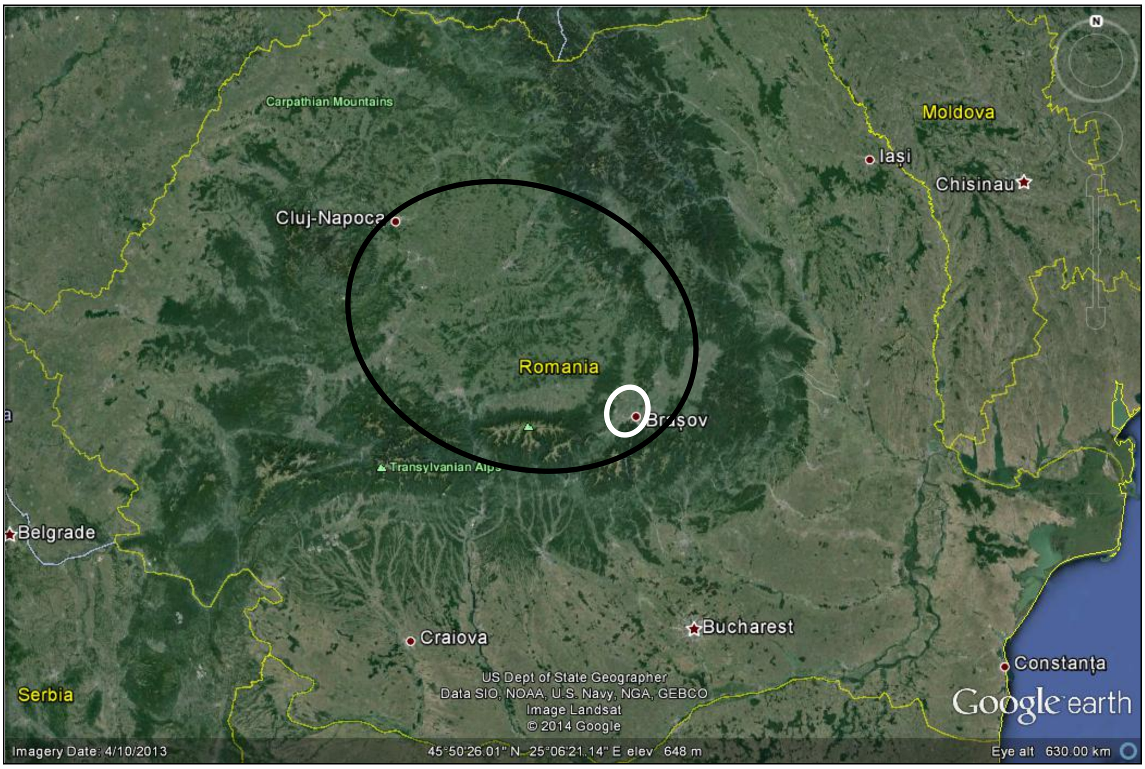

Figure 1: Study area - white are (Brașov Depression as part of Transylvania Province – black area, Romania)

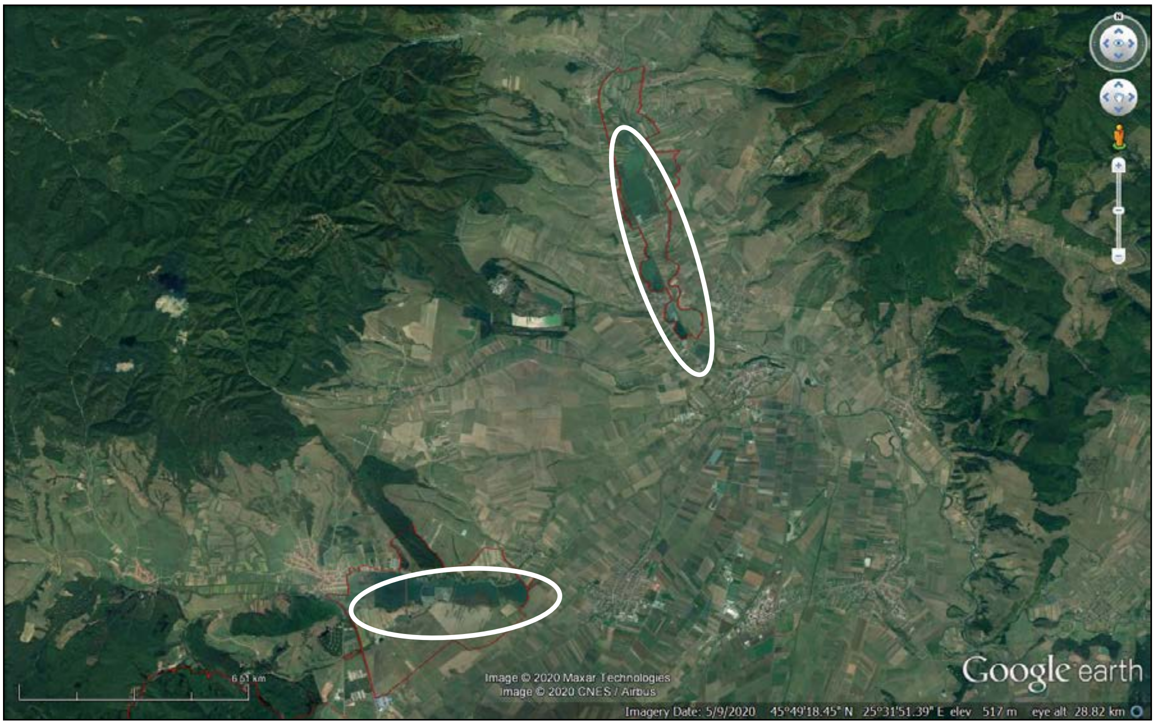

Figure 2: Study area – Dumbrăvița (bottom) and Rotbav wetlands (white areas) within ROSPA0037 (red border).

RESULTS AND DISCUSSION

During the considered period, 44 species of waterbirds (Figs. 1-8) from the discussed categories were identified (Tab. 1).

Table 1: Synthesis of our observations and those from the online database ((******, *******, ********) within the study area (1994-2020).

Species, location, habitat type	Years with months of observation	No. of ind. (min, max)	– Comments and comparisons on the status of the species in Transylvania (based on Salmen, 1980; Klemm and Kohl, 1988, online databases) and other relevant references.
Podiceps auritus[*2] D/W	2016 – 11 2017 – 03 2019 – 11	1-2	– Considered a rare or irregular migratory species (Salmen, 1980; Klemm and Kohl, 1988), quoting some observations from Transylvania.
Pelecanus onocrotalus[*3] D, R/W, M	1994 – 04 1997 – 06 2000 – 10, 11, 12 2016 – 09 2018 – 06	1-2	– Considered migratory (Salmen, 1980) and rare or irregular migratory (Klemm and Kohl, 1988), with several historical observations from Transylvania. Some data have flocks of several dozen individuals. – in Rombird database, there are only three data locations in Transylvania, in Openbirdmaps 2, and in Ornitodata, none.
Pelecanus crispus[*3] D/W	25.07.2014	1	– Salmen (1980) quotes some historical observations from Transylvanian. According to Klemm and Kohl (1988) there are no new known data. – in Rombird and Openbirdmaps databases, there is only one location from Transylvania (Cipău fishponds, Mureș County) besides the one in our study area and in Ornitodata, none.
Bubulcus ibis[*3] D/P, S	2013 – 06 2017 – 04, 05, 06, 08	1-3	– Salmen (1980); Klemm and Kohl (1988) do not present any observations of the species in Transylvania. – our observation in 2013 was the first report from the center of Romania. – in both years, most observations were within a mixed colony of herons and cormorants. No definite manifestations of reproduction were observed, but we do not exclude a further breeding in the study area. – from the three online lists of observations, there is another report from Transylvania (Sânpaul, Mureș County) – Rombird.

Piegadis falcinellus[*3] D, R/SW, C, M, S	1996 – 04, 05 1999 – 05 2002 – 04, 05 2005 – 05 2007 – 04 2015 – 04 2017 – 05, 08 2019 – 04 2020 – 05, 06	1-6	– considered a migratory species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988); – on the three on-line database, there are few observations of the species in the center of the country; – six individuals were observed during May-June 2020 perched for a while in the *Salix* scrubs within the mixed heronry (Dumbrăvița).
Platalea leucorodia[*3] D, R/M, SW	2002 – 12 2007 – 05 2009 – 05 2011 – 05 2012 – 06 2016 – 06 2019 – 05, 06 2020 – 05	1-3	– considered a migratory species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988); – on the three on-line database, there are few observations of the species in the center of the country; – for a migratory species a special observation date is 4.12.2002.
Cygnus cygnus[*4] D, R/W, I	1994 – 02, 2005 – 11, 2006 – 03, 2012 – 11, 2014 – 02, 03, 04, 05, 12, 2015 – 01, 12, 2016 – 01, 11, 2017 – 03	1-13	– considered a migratory species or wintering for Transylvania (Salmen, 1980; Klemm and Kohl, 1988; – 13 individuals represent one of the largest identified groups of the species in the center of the country.
Cygnus columbianus[*3] D/W	2011 – 11, 2014 – 03, 11, 2016 – 11, 2019 – 11	1-8	– Salmen (1980), Klemm and Kohl, (1988) do not present any observations of the species in Transylvania; – our 2011 observation is the second from Transylvania, and one of the few within central Romania; – eight individuals in group represents the largest registered number of the species in central Romania (Transylvania), according to online database.
Branta ruficollis[*3] D, R/W, M, A	2004 – 11, 2007 – 03, 2009 – 11, 12, 2011 – 11, 2012 – 10, 11, 12, 2013 – 11, 2014 – 10, 11, 2016 – 10, 11, 2017 – 11, 12, 2018 – 02	1-28	– considered a rare or irregular migratory species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988); – 28 individuals is the largest observed number in Transylvania, according to online databases.
Branta leucopsis[*1] D/W, M, A, I	2010 – 10, 11, 2015 – 11, 12, 2016 – 01	1-2	– Salmen (1980), Klemm and Kohl (1988) do not present any observations of the species in Transylvania; – our observation from 2010 was the first record from Transylvania.
Branta canadensis[*1] D/W	22.05.2018	1	– Salmen (1980), Klemm and Kohl, (1988) do not present any observations of the species in Transylvania; – our observation was the first record of this allien specie from Transylvania.

Anser fabalis[*3] D/W, M, A	1995 – 10 1996 – 10 2009 – 11 2017 – 10, 11 2019 – 11, 12	1-5	– considered a migratory species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988); - for the center of the country is a rare species of goose, with a small number of identifications and locations (online database).
Tadorna ferruginea[*3] D/W, M	2018 – 05 2020 – 03, 04	1	– considered a rare or irregular migratory species for Transylvania; – (Salmen, 1980). According to Klemm and Kohl (1988) there are no new known data.
Netta rufina[*4] D, R/W	1995 – 04, 1999 – 05, 2001 – 08, 2004 – 05, 2005 – 09, 2011 – 04, 2014 – 03, 2016 – 03, 04, 05, 06, 12, 2017 – 04, 2018 – 03, 2019 – 03	1-6	– considered a rare or irregular migratory species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988).
Aythya marila[*4] D, R/W	1994 – 11, 1995 – 10, 1996 – 11, 2004 – 11, 2013 – 04, 2016 – 11, 2017 – 11	1-3	– considered a migratory species or wintering for Transylvania (Salmen, 1980) and a rare or irregular migratory species (Klemm and Kohl, 1988).
Clangula hyemalis[*1] D/W	1.11.2003	1	– considered a rare or irregular migratory species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988); – for the center of the country is a rare species of duck, with few observations and locations (online database).
Melanitta nigra[*1] D/W	11.12.2019	1	– considered a rare or irregular migratory species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988); – for the center of the country is a rare species of duck, with few observations and locations (online database); – the first observation of the species in the study area belongs to Ilie C. Rombird database)
Melanitta fusca[*2] D/W		2-5	– considered a rare, irregular migratory or wintering species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988); – for the center of the country is a rare species of duck, with few observations and locations (online database); – the maximum identified number represents one of the largest groups of the species in the center of the country (online database).

Grus grus[*3] D (there are also a few data of one-two individuals from Rotbav fishfarm made by field staff) /A, M, SW	2001 – 03, 2002 – 12, 2004 – 10, 2007 – 10, 11, 2009 – 05, 2012 – 10, 2014 – 06, 12, 2017 – 03, 04, 05, 2018 – 03, 04, 09, 2019 – 04, 05, 06, 08, 10, 11, 2020 – 04, 05, 06, 08	1-10	– considered migratory (Salmen 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl 1988); – it is important their constant presence throughout most of the breeding season, starting with 2017. There is a possibility of breeding a pair until now or in the future. The observations from December are also interesting.
Vanellus leucurus[*3] R/SW	23.04.2000	2	– our observation was the first record of this specie from Transylvania and the second until now (Salmen, 1980; Klemm and Kohl, 1988; online database).
Haematopus ostralegus[*4] D, R/M	1996 – 08, 2008 – 05, 2010 – 03, 2016 – 08, 2017 – 09, 2020 – 03	1-3	– considered a rare or irregular migratory species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988).
Recurvirostra avoseta[*4] D, R/M, SW	1996 – 06, 2001 – 04, 2005 – 04, 05, 2007 – 04, 2008 – 04, 05, 07, 2009 – 03, 05, 2012 – 06, 2014 – 09, 2015 – 03, 04, 2016 – 03, 04, 2017 – 03, 04, 05, 2018 – 04, 2019 – 09, 2020 – 04, 07	1-11	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988).
Pluvialis apricaria[*4] D/M	2001 – 10, 2006 – 09, 10, 2007 – 03, 2013 – 03, 2018 – 10	1-2	– considered migratory or wintering species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988).
Calidris temminckii D, R/M	1995 – 09, 2005 – 09, 2007 – 07, 2009 – 04, 08, 2010 – 08, 2014 – 08,09, 2015 – 08, 2016 – 08, 09, 2017 – 04, 2018 – 09, 2019 – 07, 2020 – 07	1-8	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988); – the maximum identified number represents one of the largest groups of the species in the center of the country (online database).

*Calidris alba**4 D/M, CS	1997 – 09, 2003 – 09, 2008 – 09, 2009 – 08, 09, 2010 – 09, 2013 – 09, 2016 – 08, 09, 2017 – 09, 2018 – 09	1-4	- considered with the sign ? (Salmen, 1980) or rare or irregular migratory for Transylvania (Klemm and Kohl, 1988).
*Calidris canutus**1 D/M	10.09.2018	1	– considered with the sign ? (Salmen, 1980) or rare or irregular migratory for Transylvania (Klemm and Kohl, 1988); – there are a few observations and locations in Transylvania (online database).
*Calidris falcinellus**1 D, R/M	1995 – 09, 2009 – 08, 09, 2013 – 08, 09, 2016 – 08, 09, 2019 – 09	1-4	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988).
Lymnocryptes minimus D/MS	21.04.2004	1	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988).
*Limosa lapponica**2 D, R/M, SW	2007 – 09, 10, 2013 – 09	1	– considered a rare or irregular migratory species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988); – there are a few locations of observation in Transylvania (online database).
*Numenius phaeopus**3 D/M, CS	2009 – 04, 2018 – 04, 2019 – 07, 2020 – 04	1-2	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988); – there are a few locations of observation in Transylvania (online database).
Tringa stagnatilis D, R/M, CS	1996 – 04, 2001 – 04, 2007 – 04, 2008 – 04, 09, 2009 – 04, 2013 – 09, 2017 – 04, 2018 – 04.	1-5	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988).
*Arenaria interpres**4 D, R/M	1995 – 08, 09, 1996 – 09, 1997 – 09, 2003 – 09, 2004 – 09, 2008 – 05, 2013 – 09, 2016 – 08, 09.	1-8	– considered a rare or irregular migratory species for Transylvania (Salmen, 1980; Klemm and Kohl, 1988).
*Phalaropus lobatus**4	1996 – 09, 1997 – 08, 09, 2005 – 09, 2006 – 08, 2013 – 09, 2014 – 09, 2015 – 08, 2020 – 08	1-17	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988); – the maximum number is the largest observed in Transylvania (online database).

*Glareola pratincola**[3] D/M	2008 – 05, 2015 – 10	1	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988).
*Stercorarius parasiticus**[3] D/M	1995 – 09, 2014 – 09, 2015 – 08	1-5	– considere migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988); – there are a few locations of observation in Transylvania (online database); – the maximum number is the largest observed in Transylvania (online database).
*Ichthyaetus melanocephalus**[4] D, R/M, W	1996 – 05, 06, 1998 – 04, 06, 2007 – 05, 2008 – 05, 2009 – 04, 05, 2010 – 10, 2011 – 05, 2013 – 05, 06, 07, 2014 – 03, 04, 2016 – 08, 02 2018 – 04, 2019 – 04, 2020 – 03, 05, 06, 07	1-20	– considered rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988), the species does not appear in Salmen's monograph (1980); – the maximum identified number represents one of the largest groups of the species in Transylvania (online database); – in addition to the individuals that migrate through the study area, it bred in two years at Rotbav (2013, 2020), this being the second or the third breeding place (Ionescu et al., 2015; Keller et al., 2020) of the species in Romania and for the first time in the center of the country (Ionescu et al., 2015); - thus, for 2013, 3-12% of the national population bred at Rotbav (*, 2015). For 2020, 2.5-20% of the national population bred at Rotbav (**********); – therefore, its presence here is very important not only for the area, but also at national level, and a stable microcolony can be formed in the future, if the habitat conditions allow.
*Chroicocephalus genei**[3] D/M	06.03.2017	1	- Salmen (1980), Klemm and Kohl (1988) do not present any observations of the species in Transylvania; – this is the 3rd observation of the species in Transylvania, until now (online database).
*Larus fuscus**[4] D/M, W	1996 – 09, 2002 – 09, 10, 2003 – 11, 2005 – 05, 2006 – 09, 2008 – 04, 2013 – 10, 2014 – 09, 2015 – 07, 09, 10, 2016 – 10; 2017 - 04, 05, 2019 - 04, 10, 11	1-120	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988); - the maximum number recorded by us (over 120 individuals on 28.09.2015) is the largest number of the species for central Romania (record for Transylvania) and one of the largest in Romania (Salmen, 1980; Munteanu, 1982; Klemm and Kohl, 1988; online database).

Larus glaucoides[*1] D/W, I	13.01.2016	1	– our observation (13.01.2016) is the first definite proof of the species for Romania and the only one until August 2020 (Salmen, 1980; Klemm and Kohl, 1988; online database).
*Larus ichtyaetus**[3] D/W	15.10. 2019	1	– Salmen (1980), Klemm and Kohl (1988) do not present any observations of the species in Transylvania; – there are a few locations of observation in Transylvania (online database); – the first observation of the species in the study area belongs to Pál L. (Rombird database).
*Hydroprogne caspia**[4] D, R/W	1996 – 04, 09, 2007 – 04, 2008 – 09, 2009 – 08, 2014 – 04, 2015 – 08, 2016 – 08, 2 018 – 04, 05, 2019 – 07	1-3	– considered rare or irregular migratory species for Transylvania (Salmen, 1908; Klemm and Kohl, 1988).
*Gelochelidon nilotica**[3] D/W	2004 – 07, 2007 – 07, 2008 – 06, 2020 – 06	1-3	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988).
*Sterna sandvicensis**[3] D/R	06.06.2019	1	– Salmen (1980), Klemm and Kohl (1988) do not present any observations of the species in Transylvania; – this is a rare tern species in the central of Romania with a few locations of observation in Transylvania (online database).
*Sternula albifrons**[3] D/W, M	2005 – 06, 2008 – 07, 2012 – 06, 2014 – 06, 2016 – 06, 08	1-3	– considered migratory (Salmen, 1980) or a rare or irregular migratory species for Transylvania (Klemm and Kohl, 1988); – this is a rare tern species in the central of Romania with a few locations of observation in Transylvania (online database).

D – Dumbrăvița area; R - Rotbav area; 01, 02….12 – the months of observations.
* – species of Community interest (annex I of the Birds Directive).
** – in the table we mentioned the author of the first identification if this did not belong to us.
Habitat types:
W – water body of lakes, reservoirs or fishponds; SW – shallow water; M – mudflat; MS – marsh; R – reedbed or other types of emergent vegetation; C – canals; CS – concrete shore; P – pasture; A – arable land, crops; S – willow scrubs; I – ice on water body.

Classification of the status of species according to the online platform for ornithological observations (******):

[1] – very rare or rare species at national level (accidental or regularly occurring species in very small numbers annually). They usually have a few dozen or up to a hundred observations in Romania;

[2] – rare species at national level (species with regular annual occurrence, usually occurring in small numbers, species that appear in the form of invasion or that appear only in a few restricted areas, very localized in the country);

[3] – very rare or accidental species regionally. These species may be common in other geographical areas (i.e. white pelican in Dobrogea or Bărăgan – south of Romania), but accidental in others, such as Transylvania;

[4] – rare or sporadic species at regional level (species with annual or near-annual occurrence and in relatively small numbers).

After the period we considered, new species were identified for the area: *Stercorarius pomarinus* (Rotbav, 18.10.2020, observed by Daroczi Sz., ******), *Anser erythropus* (Dumbrăvița, 10.11. 2020, observed by Ilie C., ******).

Most species belong to the systematic groups of: waders (15 species), swans, geese, and ducks (12 species), skuas, gulls, and terns (10 species).

Figure 1: *Pelecanus onocrotalus* (Ionescu, 12.09.2016, Dumbrăvița).

Figure 2: *Bubulcus ibis* (Ionescu, 29.04.2017, Dumbrăvița).

Figure 3: *Gygnus columbianus* (Ciungara, 24.11.2011, Dumbrăvița).

Figure 4: *Melanitta nigra* (Fuciu, 13.11.2019, Dumbrăvița).

Figure 5: *Grus grus* (Ionescu, 30.03.2017, Dumbrăvița).

Figure 6: *Limosa lapponica* (Ionescu, 30.09.2007, Dumbrăvița).

Figure 7: *Calidris canutus* (Ionescu, 12.09.2018, Dumbrăvița).

Figure 8: *Larus glaucoides* (Ionescu, 13.01.2016, Dumbrăvița).

There is a variation in the total number of species or in different systematic groups, by months, seasons and main phenological periods. The months with the highest total number of species were April and September (17 species), followed by May and August (14 species). Swans, geese and ducks have the highest number of species in autumn and early winter, due to the appearance of northern species. The highest number of waders species was recorded in the months of migration: September, August and April. Concerning the distribution of the total number of species records by seasons, autumn and spring have the highest number (44 and 40 records, respectively). Distribution of the number of species records by main phenological periods is also variable, both in the total number of species and in main systematic groups (Tab. 2).

Table 2: Distribution of the number of species records (the most important systematic orders) by main phenological periods.

No. of species records	Spring migration (months: 03, 04, 05)	Autumn migration (months: 08-11)	Wintering (months: 01, 02, 12)
Swans, geese, ducks	12	15	12
Waders	13	20	–
Skuas, gulls, terns	9	10	1

As expected in the two migration periods, the highest number of species was identified.

In terms of feeding and resting habitat, most species were attracted to mudflat (26 species) and water body (21 species). Through the integrated management of the Natura 2000 Site at any time of the year there are filled lakes or fishponds, and during the autumn migration (August-November) mudflat habitats and possibly with shallow water. The management plan of ROSPA0037 provides that during the autumn migration the fishponds will be drained (this is the usual fish harvesting time and method) so that the birds benefit from the mudflat and shallow water habitats. Practically all the species discussed currently benefit from improved habitat and food conditions or completely new ones compared to those before human interventions in the years 1970-1980.

From a quantitative point of view, the number of species by categories of maximum numbers shows that most species fall into the category 1-5 individuals (73%). Only one species had a maximum number of over 101 individuals (table 3).

From a quantitative point of view, the number of species by categories of maximum numbers shows that most species fall into the category 1-5 individuals (73%). Only one species had a maximum number of over 101 individuals (table 3).

Table 3: Distribution of the number of species by categories of maximum number of individuals.

No. of species	Categories of maximum number of individuals				
	1-5	6-10	11-20	21-100	> 101
Total nomber of species	32	6	4	1	1
Swans, geese, ducks	8	2	–	1	–
Waders	11	2	2	–	–
Skuas, gulls, terns	8	–	1	–	1

As we pointed out, species from rare or irregular migratory categories can also be of conservative interest. Of the 44 species considered, half (22 species) are of Community interest (included in Annex I of the Birds Directive). In this regard, all data on species of Community interest, concerning presence, numbers, habitats, etc. they are of priority and can scientifically support various further management decisions.

CONCLUSIONS

Data on rare or irregular migratory bird species are important as part of local avifauna inventory, but sometimes also at regional or national level. All these species are attracted by various habitat and food conditions, especialy within man-made wetlands such as fish farms as part of Natura 2000 Sites (SPAs) where integrated management is applied. In this sense, fish farms are feeding areas and stop-over areas of prime importance for birds that require continuity of fisheries management, including the drainage of ponds in autumn or spring.

The inventory of local avifauna will continue and focus on species of community interest for the further management measures especially if their frequency or number of individuals will increase, or if they change their phenological status (i.e. they become breeding species, regular wintering or passage species, etc.).

The creation of databases on avifauna, which also includes rare or irregularly migratory species and their publication are desirable for all wetlands in Romania, with an emphais on man-made ones. It would also be necessary a general and comparative study of biodiversity/avifauna within man-made wetlands (reserviors, artificial lakes, and fishponds) in Romania and possibly the publication of a monograph in this regard.

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