POPULATION DYNAMICS OF FISH FROM THE DANUBE RIVER IN THE SECTOR KM 1047 - 1071: ESTIMATION OF GROWTH AND MORTALITY PARAMETERS

M.D. Stroe[1*], M. Crețu[1,2*], A. Dobre[1,2], D. Mirea[1], G. Ion[1], M.F. Dima[1]

[1]Research and Development Institute for Aquatic Ecology, Fishing and Aquaculture, Galați, Romania
[2]"Dunărea de Jos" University of Galați, Faculty of Food Science and Engineering, Center for Modelling Recirculating Aquaculture, Galați, Romania

Abstract

As the human population continues to grow, the demand for food resources rises, consequently exerting greater pressure on aquatic ecosystems. Given the scarcity of suitable information for stock assessments, the growth and mortality of certain commercial fish species from the Danube River were estimated based on length-frequency data. In this context, growth and mortality parameters were determined for the following species: common carp (Cyprinus carpio), pike perch (Sander lucioperca), crucian carp (Carassius gibelio), common bream (Abramis brama), and European catfish (Silurus glanis). Fish were captured in the Danube sector between kilometers 1047 and 1071, situated between two hydrological stations: Baziaș and Moldova Veche, during the period from January 2021 to August 2023. The results of our research indicate overexploitation of pike perch (E=0.64), crucian carp (E=0.71), common bream (E=0.64), and European catfish (E=0.55). Our study highlights the importance of maintaining balance within the fish community of the Danube and the need to develop effective strategies for the conservation and management of fishery resources.

Key words: *population dynamic; fish stock, age and growth, mortality*

INTRODUCTION

The Danube River, one of Europe's largest and most significant rivers, hosts an impressive diversity of fish species that have played a significant role in the history and culture of the regions through which it flows. Its course begins at the confluence of the Breg and Brigach rivers in the Black Forest Mountains, Germany, and covers 2826 kilometers before flowing into the Black Sea. The Danube is the second-largest river in Europe and represents a major navigational artery (Figure 1).

Over a length of 1,075 kilometers, or approximately one-third of its total length, the Danube passes through Romania, which holds the longest stretch of the river. Initially, it forms the border with Serbia and Bulgaria, then, in the region between Bărăgan and Dobrogea, goes around the Dobrogea Plateau to the north before flowing into the Black Sea, marking the border with Ukraine.

The Danube is the richest among all the hydrographic basins in Europe. Most of the common freshwater fish species in Europe are present in the Danube, with 115 native species [1], along with species that are not found in Western Europe, as well as endemic species from the Danube basin. We find fish species such as: carp (*Cyprinus carpio*), tench (*Tinca tinca*), crucian carp (*Carassius carassius*), barbel (*Barbus barbus*), European catfish (*Silurus glanis*), white bream (*Blicca bjoerkna*), white eye bream (*Ballerus sapa*), common bream (*Abramis brama*), asp (*Aspius aspius*), ide (*Leuciscus idus*), vimba (*Vimba vimba*), roach (*Rutilus rutilus*), European chub (*Squalius cephalus*), rud, (Scardinius

* Corresponding author: sdesimira.icdeapa@gmail.com; cretumirela.icdeapa@gmail.com
The manuscript was received: 03.10.2023
Accepted for publication: 14.03.2024

erythrophthalmus), Eurasian minnow (Phoxinus phoxinus), belica (*Leucaspius delineates*), the common nase (*Chondrostoma nasus*), pike (Esox lucius), pike perch (*Sander lucioperca*), and six sturgeon species, sterlet (*Acipenser ruthenus*), beluga sturgeon (*Huso huso*), stellate sturgeon (*Acipenser stellatus*), Russian sturgeon (*Acipenser gueldenstaedtii*), European, sturgeon (*Acipenser sturio*), Fringebarbel sturgeon (*Acipenser nudiventris*).

Figure 1: The Danube River Basin (Sursa: www.wikipedia.org)

Human activities, such as mining, dam construction, nutrient pollution, construction of river dams, and some recreational activities, have had a significant negative impact on water quality, ichthyofauna, and the surrounding environment. These influences can affect aquatic organism communities and may lead to a reduction of species diversity and even their disappearance [2]. Furthermore, the fish species are dependent on environmental parameters [3].

The objective of this study was to provide information regarding the growth parameters and mortality rates of some fish with higher commercial value, based on length-frequency data analyses, to inform stock assessment and improve fisheries management. The findings of this study can be used for the development of effective strategies for the conservation and management of fish stocks from the Danube, taking into consideration their significance for the environment and the human communities, which are dependent on this vital river ecosystem.

MATERIAL AND METHOD

Data Collection. Data collection was carried out by fishermen and researchers from the Research and Development Institute for Aquatic Ecology, Fishing and Aquaculture, Galați in the period January 2021-August 2023. Fish were caught on the Danube sector between km 1047 and 1071, between two hydrological stations: Baziaș and Moldova Veche.

The fishing was done with gears, fixed nets, and floating nets. The dimensions of the fishing gear, were as follows: For fixed nets, the set length (Lp) ranges from 100 to 200 meters, the standing height (Hp) varies between 2.5 and 3.5 meters, and the eye side (a) measures from 40 to 60 millimeters. In the case of floating nets, the set length (Lp) is in the range of 150 to 200 meters, the standing height (Hp) can be between 2.5 to 4.0 meters, while the eye side (a) varies from 40 to 80 millimeters.

Growth Parameters. During the mentioned period, 1062 specimens of common carp (*Cyprinus carpio*), 1093 common bream (*Abramis brama*), 1361 specimens of crucian carp (*Carassius carassius*), 164 pike perch (*Sander lucioperca*), 454 European catfish (*Silurus glanis*), 7 pikes (*Esox lucius*), 14 silver carps (*Hypophthalmichthys molitrix*), and 15 bighead carp (*Hypophthalmichthys nobilis*) were captured. All the fish were measured with an ichyometer (with a precision of ±0.01 cm) for total length (cm), standard length (cm), and height (cm). Individual weight was recorded with the help of a scale (±0.0g).

One of the main objectives of this work is to underline the relationships established between different species within the ecosystem to identify the species with the highest proportion in the ecosystem. For this purpose, the following indicators were calculated:

Growth parameters were estimated using length-frequency analyses using the ELEFAN model from FISAT II. All fish were grouped in 3 cm length class intervals. As the length data were not separated for males and females, growth parameters were estimated for pooled sexes. The asymptotic length ($L\infty$; cm) and the growth coefficient (k; year $^{-1}$) were calculated. The asymptotic length represents the maximum length at which a fish can reach in its natural habitat. Different values of $L\infty$ for the studied species indicate specific adaptations to the Danube's habitat and conditions. For example, species with higher $L\infty$ values may have slower growth but can eventually reach larger sizes.

The "k" coefficient reflects the population growth rate and how it changes as individuals grow. Species with a high value of "k" may experience rapid growth in their youth, while species with low values may have more consistent growth throughout their lives. Variability in "k" values can influence the diversity and population dynamics in the Danube.

Mortality rates. The total mortality rate (Z; year^{-1}) was estimated based on the linearized length–converted catch curve with the help of FISAT II. The total mortality (Z) is divided into two types: the natural mortality (M; year^{-1}), which was calculated using Pauly's empirical formula [4], and the fishing mortality (F; year^{-1}), which was calculated using the relationship: F=Z-M [5].

Knowing natural mortality is essential for estimating the reproductive potential of a species. The value of M reflects natural mortality in a natural environment, without anthropogenic influences such as fishing or pollution. The analysis of fishing mortality allows us to assess the impact of fishing activities on the studied species. If fishing mortality is significant, it can have negative consequences on the sustainability of fishery resources.

The exploitation rate of fish. The exploitation level (E) was obtained using the relationship: E=F/Z This index reflects the degree of exploitation of a species through fishing. High values of the exploitation index (E>0.5) indicate increased pressure on fishery resources and may require management measures to prevent stock depletion.

In addition to growth parameters, considering the total values of the catches made, the abundance index, Shannon-Wiener diversity index, and Simpson index were calculated and analyzed. Species abundance is a particularly important criterion in prioritizing species of conservation interest [6].

It can be calculated using the formula: Ar = (N/n) × 100, where:

- "n" represents the number of individuals of a specific species,
- "N" represents the total number of individuals in the ecosystem.

These data can then be divided into abundance classes to provide a more detailed perspective on the distribution of species within the community.

The Shannon Equitability Index, considers the abundance of species in the natural environment, as shown in the equation below [7]. It was calculated based on species abundance using the following formula: H' = -[ΣPI In PI] where, H' = Diversity Index, PI = The proportion of the species relative to the total number of species; ln PI = Natural logarithm of this proportion. A higher value of the diversity index indicates variability in species types and heterogeneity in the community, while lower values indicate homogeneity in the community. However, the presence of an individual of a species was not necessarily indicative that the species was present in a large number [8].

To understand this, we used the Simpson index formula, which is calculated as follows: Simpson Index = 1 - (Σ(pi)^2). In this formula, "pi" represents the proportion of each species within the community. The Simpson index will be lower as the number of species present and their proportions are more balanced.

Data analysis. All the obtained data were statistically processed using Microsoft 365 Excel and FISAT II software programs.

RESULTS AND DISCUSSION

In table 1 are presented the values of the minimum and maximum total length and the growth parameters of the caught fish populations.

Table 1 Parameters of the von Bertalanffy growth equation for the captured fish population

Species	Number of fish	Lt min (cm)	Lt max (cm)	L∞	K	M	Z	F	E
Common carp (*Cyprinus carpio*)	588	30	91	97.65	0.28	0.41	0.71	0.31	0.43
Pike perch (*Sander lucioperca*)	93	28	46	48.3	0.8	0.98	2.69	1.71	0.64
Crucian carp (*Carassius gibelio*)	549	28	43	45.15	0.63	0.85	2.96	2.11	0.71
Common bream (*Abramis brama*)	290	28	42	45.15	0.63	0.91	2.51	1.6	0.64
European catfish (*Silurus glanis*)	286	54	93	97.65	0.31	0.43	0.97	0.54	0.55

Note: L∞ - asymptotic length (cm); k - growth rate coefficient of Von Bertalanffy; Z - total mortality ($year^{-1}$); M - natural mortality ($year^{-1}$); F - fishing mortality ($year^{-1}$); E -exploitation rate.

For the common carp (*Cyprinus carpio*) the L∞ and k were estimated at 97.65 cm and a relatively low growth coefficient (K) of 0.28. Natural mortality (M) was 0.41 $year^{-1}$ and total mortality (Z) at 0.71 $year^{-1}$. These data indicate that the carp population in the Danube River has a relatively good survival rate. Fishing mortality (F) was 0.31, and the calculated exploitation rate (E) was 0.43. These values suggest that fishing has a moderate impact on the Danube carp population and that it is managed in a relatively sustainable manner (Figure 2).

For the pike perch (*Sander lucioperca*) the asymptotic length (L∞) was approximately 48.3 cm, while the growth coefficient (K) registered a value of 0.8, aspect which indicate a relatively rapid growth. However, natural mortality (M) is 0.98, and total mortality (Z) is 2.69, suggesting that the species' survival rate may be affected by various factors, including fishing. Fishing mortality (F) is 1.71, and the exploitation rate (E) is 0.64. These values indicate that fishing can have a significant impact on the Danube pike perch population and careful management is necessary to maintain fish stocks (Figure 3).

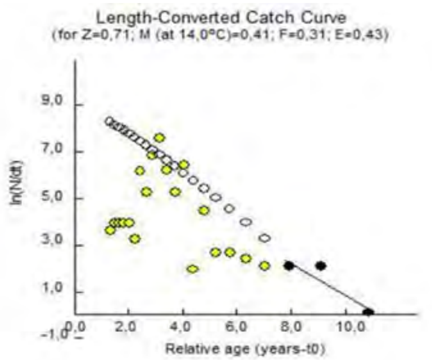

Figure 2. The length converted catch curve of common carp (*Cyprinus carpio*)

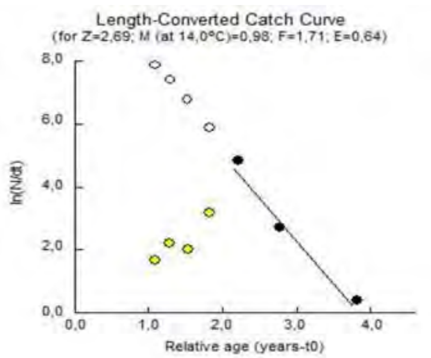

Figure 3. The length converted catch curve of pike perch (*Sander lucioperca*)

The crucian carp (*Carassius gibelio*) has a maximum length of individuals (L∞) of approximately 45.15 cm and a growth coefficient (K) of 0.63.

The natural mortality (M) for crucian carp is 0.85 year^{-1}, and the total mortality (Z) is 2.96 year^{-1}, suggesting a moderate survival rate for the species. Fishing mortality (F) is 2.11 year^{-1}, and the exploitation rate (E) is 0.71.

These values indicate that fishing can have a significant impact on the Danube crucian carp population, and its management should be closely monitored to avoid the depletion of fish resources (Figure 4).

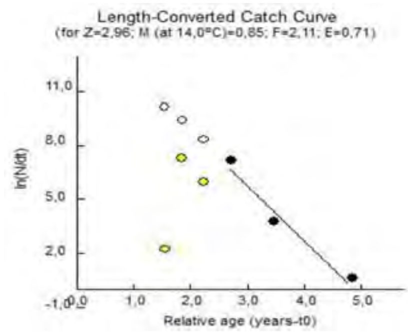

Figure 4. The length converted catch curve of crucian carp (*Carassius gibelio*)

The common bream (*Abramis brama*) has an asymptotic (L∞) of approximately 45.15 cm and a growth coefficient (K) of 0.63, indicating relatively rapid growth (Figure 5).

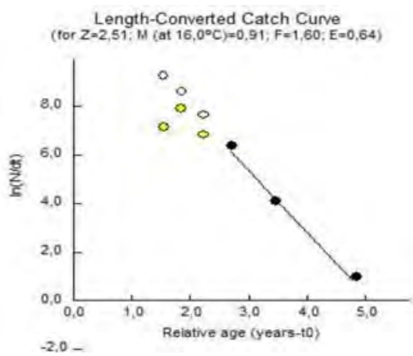

Figure 5. The length converted catch curve of common bream (*Abramis brama*)

However, the natural mortality (M) for bream is 0.91 year^{-1}, and the total mortality (Z) is 2.51 year^{-1}, suggesting a moderate survival rate for the species. Fishing mortality (F) is 1.6 year^{-1}, and the exploitation rate (E) is 0.64. These values indicate that fishing can have a significant impact on the Danube bream population, and its management should be closely monitored to avoid the depletion of fish resources.

The European catfish (*Silurus glanis*) has a maximum length of individuals (L∞) of approximately 97.65 cm and a relatively low growth coefficient (K) of 0.31. The natural mortality (M) for catfish is 0.43 year^{-1}, and the total mortality (Z) is 0.97 year^{-1}. Fishing mortality (F) is 0.54 year^{-1}, and the exploitation rate (E) is 0.55 (Figure 6). These values indicate that fishing has a moderate impact on the Danube catfish population and that it is managed in a relatively sustainable manner.

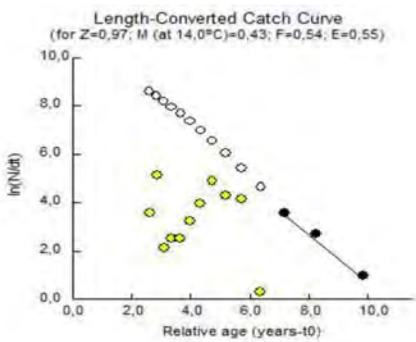

Figure 6. The length converted catch curve of the European catfish *(Silurus glanis)*

Our study indicates that the fish species in the Danube River exhibit variable growth and mortality parameters, which can influence their dynamics and survival in the river environment. It is important to consider these variations in the development of management and conservation strategies for fish resources. Species with higher growth coefficients, such as pike perch, may have a greater capacity to adapt to changes in the surrounding environment. However, species with higher total mortality (Z) may be more vulnerable to environmental pressures, including fishing. Fishing mortality (F) and the exploitation rate (E) indicate that fishing can have a significant impact on some species in the Danube, such as crucian carp and bream. Therefore, fisheries management should take these effects into account to ensure the sustainable use of fish resources.

In conclusion, our data provide a detailed image of the situation of fish species in the Danube River and highlight the need for effective management and conservation strategies to protect these valuable resources and maintain balance in the river ecosystem.

Table 2 presents the abundance indices of fish species fishing during the period January 2021-August 2023. We observe that over time, fish catches have consistently declined, regardless of the species type (peaceful or predatory). However, the overall structure of catches has remained relatively constant over the years, with peaceful species clearly dominating.

Table 2. Abundance Indices of Species

Capture	2021	2022	2023	TOTAL	Abundance (%)	Class of abundance
Common carp (*Cyprinus carpio*)	530	310	222	1062	25,46	1
Crucian carp (*Carassius gibelio*)	897	271	193	1361	32,64	2
Common bream *(Abramis brama)*	896	161	36	1093	26,21	1
European catfish (*Silurus glanis*)	197	161	96	454	10,89	1
Pike perch (*Sander lucioperca*)	115	43	6	164	3,93	0
Pike (*Esox lucius*)	7	0	0	7	0,17	0
Silver carp (*Hypophthalmichthys molitrix*)	14	0	0	14	0,34	0
Bighead carp (*Hypophthalmichthys nobilis*)	15	0	0	15	0,36	0
TOTAL	**2671**	**946**	**553**	**4170**	**100,00**	

The species structure is presented in Figure 7. Regarding the composition of fish communities, the *Cyprinidae* family has a predominant presence. This is represented in our catches by the species Carp, Crucian Carp, and Bream, which together account for a significant proportion of the total catches. Specifically, the common carp represents 32.64% of the total catches, the crucian carp represents 26.21%, and the common bream represents 25.46% (Figure 3).

These data suggest that the *Cyprinidae* family has a significant influence on the fish communities of the analyzed ecosystem and may play an important role in the studies and conservation strategies for these fish species.

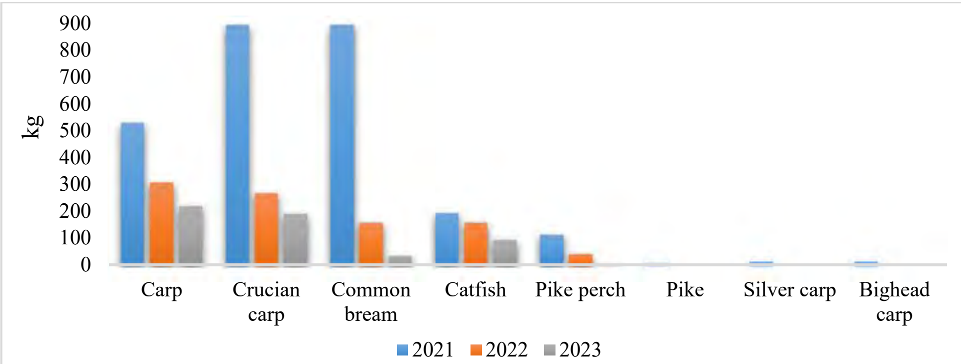

Figure 7. The species distribution of catches during the period 2021 – 2023

Considering that there are species resilient to hydroclimatic variations, characterized by their ability to produce many offspring, contributing to maintaining of healthy populations and increasing availability within the catches, the high proportion of these species is understandable.

The proportion of predatory species is lower during the analyzed period, with the *Siluridae* family - catfish, accounting for 10.89%, and the *Percidae* family – pike perch, at 3.93% (Figure 8).

These proportions can be explained using the Shannon equitability index, which provides a more accurate picture of ecosystem diversity (E=Hrel) and its overall health. When dominant species are present in the studied samples, represented by many individuals, Hp decreases. Conversely, when there are many species without clear dominance over the others, Hp increases, approaching Hmax [9].

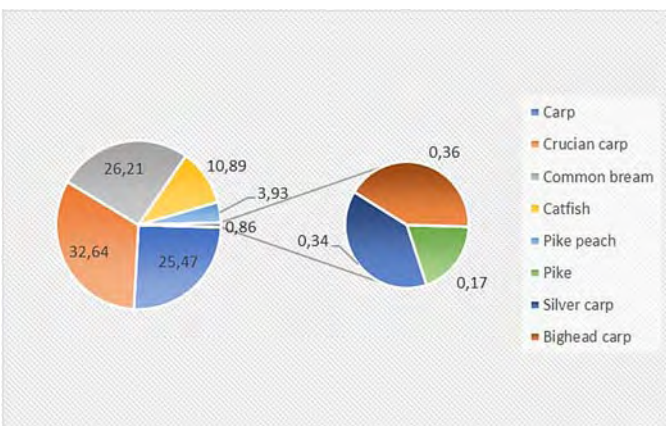

Figure 8. The relative abundance of captured species in the sector between km 1047-1071 during the period 2021 – 2023

Furthermore, the HRel value indicates to what extent the observed diversity departs from the hypothetical (maximum) diversity; the higher the percentage, the closer the real diversity approaches the hypothetical one [10]. The values of Hmax, Hrel, and Hp are presented in Table 3.

Table 3. Representative indices of ecosystem diversity

No.of. Species	Hmax	Hrel/E	Hp
8	0,903	0,713	0,644

It is observed that the equitability index E=0.713 tends towards the value Hmax = 0.903, highlighting that there are many species in the studied ecosystem, while Hp = 0.644 decreases in relation to Hmax, given that there are 3 species that dominate the catches. Thus, the greater the diversity and proportion of species in an ecosystem, the higher the value of the Hp index. Furthermore, the Simpson index reaches a value of 0.75, indicating a situation where the diversity or variety of species in a particular community or ecosystem is relatively high, but there is still significant dominance by one or a few species in that community.

The Simpson index of 0.75 suggests a relative balance among the species in the community, but some species are still more predominant than others. On the other hand, a higher Simpson index approaching 1 would indicate a community where one or more species greatly dominate and have a very strong presence, while the other species are underrepresented. The closer the index is to 1, the lower the diversity of species in the community. In conclusion, a Simpson index of 0.75 indicates moderate diversity in a community or ecosystem, with a few species having a significant influence on the overall species composition.

Based on the analysis of synecological indices (Bulat, 2017), it can be concluded that the studied ecosystem, between km 1047-1071, is characterized by moderate diversity, but it is dominated by the three relevant species.

CONCLUSIONS

Our study on the ichthyofauna of the Danube River has provided a detailed overview of species diversity, growth parameters and mortality rates. The results have highlighted the importance of maintaining balance within the fish community of the Danube and the need to develop effective strategies for the conservation and management of fishery resources.

The inequitable abundance of species underscores the significance of protecting less abundant species to preserve biodiversity. Additionally, data on fishing mortality and exploitation indices suggest that fishery management must be closely monitored to prevent the depletion of fishery resources. As a result of this study, we can conclude that the conservation of fish biodiversity in the Danube River is essential for the environment and for human communities dependent on this vital riverine ecosystem. Our study provides a solid foundation for the development of sustainable fishery resource management strategies in the Danube.

ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Agriculture and Rural Development of Romania for financially supporting this research under budget code ADER 14.1.1./11.07.2023.

REFERENCES

1. Kottelat, M.; Freyhof, J Handbook of European freshwater fishes. Publications Kottelat, Cornol and Freyhof, **2007**, Berlin. 646 pp. [http://www.fishbase.se/summary/*Cyprin us-carpio*.html].
2. Primack, RB.; Rodrigues, E Biologia da Conservação. Londrina: Editora Viva, **2001,** 328 p.
3. Stroe, MD; Mirea, D., Patriche, N., Dima, FM New Contribution to the Knowlendge of the

Status of Freshwater Peaceful Fish and Predatory Species in the Danube River km 1047-1071. *Animal & Food Sciences Journal Iasi*, **2023**, *73(3)*, 147-152.
4. Pauly D On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. *Const. Int. Explor. Mer* **2009**, *39*, 175- 192.
5. Gulland, JA The Fish Resources of the Ocean. **1971.** West Byfleet, London, UK: Fishing News Books.
6. Bulat, D Ihtiofauna Republicii Moldova: amenințări, tendințe și recomandări de reabilitare **2017** Chișinău: Foxtrod., 343 p ISBN 978-9975- 89-070- 0.
7. Shannon, CE; Weaver, W The Mathematical Theory of Communication. Urbana, **1963**, I.L: University of Illinois Press, pp. 3135.
8. Baboo, I Ecology, and diversity of freshwater fishes of head qadirabad, gujranwala. *Punjab Univ. J. Zool*., **2011,** *26(1)*, 1-7.
9. Cenușă, R; Teodosiu, M; Cenușă, E. Aspecte privind diversitatea şi succesiunea în ecosisteme forestiere marginale (Dealul Radu) din Obcinele Bucovinei. *Bucovina Forestieră*, **2004,** *12(1-2)*, 31-46.
10. Nolan, KA; Callahan, JE Beachcomber biology: The Shannon-Weiner Species Diversity Index. Pages 334-338, in Tested Studies for Laboratory Teaching, **2006**, *27* (M.A. O'Donnell, Editor). Proceedings of the 27th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 383 pages.