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SADRŽAJ:

Biology and ecology students' biodiversity fixations: "biodiversity – the diversity of species" and "higher richness – higher nature conservation value"

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Abstract

This paper discusses the challenges of understanding the term biodiversity and the interpretation of biodiversity indices in complex ecological processes like succession. We compared the understanding of the term „biodiversity" between university Biology and Ecology students. First, we tested how strongly the fixation „biodiversity – the diversity of species" is present in both groups. Then both groups combined were offered a field trip experience to compare „climax" and successional forest by students performing biodiversity evaluation and calculating biodiversity indices (S, H', E). The post-field trip exam enabled us to test the presence of the second fixation: high species richness implies high conservational value. Students' personal experience in the field helped them overcome the fixations. Above 70 % chose the „climax" forest for conservation even though the species richness and biodiversity indices were lower than for the successional forest. This was evident from students' arguments in the exam, where students pointed out that forest age, habitat stability and nativeness of species mattered in their decision for conservation. Around 40 % of students used the calculated biodiversity indices in their argumentations and interpreted them correctly. The fixation „higher richness – higher nature conservation value" was detected in slightly more than 10 % of students. Results show that both studied fixations exist in students' perception of biodiversity since complex biodiversity-related situations like successions can challenge students' perceptions. However, if we provide learning activities that are reflective and encourage students to be critical of their own understanding, both biodiversity-related fixations can be overcome by students.

Key words: higher education, knowledge, ecological succession, biodiversity indices.

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Introduction

The high diversity of living organisms in nature has long astonished mankind. There were many attempts to record it, which all failed to produce a precise estimation. To talk about the diversity of all living organisms, describe it, understand it, and discuss theories demanded a concept of „diversity of all biotas". Therefore, the term „biodiversity" was coined by Walter G. Rosen in 1985, and the wider scientific community quickly accepted it. Two years later Edward O. Wilson launched the term biodiversity into general use (Harper and Hawksworth, 1994).

„Biodiversity" is a modern term; however, it is a word unproportionally often used. If we search Google for „biodiversity" we get considerably more hits (about 52.900.000 at the time of the preparation of this manuscript) than for the search term „Charles Darwin" (18.000.000 at the time of the preparation of this manuscript). The word „biodiversity" is used in scientific language, political debates, schools, as well as in everyday conversation. Despite the frequent use, the definition of the term „biodiversity" is constantly evolving, adding aspects to the concept of biodiversity. First, definitions included only the diversity of various organisms – what we would today describe with the term species richness. New methods and theories at a broader scale let us recognize biodiversity at levels of genes, functions, individuals, populations, communities, and ecosystems: „Biodiversity is the variety of life on Earth, it includes all organisms, species, and populations; the genetic variation among these; and their complex assemblages of communities and ecosystems." stated by the World Conservation Monitoring Centre of the United Nations Environment Program.

However, most people still understand the term „biodiversity" intuitively as the species richness estimated as the number of species (S). While this does not represent a concern for everyday use, it is essential for students, who will become professionally involved in biology, ecology, and nature conservation. They require a much more complete understanding of biodiversity and the complexity of ecological systems (Balgopal et al., 2012). Therefore, the first aim of our study was to evaluate how biology and nature conservation students understand and describe the term „biodiversity". We hypothesized that most students understand the term „biodiversity" intuitively as the diversity of species.

A better description of biodiversity than species richness can be provided by calculations, which consider the proportion of each species and therefore enable a distinction between samples with the same species richness (Konopiński, 2020). There are several biodiversity indices in use and one very commonly used is the Shannon-Weaver diversity index (H') calculated as the weighted geometric mean of the proportional abundances of each species. It is widely used for comparing diversity between various habitats (Magurran, 2004). The correct understanding of biodiversity is crucial for students' ability to make the right decisions to prevent the global decline of biodiversity with increasingly great human impact on the Earth's ecosystems (Tilman, 1999). Especially, since it is broadly recognized that high biodiversity sustains healthy ecosystems and benefits human life.

However, nature conservation decisions should not be based solely on values of calculated indices. For example, for plant communities time since establishment or time since the last disturbance can influence diversity indices throughout the successional processes showing that high species richness is a transient successional property (Sheil, 2001). For that reason, our second aim was based on a field excursion to a protected river island where they performed 2 biodiversity study activities – i) vegetation surveys in two parts of the island – old-growth forest of high value and disturbed secondary successional forest by estimating species richness (S) and ii) afterward calculating Shannon-Weaver diversity index (H') and evenness (E). Students therefore obtained results showing higher S and H' values for the successional forest, however, more important ecologically was the old-growth forest. In general, successional forest stages are often species richer than those of mature stands (Widenfalk and Weslien, 2009). This might cause a less experienced observer to recognize wrongly the successional stand to be more valuable for conservation if the decision is based on richness and diversity indices alone.

Our second aim was therefore to test whether students understand these discrepancies between indices values and the situation in nature and can overcome the biodiversity-related fixation: higher richness – higher nature conservation value by asking them to argue which part of the island they find more important to protect in a hypothetical destruction of the island's half according to their results. We hypothesized that the biodiversity-related fixation is strongly present among students, and we aimed to encourage students' understanding that only species richness is not a sufficient biodiversity measure.

Materials and methods

Students' background knowledge

Our test groups included the second-year students from the Faculty of Natural Sciences and Mathematics (University of Maribor, Slovenia) enrolled in two study programs: a) Biology and b) Ecology with nature conservation. Before the first part of the study, all students attended lectures about taxonomical botany and invertebrate zoology as well as basic and animal ecology. Before the second part of the study, students attained also lectures about plant ecology and biogeography. Before the study, the students were familiar with the fieldwork site – the Island Mariborski otok, its protection status, and its natural value in terms of ecosystem services. This is a place commonly used for walks and as a summer swimming resort. However, if not before, each student visited the island at least once during botanical practical class prior to our study. In that class they gained knowledge about herbaceous and woody species identification, and they had to pass a botanical taxonomy exam after the first year required for 2nd year enrollment.

The study area

The natural river island Mariborski otok (46°34′01.2″N, 15°36′43.0″E) on the river Drava near the town Maribor (95,000 inhabitants) in Slovenia. The island climate is continental, with mean annual temperatures around 10°C and mean annual rainfall about 1000 mm (Slovenian Environment Agency, 2013). Differences in the topography of the lower part of the island and the steep riverbanks were one of the reasons why the island was never used historically for human settlement (Baš, 1934). The high animal and plant diversity of the island was soon recognized, and since 1951 the island has been protected as a botanical natural monument and is today included in the Natura 2000 network.

The island has been forested continuously at least from 1824 according to the oldest map (Karlo and Šajna, 2014). The most intensive human impact began in 1929, when a swimming pool was built in the central part of the island. As a result, the forest was divided into western and eastern parts of comparable size (3 ha), which later experienced different management regimes until 30 years ago. These resulted in different species composition on the island along with different species richness and abundance between the eastern and western forest parts still recognizable today (Šipek et al., 2023).

The forest vegetation biodiversity is assessed well (Kaligarič and Bakan, 2009; Karlo and Šajna, 2014; Šipek et al., 2023). The western part is a well-conserved old-growth Illyrian collinar neutrophile beech forest type dominated by large *Fagus sylvatica* L. trees and an understorey with several geophytes typical for old-growth forests (e.g. *Anemonoides nemorosa* (L.) Holub, *A. trifolia* (L.) Holub, *Erythronium dens-canis* L.). The eastern part is a younger, late successional Illyrian calcicline sessile oak-hornbeam forest, with some planted trees. The species richness for woody species is greater here because of the succession by woody shrubs *Crategus monogyna* Jacq., *Prunus padus* L., *Euonymus europaea* L., *E. verrucosa* Scop., *Viburnum opulus* L, *V. lanta*na L., *C. avellana* L.) and scattered *Quercus robur* L., *Acer pseudoplatanus* L., *Fraxinus excelsior* L. trees (Karlo and Šajna, 2014). Additionally, the species richness of understorey is higher in the Eastern part as compared to the Western part, however, this is less evident if vegetation is observed in small plots.

Therefore, history and different management of potentially the same forest vegetation make the island very suitable for biodiversity studies and practical testing of biodiversity related fixation: higher richness – higher nature conservation value. If focusing on nature conservation, the western part of the forest is more interesting because of longer forest presence in time, lesser human impact, the presence of large trees, and understorey with several rare spring ephemeral geophytes. However, if we combine both forest parts only by numbers describing species richness and diversity, numbers are in favor of the successional forest.

Research Design

Evaluating student's definitions of the term „biodiversity"

The research design for this study was comparative between students attending the two study programs: a) Biology and b) Ecology with nature conservation. It was designed to elucidate evidence of understanding of the biodiversity concept and the existence of a common fixation: biodiversity is species richness. At the beginning of the 4th semester, we asked students to write down their definitions of the term „biodiversity" anonymously. We handed out 6x6 cm papers to students to encourage concise answers. The time for answering was limited to 5 min. Every student's response was evaluated according to how many levels of diversity were included in their definition: genes, organisms, species', populations, communities, and ecosystems. The results obtained were analyzed by comparing students attending the two study programs.

Evaluating biodiversity-related fixation: higher richness – higher nature conservation value

The research design for the second part of the study was designed to generate an evidence-based understanding of the biodiversity concept according to the student's personal experience at the study site. The students' work involved:

(a) an introduction to the field excursion in a lecture room – the introduction by the lecturer included a summed 20 min lecture about different levels of biodiversity and the presentation of the definition of biodiversity indices (S – species richness, H' – the Shanonn-Weaver index, E - Evenness);

(b) a brief supervised tour in the field – supervisor sharing information about each forest stand (forest type, age, history, human disturbance), a short recapitulation of plant species, and a demonstration of vegetation survey procedure;

(c) collaborative fieldwork performing vegetation surveys in each part of the island (a group of four), individualized data compilation, and written report according to instructions of the student's handout (table 1).

Table 1. *Student's handout with theoretical background, field survey and calculation instructions, and discussion cues.*

Topic	Explanation
Why study trees?	The biodiversity of vegetation (the primary trophic level) in terrestrial landscapes often reflects the biodiversity in other trophic levels that depend upon it. Trees are a dominant species in a landscape and tree diversity is closely linked to the diversity of the many species that are dependent upon them. Therefore, human disturbance, in this case cutting, may dramatically change tree species richness and evenness, and consequently insects, birds and mammals as well.
What is biodiversity?	Biodiversity is the variety of life, in all its manifestations. Key elements of this variety can be recognized as comprising of three nested hierarchies: genetic, species, and

Topic	Explanation
	ecological diversity. Because the variety of life can be expressed in a multiplicity of ways, there is no single overall measure of biodiversity, rather there are multiple measures of different facets. While it has some significant limitations, species richness (S) has become the common currency of much of the study of biodiversity and has proven valuable for many scientific and practical purposes.
How to measure biodiversity?	Measurement indices of biodiversity typically have two elements: richness (S) and evenness (E). Richness is the easiest to visualize. Think of two 1x1 m plots on the ground. If there is only one species inside the first one (S=1) and four species inside the second one (S=4), the second is more species rich. Say there was a third 1x1 m plot on the ground and it had four species like the second one. However, the second plot may have one individual of each species and the third plot may have four individuals of the third species and one individual in each of the other species. The second plot would still contain a more diverse area because none of the plants were dominating. Evenness is considered important in biodiversity, but not as important as richness, both are combined in the Shannon-Weaver index.
Procedure in the field	In your group, choose a random point along your transect line. Have one person stand at that point with the tape measure. Have another person walk out 5 meters and put in another stick. Record all of the species, and the number of individuals/species, for the entire radius of the circle, on your data sheet. Do this 2 times for each habitat (and share your data with 2 other groups).
Equations and abbreviations	Species richness (S): the number of species in an area; Evenness (E): relative numbers of individuals/species; E = H'/ln S; Shannon-Weaver Index: H' = -∑pi * (ln pi). *s* is the total number of times that the equation is calculated, once for each species. *i* indicates the particular species for which the equation is calculated. *p* is the proportion of individuals out of the total number of individuals.
Questions for the discussion	What is your hypothesis regarding species diversity between the two communities we examined? Using the data from your sampling, determine the species richness (S) of each community. Determine the heterogeneity of each community using the Shannon-Weaver index (H'). From your estimate of heterogeneity (using the Shannon-Weaver index) calculate the evenness (E) of each community. Compare the two communities in terms of richness, diversity, and evenness. (i.e., which was most rich, least rich, etc.). Why do you think the two communities were similar or different? What impact did human disturbance have on the tree richness and evenness?

After one week a written exam was mandatory for each student to assess students' understanding and interpretation of the biodiversity in the field. The exam question was formed in a way to allow expressive writing – an activity that is reflective and encourages students to be critical of their own understanding (D'Avanzo, 2003). At the same time, this approach allowed students to reflect on their idea and provided the opportunity to reconsider and connect prior and new conceptions (Keys, 1999; Balgopal et al., 2012). We asked the students a hypothetical question, which part of the island's forest (western or eastern) should not be disturbed in the case of an urbanization attempt on the island? The question was formulated as: „The Field trip to the island Mariborski otok – you calculated H', S, and E for climax and secondary successional forest. Argue which forest stand would be more important to conserve." Because students from both study programs (Biology and Ecology with Nature Conservation) listened and attended the same lectures and the field trip, the results were evaluated for both groups of students combined.

With such an approach we asked a question that can indicate student's skills like interpreting results and decision-making by their proposal of a conservation action. We wanted to encourage students to address their results and understanding of biodiversity analytically, combined with personal experience in the field. Students' responses were analyzed according to which forest stand was selected for conservation, what was the argumentation, and if the argumentation included biodiversity indices.

Results

Students' definition of the term „biodiversity"

All 5 levels of biodiversity: genes, organisms, populations, species, communities, and ecosystems were never listed together by a student, even though all five levels were recognized in the entire sample of students' responses. The most precise definitions included 4 levels of biodiversity since the „community" level was never included (figure 1), however, definitions comprising 4 levels of biodiversity were recorded only among Biology students. Additionally, fewer Biology students (40%) included only one level of biodiversity in their definitions compared to more than half of Ecology and Nature Conservation students (62 %, figure1).

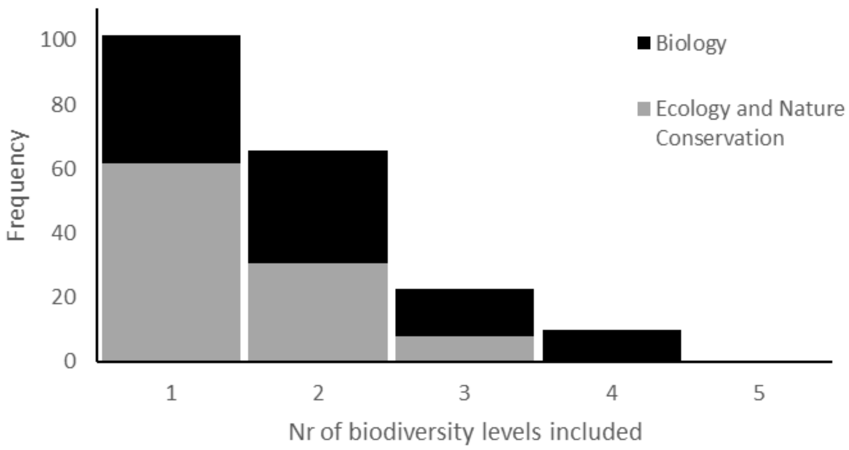

Figure 1. Frequency diagram of the accuracy of the term „biodiversity" provided by students enrolled in 2 study programs (Biology, Ecology and Nature Conservation). The accurate definition should include 5 levels: genes, organisms, populations, species, communities, and ecosystems.

The most frequently recognized level was the „species" level (table 2): 79% in total for both study programs, 85% for Biology students, and 69% for Ecology and Nature Conservation program students, respectively. About one-third of all students described „biodiversity" solely in terms of „species diversity" (30% in Biology, 39 % in Ecology and Nature Conservation). Next frequently were definitions including the level of „organisms" (49 % in total) and „ecosystems" (21 % in total). When comparing both groups of students, biology students more often included the level of „genes" and the level of „organisms" in the definitions than students of Ecology and Nature Conservation. Overall, Biology students provided more accurate definitions, with 25 % including 3 or more levels of biodiversity in their definitions, compared to just 8 % of Ecology and Nature Conservation students. Additionally, several definitions provided stressed the importance of distribution in space and time. One definition included the importance of abundance and one the importance of evenness.

Table 2. Comparisons of the definitions of the term „biodiversity" provided by students enrolled in two study programs (Biology; Ecology and Nature Conservation) according to the number of biodiversity levels included.

Study Program	**Level of biodiversity included in students' definition**					
	Genes	**Organisms**	**Populations**	**Species**	**Communities**	**Ecosystems**
Biology	5 (25 %)	11 (55 %)	2 (10 %)	17 (85 %)	0	4 (20 %)
Ecology & NC	1 (8 %)	5 (39 %)	1 (8 %)	9 (69 %)	0	3 (23 %)
Cumulative	6 (18 %)	16 (49 %)	3 (9 %)	26 (79 %)	0	7 (21 %)

Biodiversity-related fixation: higher richness – higher nature conservation value

Thirty-three students participated in the exam, while among those 3 students did not answer the question. Among students who addressed the question, 23 students (77 %) responded to conserve the „climax" forest. When their argumentations were analyzed in more detail (figure 2), we found that 83 % were correct. Among those, 53 % used stand's age, native origin, indigenous plant community and stability in their answers, while 32 % used the argument of low anthropogenic impact in the past. The rest of the correct argumentations included the low presence of invasive alien species, high evenness, and protection required because of future anthropogenic impacts. Four answers used a false argumentation why the conservation of the „climax" forest was needed. For example, one respond was not related to the experience from the field trip and was based on the wrong assumptions that the „climax" forest had more species and higher diversity. However, three other responses showed a different understanding why conservation is needed, because students argued that low species richness needs conservation because it is more threatened than high richness plant community. In total, 60 % of students used indices calculated in their argumentation. Among answers in favor of the successional forest protection, 57 % of answers (or 13 % of all students answering the question) exhibited student's understanding that high values for species richness and diversity index H' imply conservation.

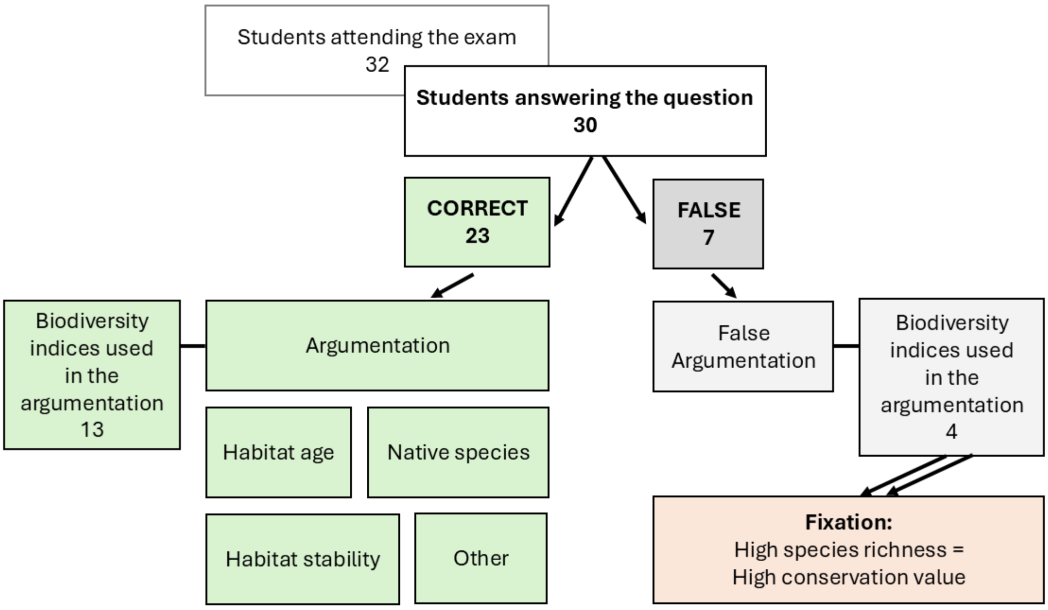

Figure 2. Existence of the biodiversity-related fixation: higher richness – higher nature conservation value in responses and argumentations of students enrolled in 2 study programs (Biology, Ecology and Nature Conservation) to the exam question, which forest stand would be more important to conserve.

Discussion

Recent global efforts to halt the decline in biodiversity – the Aichi Biodiversity Targets established in 2010 by the Convention on Biodiversity (CBD, 2010), have fallen short (Rounsevell et al., 2020). Despite the participation of 193 nations, these efforts failed to meet the 20 biodiversity-related goals by the 2020 deadline. Much of this failure can be attributed to the insufficient integration of biodiversity into public policy, low public awareness, and the weak advocacy by politicians regarding biodiversity loss (Rounsevell et al., 2020). In the future, we must do better, particularly as biologists' and ecologists' efforts to raise awareness about biodiversity loss are often undermined by the growing organized denial of scientific evidence (Lees et al., 2020). Therefore, future biologists and ecologists must be proficient in evaluating current biodiversity and understanding how various processes like succession shape it over time.

Students' understanding of the term „biodiversity"

While the understanding of biodiversity by the general public is shaped largely by personal experiences, common sense beliefs and how one values the nature (Buijs et al., 2008) we expected the prospective biologists and nature conservationists to build their understanding of biodiversity on biological and ecological knowledge and concepts. This would be demonstrated by complex definitions of biodiversity. Definitions offered by students included a maximum of four levels of biodiversity from the expected five. In general, our results show that the Biology students included more levels in their biodiversity definitions than Ecology and Nature Conservation students, whereby the „species" level was dominating the definitions of both student groups. Our evaluation of students' »biodiversity« definitions revealed a strong intuitive understanding of biodiversity as simply the number of species for both study groups and the existance of the fixation „biodiversity – the diversity of species". This was expected because of the widespread recognition of the significance of the species as a biological and ecological unit (Fitzhugh, 2013).

Biodiversity-related fixation: „higher richness – higher nature conservation value"

However, elucidating the strong presence of the fixation: „high species richness – high biodiversity", we expected that students might be misled by temporal changes in plant diversity, such as those occurring during secondary succession. The second part of our study enabled us to evaluate students' understanding that during a succession of plant communities mid-stages (serals) can usually have higher diversity than later, more stable »climax« stages. First hand experience of secondary succession as an ongoing process rather than a steady state, even though biodiversity may be higher during certain periods than in a climax community.

The field-based experience helped 19 students (63 % of all students that had correct answers and a correct argumentation) understand that a measure of taxonomic diversity like species richness can not necessarily be used effectively to guide conservation strategies. Therefore, rather than the number of species their abundance and functional traits should be considered (Stuart-Smith et al., 2013). Results indicated a superficial knowledge gap – the overestimation of the importance of the species richness (S) value. All students found that the higher the S, the more species rich is the site, which corresponds with the facts. However, 13 % of students also connected high S with high conservational value – a relation, which is true only if other indices like H' and E are taken into consideration. Currently, major knowledge needs linked with the EU Biodiversity Strategy 2030 require better determination of what constitutes a favorable ecological condition and good conservation status to better guide conservation strategies and management (Eggermont et al., 2021). When asking students which part of the forest is more valuable for conservation they expressed rather good understanding of main drivers causing biodiversity decline.

Conclusion

Biologists and ecologists have to communicate scientific facts, which are based on numbers and first we have to present correct numbers without over- or under-exaggeration and we have to explain what we mean by the numbers. Even though this is the basic biological knowledge for professionals and the general public alike, to improve public support for biodiversity a wider variety of public attitudes need to be considered (Buijs et al., 2008). Particularly, since the loss of experience and the gradual fading of cultural knowledge and collective memory of species is happening as a general and global consequence of the global biodiversity crisis (Jarić et al., 2022). Therefore, to deliver the biodiversity content to students most effectively, an approach of nature observation and personal experience of authentic reality in the field is highly recommended and also very well accepted by biology students in general (Delić et al., 2019). In our study, because of students's personal experience when visiting the study site, even though they recorded high S values in the successional forest they were also able to observe the appearance of the successional forest. Additionally, by understanding biodiversity in terms of the succession processes, which describe continuous changes of biodiversity through time, 63 % of students were be able to recognize later successional stages (serals) like the situation in the „climax" forest to be more valuable for conservation than earlier successional stages.

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