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How Many Species Are There? Public Understanding and Awareness of Biodiversity in Switzerland

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Abstract This paper presents the results of interviews and a questionnaire study on public knowledge of the concept of biodiversity and of plant species richness in Switzerland. Despite its extensive use in science and policy making, the concept of biodiversity is not widely recognized or known to people in Switzerland. Overall, 60% of all study participants (161 grammar school pupils, 110 non-graduates, and 96 graduates in the Canton of Zurich) had never heard the term biodiversity, while the others had come across it primarily in the media. Few study participants considered their school education a relevant source of information about biodiversity. Study participants most frequently referred to the diversity of plants and animals when defining biodiversity, but also quite often believed that biodiversity had something to do with ecological concepts such as the equilibrium between all components of nature. Both young people and adults held widely inaccurate ideas of the plant species richness of communities. Particularly for Switzerland, plant species richness was strongly overestimated.

Keywords Biological diversity · Plant species richness · Public knowledge · Survey

Introduction

Human activities such as harvesting, habitat destruction and modification, overexploitation, and the introduction of exotic species have been and are continuing to alter nature on local and global scales (Trombulak *et al.* 2004; Hooper *et al.* 2005). Many of these alterations are leading to a loss of biodiversity (Hooper *et al.* 2005). The term biodiversity encompasses a broad spectrum of biotic scales, from genetic variation within species to biome distribution on the planet (Wilson 1988; Purvis and Hector 2000). Biodiversity can thus be described in terms of the number of entities (how many genotypes, species, or ecosystems), the evenness of their distribution, the differences in their functional traits, and their interactions (see detailed discussion in Hooper *et al.* 2005). In a strict scientific sense, the term biodiversity means the variability among living organisms, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species, and of ecosystems (CBD 1992). Altered biodiversity either from the loss of species or the introduction of exotic species has lead to widespread concern for a number of both market (e.g. for medicines) and non-market (e.g. ethical and aesthetic) reasons (see discussion in Hooper *et al.* 2005). This leads to the notion that biodiversity not only embraces a scientific view of the world but also an economic, ethical, spiritual, and cultural one (McLeish 1997; Kassas 2002; Van Weelie and Wals 2002). In consequence, as multiple values are attached to biodiversity and its conservation (see Saunders 2003), it can be discussed in many ways—often controversial—which makes it a challenge for conservation education (Trombulak *et al.* 2004).

Biodiversity is strongly declining worldwide (Thomas *et al.* 2004a, b) and in Europe (Thomas *et al.* 2004a, b). Of the 40,177 species assessed worldwide using the IUCN Red List criteria, 16,119 are currently listed as threatened with extinction. This includes one in three amphibians and a

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quarter of the world's coniferous trees, on top of the one in eight birds and one in four mammals known to be in jeopardy (IUCN 2006). In Switzerland, more than 200 species have become or are presumed to have become extinct over the last 150 years and, depending on the taxonomic group, 31% to 79% of all plant and animal species are currently included in the Red Lists (BAFU 2006). The conservation of biodiversity is therefore considered to be one of the most urgent environmental issues globally and within Switzerland (UNEP/CBD/COP/8/14 2006). At the 2002 World Summit on Sustainable Development in Johannesburg, South Africa, world leaders agreed to significantly reduce the current rate of biodiversity loss by 2010 (UN 2002, article 44). This cannot be done effectively without the participation of society at large, which has to be convinced of the importance of biodiversity if there is to be any real hope of implementing meaningful measures (Hanski 2005).

However, people's responses to the decline of biodiversity, i.e. the local, regional, or global extinction of species, and their support for conservation measures will depend on their knowledge about biodiversity, their conceptions of the number of species present and an awareness of the seriousness of the threat of extinctions. Although raising public awareness of the need to preserve biodiversity is official policy since the signing of the biodiversity convention (WRI, IUCN and UNEP 1992; UNEP/CBD/COP/8/14 2006), studies indicate that the general public has little knowledge of the concept of biodiversity (Turner-Erfort 1997; Hunter and Brehm 2003). Moreover, research suggests that people have widely inaccurate ideas of the species richness of communities (Dunning 1997). In addition, several studies have shown that the public's ability to identify species is very limited (e.g. Lindemann-Matthies 2002; Balmford *et al.* 2002; Bebbington 2005). When, for instance, in Switzerland more than 6,000 young people between the ages of eight and 18 were asked about organisms in their immediate environment, on average five plants and six animals were named and unspecified taxa like 'birds', 'trees', and 'grasses' were among the most commonly listed in all age-groups (Lindemann-Matthies 2002). Garden and decorative plants with large and brightly colored flowers and pets such as cats and dogs were frequently perceived organisms, and also the ones the respondents liked best (Lindemann-Matthies 2005). If it is true that people care only about what they know (Balmford *et al.* 2002), such findings are not encouraging in terms of biodiversity conservation.

To conserve biodiversity, more efforts have to be undertaken to educate people accordingly. However, to identify areas for increased public education efforts, a better understanding of the public's knowledge of the concept of biodiversity, its importance, and the actual number of species are needed. The key objectives of our study were thus to investigate:

(1) how familiar grammar school pupils, non-graduates, and graduates or students in the Canton of Zurich are with the term biodiversity and where they received their information from;
(2) how accurate their estimates of the number of plant species worldwide, in Switzerland, and in specific habitats in Switzerland are;
(3) whether age, gender, and botanical expertise influence people's familiarity with biodiversity and their knowledge of plant species richness.

Methodology

Data collection

Data were collected in 2003 and 2005 at various places in the Canton of Zurich by using two approaches. In the first, oral interviews with 41 adults were carried out, while in the second a written questionnaire was administered to 161 grammar school pupils and 165 adults. The in-depth interviews allowed us to investigate people's understanding of and familiarity with the term biodiversity step-by-step in open questions, to clarify queries, and to write down observations, while the written questionnaire which consisted mainly of close-ended questions allowed us to collect data from a large number of people.

The 25-min interviews were carried out in a well-visited park in the city of Zurich, in the universities and in a natural history museum. The 10-min written questionnaire was administered in the botanical garden of the University of Zurich and in three grammar schools in the Canton of Zurich. Study participants were chosen at random. However, we focused on a potentially more 'biodiversity-knowledgeable' segment of the public, i.e. visitors to botanical gardens and museums, but also students who might have heard or, in the case of grammar school pupils, should have heard about biodiversity. We also tried to question people in their leisure time when they were not stressed and willing to take their time to fulfill the required tasks. We therefore approached the public in parks and free-choice learning settings, students at lunch time in front of the refectories and pupils during afternoon work sessions in school.

The instruments

In the oral interviews, participants were first asked whether they had already come across the word 'biodiversity' and, if so, where. They were then asked to specify their sources of information in more detail. They were then asked to

provide a definition of biodiversity. The interviewer recorded whether people could fulfill the task, merely deduced the meaning from the terms 'bio' and 'diversity', or could not come up with a definition. If respondents could not provide a definition, they were told that biodiversity is just another word for biological diversity. The interviewer recorded whether this extra information was helpful or not. Finally, all interviewees received the following definition: 'Biodiversity is defined as the diversity of animal and plant species, genetic diversity and the diversity of habitats.' They were then asked whether they thought it important to conserve biodiversity or not and to explain their reasons. They were further asked about their interest in biodiversity issues with the help of a five-step rating scale, ranging from 1: no interest at all, to 5: very strong interest. All answers to the open questions were recorded by the interviewer and later categorized according to the type of response given.

In the written questionnaire, study participants were first asked to tick whether they had already come across the word 'biodiversity' and, if so, to indicate where by choosing the appropriate answers out of seven preconstructed ones. They were then asked to choose from seven preconstructed definitions of biodiversity (false and true ones) the ones they thought fitting.

In both the interviews and the questionnaire, all study participants were asked in open questions to estimate the number of plant species worldwide and in Switzerland, and in a 100×100 m area of an Alpine meadow, a lawn, a beech forest, and a Norway spruce forest. We asked for the number of species in habitats of a standard size (100× 100 m) because species numbers increase with area (species area curve, e.g., Crawley and Harral 2001). For all numbers asked, actual data were available (e.g., Groombridge 1992; Heywood 1995; Lauber and Wagner 2001) to which the estimates of the participants could be compared.

To test whether botanical knowledge and professional background influenced people's knowledge about biodiversity and their estimates of plant species richness, all adults were asked to self-estimate their taxonomic knowledge in comparison to that of the general public by ticking one of the possible answers of a five-step rating scale (very poor=1, rather poor= 2, neither poor nor good=3, rather good=4, very good=5). Participants were also asked to write down their profession or, in the case of students, their study subject. From these data two variables were created that indicated whether a participant was a graduate (including students) or not, and whether she or he had a professional background in biology or not. All study participants were further asked about their age and gender.

Respondents

To be able to analyze responses by age and education, we divided our questionnaire sample into three groups: youth (161 grammar school pupils, 39% girls, mean age: 16 years), non-graduates (64 persons, 58% women, mean age, 43 years) and graduates or students of different subjects (101 persons, 56% women, mean age, 38 years). Overall, 12% of the adults had a professional background in biology or botany, i.e. they were gardeners, farmers, landscape architects, biology teachers, biologists, or students of these subjects. Both non-graduates and graduates considered their taxonomic knowledge of plants as average compared to that of the general public (mean score 3.1 on the five-step rating scale).

Nine non-graduates and 32 graduates (51% women, mean age: 35 years) participated in the oral interviews. Of these, 29% had a professional background in biology or botany. Both non-graduates and graduates considered their taxonomic knowledge of plants as average (mean scores 3.6 and 3.3, respectively, on the five-step rating scale).

Statistical analysis

Differences between grammar school pupils, adults without a university degree, and graduates or students in their familiarity with the term biodiversity were analyzed by using chi-square-tests[1].

To test whether age, gender, and in the case of participating adults, botanical expertise (measured as people's self-estimated taxonomic knowledge of plants and professional background in biology/botany) influenced people's familiarity with biodiversity and which sources of information they used, the data were analyzed by multiple logistic regressions[2]. A final minimum adequate model was obtained by backward elimination of non-significant ($p>$ 0.05) variables.

We present the range (minimum and maximum) and the quartiles of people's estimate of plant species richness. As in previous studies by Meffe (1994) and Dunning (1997), we included log-transformed data with outliers removed in the analyses. To test whether age, gender, and in the case of adult participants botanical expertise influenced people's estimated plant species richness in different habitats, the data were analyzed by general linear models[3]. Initially, all independent variables were included in the model. The final

[1] The chi-square test is a statistical test which calculates the probability that the differences in the proportion of different groups are due to chance.

[2] Logistic regression is a form of regression which is used when the dependent is a dichotomous variable and the independents are of any type.

[3] General linear models (GLMs) are a set of models that comprise linear regression, ANOVA, and ANCOVA. The GLM underlies most of the statistical analyses that are used in applied and social research (for a simple explanation see http://www.socialresearchmethods.net/kb/genlin.php).

minimum adequate model was obtained by backward elimination of non-significant ($p>0.05$) variables (Crawley 2005). All analyses were carried out with SPSS for Windows 12.0.1.

Results

Familiarity with the term biodiversity and sources of information

Overall, 60% of all study participants had never heard the term biodiversity, while the reminder had heard about it primarily in the media (Fig. 1). Although a group of young, well-educated pupils from the grammar school and a considerable number of students and graduates had answered the question, only few considered their school education as a relevant source of information about biodiversity.

Grammar school pupils were particularly unfamiliar with the term biodiversity (Table 1). It is thus not surprising that only 16% of pupils named their school education as a source of information about biodiversity. Both graduates and non-graduates regarded daily newspapers and journals as important providers of information on biodiversity, but graduates made significantly more use of the media than non-graduates did.

Participants in the oral interviews also indicated print media as their main information sources about biodiversity. They explicitly stated they had read articles on biodiversity in their local newspapers (44%), in membership magazines of popular NGOs such as Pro Natura (Swiss Conservation Organization), the WWF or Greenpeace, or in easy-to-read magazines (32%). Moreover, documentaries and nature films on national and international TV channels (22%) as well as local radio programs (20%) provided them with information about biodiversity. School biology and geography lessons had also contributed to people's knowledge about biodiversity (reported by 24% of the interviewees who were all graduates or students).

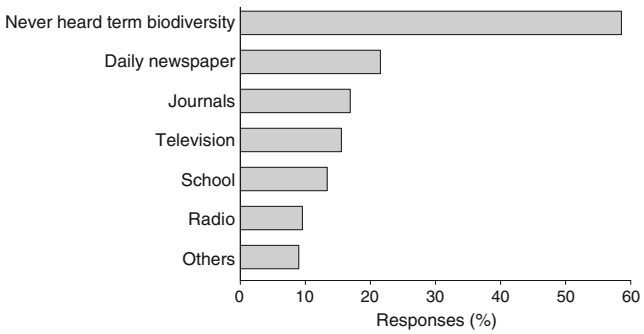

Fig. 1 Familiarity with the term biodiversity and sources of information. Overall, 367 people (youth, non-graduates, graduates or students) in the Canton of Zurich were asked whether they had already come across the term biodiversity and, if so, to state their sources of information. Multiple answers were possible. About 9.5% of all participants had heard the term in university (graduates or students)

People's familiarity with biodiversity and their sources of information were not influenced by gender, but by age. With increasing age the probability decreased that a study participant was familiar with the term biodiversity ($b=-0.03$, $\chi^2=20.17$, $p<0.001$; Fig. 2a) or had heard about it in school ($b=-0.03$, $\chi^2=6.33$, $p=0.025$; Fig. 2b).

However, the probability that a participant had heard about biodiversity in the media increased with age (TV: $b=0.02$, $\chi^2=6.88$, $p=0.007$, Fig. 2c; radio: $b=0.03$, $\chi^2=9.54$, $p=0.001$, Fig. 2d; daily newspapers: $b=0.03$, $\chi^2=20.09$, $p<0.001$, Fig. 2e; journals: $b=0.04$, $\chi^2=22.08$, $p<0.001$, Fig. 2f).

We also tested whether people's familiarity with biodiversity was influenced by their professional background in biology or knowledge about plants (self-estimated). With increasing knowledge about plants the probability increased that a study participant was familiar with the term biodiversity ($b=0.79$, $\chi^2=16.71$, $p<0.001$).

Knowledge about biodiversity

In the oral interviews, 11 of the 41 study participants defined biodiversity as the diversity of plants and animals, which is not wrong but only part of the definition. Only four interviewees knew that the concept of biodiversity also includes genetic and ecosystem diversity. An additional eight participants knew that 'bio' means life and deduced that biodiversity might be the diversity of organisms or, more generally, the diversity of life-forms. Eleven respondents were under the impression that biodiversity had something to do with ecology or ecological concepts such as the interconnectivity of organisms, biological cycles, food chains or with habitats for animals. Six respondents mistook biodiversity for the diversity of biological subjects or thought it just another word for the diversity of (organic) vegetables.

The results of the questionnaire study were similar to those of the interviews. Again, people most frequently referred to the diversity of plants and animals when thinking about biodiversity (Table 2). Only 9% of the young people and 8% of the adults knew the three elements of biodiversity (correct answer combination in Table 2). As in the interviews, participants frequently believed that biodiversity had something to do with ecological concepts such as the relationship between organisms or the equilibrium between all components of nature. However, significantly more non-graduates than graduates or students held these misconceptions (Table 2). Moreover, non-graduates were least and graduates most knowledgeable about biodiversity (correct answer combination: 7.3% non-graduates, 18.9% pupils and 33.3% graduates or students; $\chi^2=9.03$, $p=0.01$).

Table 1 Familiarity with the term biodiversity and sources of information

Sources of information	Youth (%)	Non-graduates (%)	Graduates or students (%)	χ^2-value and sig.
Never heard about biodiversity	77.0	59.4	29.7	44.18***
Daily newspapers	6.2	20.8	46.9	50.20***
Journals	4.3	20.8	32.8	32.86***
Television	7.5	16.8	29.7	18.55***
Radio	3.1	8.9	20.3	17.93***
University	–	–	29.1	–
Others (work, friends, NGOs)	3.7	7.9	14.1	7.63*
School	15.5	3.0	17.2	11.36**

With the help of a written questionnaire, grammar school pupils (n=161), adults without a university degree (n=101) and graduates or students of different subjects (n=64) in the Canton of Zurich, Switzerland were asked whether they were familiar with the term biodiversity and, if so, to indicate their sources of information about biodiversity by choosing the appropriate answers out of seven preconstructed ones. Multiple answers were allowed. Differences between the three types of participants were analysed by using chi-square-tests.
*p<0.05, **p<0.01, ***p<0.001

Whether a person was familiar with the three elements of biodiversity or not was neither influenced by gender nor age (questionnaire study). However, about 50% of participants with a professional background in biology but only 16% without such a background knew about the three elements of biodiversity (χ^2=10.00, p=0.002).

Importance of biodiversity

Interviewees showed a considerable interest in biodiversity issues (mean estimate 4.0 on the five-step rating scale) and all of them thought it important to preserve biodiversity. When asked why biodiversity should be preserved, participants frequently referred to the interconnectivity of organisms or the equilibrium between all components of nature (31% of all answers), but also to the aesthetic value of biodiversity (24% of answers). They argued, for instance: 'Everything is connected and the loss of biodiversity might have serious consequences. If habitats are destroyed, certain organisms can no longer exist but others will become more frequent which might result in strongly unbalanced systems' (housewife, 57 years old). 'The extinction of organisms will have serious consequences which at present are underestimated. Moreover, biodiversity enriches our everyday lives and should be enjoyed instead of destroyed' (accountant, male, 35 years old). 'Every species has its specific function in the cycle of life. Moreover, plants are pleasant to look at and colorful meadows are beautiful. A diverse forest is much more attractive than a monoculture is' (housewife, 31 years old). 'Just wheat in the agricultural landscape would be boring; diversity is important' (engineer, male, 45 years old).

Several participants referred to the importance of genetic diversity (29% of all answers). They argued, for instance: 'The more genetically diverse life forms are, the more resistant they are against diseases and extinction' (primary school teacher, female, 34 years old). 'Genetic diversity prevents inbreeding depression' (engineer, male, 35 years old). 'A large gene pool secures against diseases' (biology student, male, 22 years old).

Other participants put forward ethical arguments (10% of all answers): 'Maybe it is possible to live with only few species. However, for ethical reasons we have to keep nature as it is' (farmer, male, 42 years old). 'Nature in itself has a value which must not be destroyed by humans' (engineer, female, 32 years old). However, some students were also critical about the protection of biodiversity (7% of all answers) and argued, for instance: 'Should we really conserve human-made habitats? Habitats were naturally much less diverse than they are nowadays' (PhD student environmental sciences, male, 29 years old).

Estimation of plant species richness

All study participants were asked to estimate the number of plant species worldwide, in Switzerland, and in an 100× 100 m area of four different habitats in Switzerland. Because the same questions were asked in a similar way in both the interviews and the questionnaire study, the data were combined and analyzed together. In all regions but especially in Switzerland, plant diversity was overestimated (Table 3).

However, study participants with a professional background in biology estimated plant species richness in Switzerland more accurately (absolute difference between estimated and actual diversity) than did people without such a background ($F_{1,143}$=44.62, p<0.001). They also estimated plant species richness in specific habitats in Switzerland more accurately (alpine meadow: $F_{1,150}$=3.95, p=0.049; spruce forest: $F_{1,142}$=4.79, p=0.030; beech forest: $F_{1,144}$= 10.56, p=0.001). Moreover, with increasing taxonomic knowledge about plants (self-estimated), people estimated the number of plant species in a lawn more correctly (r= 0.27, $F_{1,144}$=10.97, p=0.001).

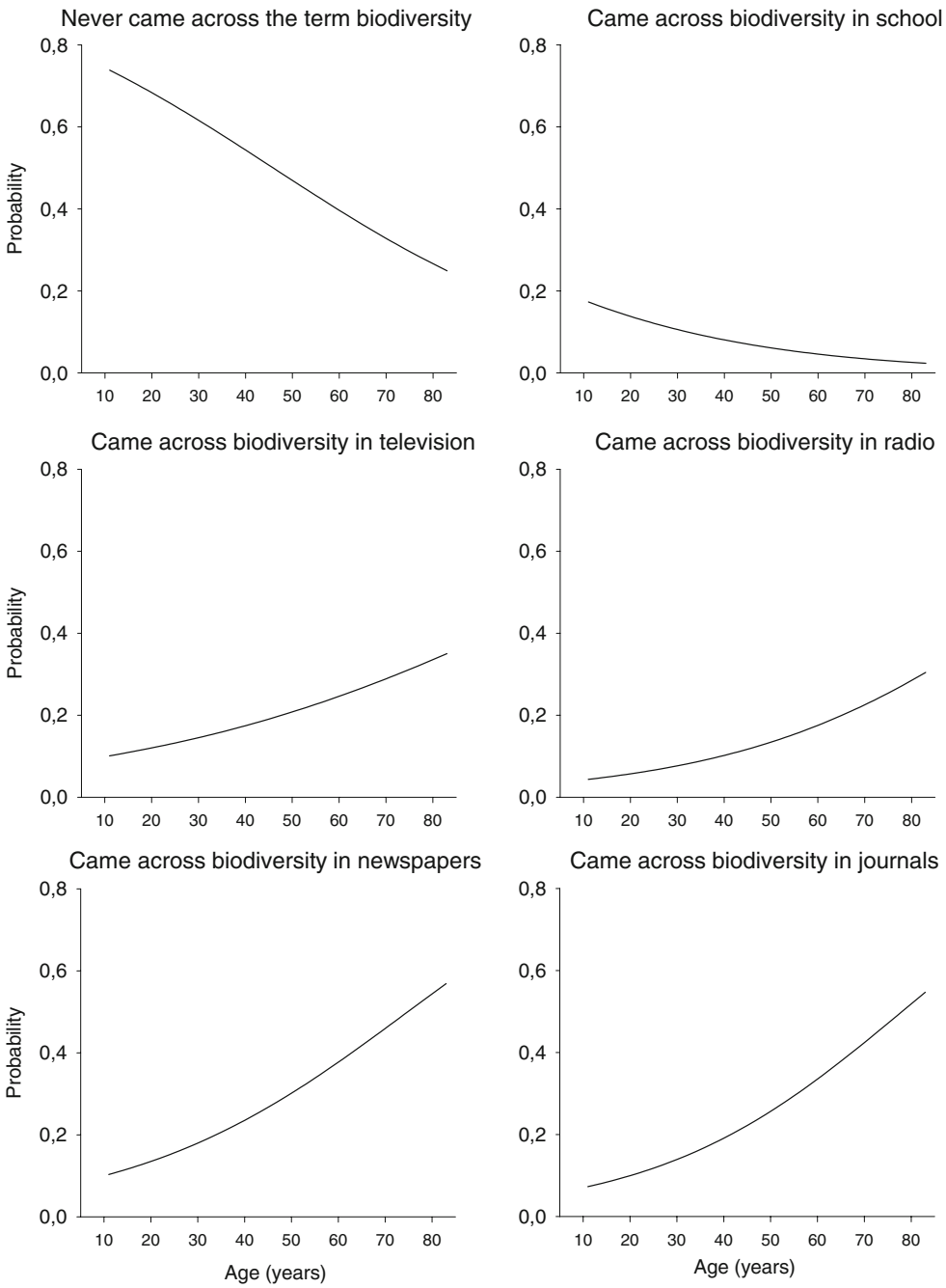

Fig. 2 The relationship between the probability that study participants were either unfamiliar with the term biodiversity or had come across it in school and the media, and the age of the participants. Overall, 367 people (youth, non-graduates, and graduates or students) in the Canton of Zurich answered the questions. Multiple answers were possible. The data were analysed by logistic regressions

Discussion

Our results clearly demonstrate that 11 years after the Convention on Biodiversity came into force (Switzerland: signed 1992, ratified 1994), and more than 20 years after the first usage of the term biodiversity (Wilson 1988), people in Switzerland, at least in the Canton of Zurich, are still unfamiliar with its meaning. Almost two-thirds of our study participants had never heard about biodiversity, but familiarity with its meaning increased with the educational level of respondents (but see Colton and Alpert 1998). In light of similar findings from a study undertaken almost 12 years ago in the USA (Turner-Erfort 1997), the general public appears to be quite resistant to information on biodiversity. This limited knowledge of the public about biodiversity might explain why in surveys the loss of species is considered only a minor environmental problem (Gigliotti 1994; Ayres 1998).

We expected that young, well-educated people would name their school education as a main source of knowledge about biodiversity. However, although school education was increasingly named with decreasing age, it was hardly considered a serious source of information about biodiversity. One reason might be that in the last decade academic

Table 2 Definitions of the term biodiversity chosen by 37 grammar school pupils, 41 adults without a university degree, and 45 graduates or students of different subjects in the Canton of Zurich, Switzerland

Definitions of biodiversity	Youth (%)	Non-graduates (%)	Graduates or students (%)	χ^2-value and sig.
Diversity of plants and animals[a]	75.7	82.9	88.9	2.50
Diversity of ecosystems[a]	32.4	39.0	60.0	7.05*
Genetic diversity[a]	32.4	24.4	48.9	5.86
Equilibrium between all components of nature	8.1	48.8	22.2	17.16**
Relationship between plant and animal species	0.0	39.0	20.0	18.29**
Variety of organic food	0.0	2.4	0.0	2.02
Biological washing powder	0.0	0.0	0.0	–

Study participants were asked to choose among seven preconstructed definitions of biodiversity the appropriate ones. Only participants who had stated to be familiar with the term biodiversity were included.
*$p<0.05$, **$p<0.001$
[a] Denotes the correct answer combination. Differences between the three types of participants were analysed by using chi-square tests.

biology (Greene 2004) and, in consequence, school biology has become increasingly dominated by physiology, molecular biology, and genetics (Hershey 1996; Yore and Boyer 1997; FSC and BES 2002). Therefore, many teachers today have very little experience with fieldwork, ecology, whole organism biology, and biodiversity (FSC and BES 2002; Lindemann-Matthies and Kadji-Beltran 2006). In consequence, they might not be able or even willing to teach about biodiversity. In a recent study, nature-based investigations which are seen as an important component of biodiversity education (McLeish 1997; Van Weelie and Wals 2002), were found to be particularly restricted by the belief of teachers that they would require more specialist knowledge than they have (Brewer 2002).

The term biodiversity encompasses a broad spectrum of biotic scales, from genetic variation within species to biomes of the planet and is frequently described in terms of numbers of genotypes, species, or ecosystems (IUCN, UNEP and WWF 1991; Hooper *et al.* 2005). In our study participants most frequently referred to the diversity of plant and animal species when defining biodiversity, but also quite often believed that biodiversity had something to do with ecological concepts such as the equilibrium between all the components of nature. However, as the present data indicate even people hardly familiar with the term biodiversity might at least know something about the implications of the loss of biodiversity if the term is explained to them. They notably argued in ecological terms, probably because ecology has for a long time been taught in schools in Switzerland. Study participants also wanted to preserve the diversity of species for aesthetic reasons or just felt that diverse landscape elements contribute to the well-being of humans. A strong preference for diverse vegetation has also been found in other studies. In these studies experimentally arranged plants in meadow-like arrays of different levels of diversity, but also natural vegetation plots along waysides were presented to more than 1,000 randomly selected people. The more species-rich a plant community was, the more it appealed to people (Junge *et al.*, 2004). Moreover, high plant species richness was also a typical feature of ideal meadows that people were asked to create by themselves, and diversity was explicitly stated as a main assemblage criterion (Lindemann-Matthies and Bose 2007).

Rough estimates of the number of species on earth range from 10 to 100 million species (overview in Heywood 1995), with a mean estimate of approximately 14 million species (Purvis and Hector 2000). For plant diversity, the estimates are much more precise than for animal diversity. To be able to compare at least rough estimates with real numbers, we only investigated people's estimates of plant species richness. The results strongly indicate that people have widely inaccurate ideas of the number of plant species

Table 3 Estimated number of plant species worldwide, in Switzerland, and in 100×100 m areas of different habitats in Switzerland by 367 people in the Canton of Zurich, Switzerland

	World	Switzerland	Alpine meadow	Lawn	Spruce forest	Beech forest
Minimum	200	100	10	1	2	2
Maximum	1×10^{15}	4×10^{9}	1×10^{9}	2×10^{9}	1×10^{6}	1×10^{8}
Percentile 25	400,000	8,000	60	10	20	30
Median	3,000,000	94,000	120	20	50	70
Percentile 75	66,981,623	712,500	598	100	200	200
Actual number	285,000	3,000	≤100	≤10	≤20	≤40
Overestimation (median/real)	10.5	31.3	1.2	2.0	2.5	1.8

in communities. Particularly for Switzerland plant species richness was strongly overestimated by both young people and adults. Unfortunately, convincing people about the problem of the loss of plant diversity might be more difficult when the perception of the current number is so different from reality. In Switzerland, for instance, 1,000 of the 3,000 higher plant species are currently threatened and on the Red List (Moser *et al.* 2002). If this quantity is communicated to a public who, as our data suggest, estimates that there are 31-times more species, the loss might not be perceived as a serious problem at all.

In view of the increasing attention that is given to the need to preserve biological diversity since the signing of the biodiversity convention, our results are surprising. Educational efforts do not appear to have improved the level of public knowledge and awareness about biodiversity very much either in Switzerland or elsewhere (see Colton and Alpert 1998). The concept is only vaguely known from the media. However, the media often present a biased view of the natural world by focusing on impressive scenery, habitats and animals. In consequence, most natural environments must appear dull and insignificant, and hence of little value to people (Hanski 2005). Our results are particularly remarkable because our study participants are very likely more knowledgeable than the general public. Visitors to botanical gardens and museums, and highly-educated grammar school pupils are more likely to be interested in and knowledgeable about biodiversity than the average person. Moreover, people participating in the oral interviews had ample time to indicate any knowledge they might have about biodiversity, and were even given clues. However, caution should be exercised in generalizing the results of the present study since the findings are based on investigations involving overall only 400 people in one canton of Switzerland.

At present, the loss of biodiversity does not affect people in Switzerland and its reduction might therefore not be considered a serious problem. Yet measures to preserve biodiversity are urgently needed, and the necessity to mobilize popular and political support for its conservation and sustainable use has frequently been pointed out (CBD 2002; Hanski 2005; UNEP/CBD/COP/8/14 2006). In particular, it has been postulated that high priority should be given to the integration of biodiversity education into curricula from kindergarten to university (UNEP/CBD/COP/8/14 2006, p. 24). However, such recommendations are often expressed in hypothetical terms, leaving the reader to decide which approaches should best be used to make laypersons understand the relevance of biodiversity for their everyday lives.

Extensive research has been undertaken to evaluate the main predictors for responsible proenvironmental behavior (see references in e.g. Hines *et al.* 1986; Hungerford and Volk 1990; Leeming *et al.* 1993; Leeming *et al.* 1997; Stern 2000; Kollmus and Agyeman 2002; Chawla and Cushing 2007), and conclusions for education have been drawn. As mentioned by Hungerford and Volk (1990), educators often assume that by simply making students more knowledgeable about the environment and its problems their behavior can be changed. This approach is based on the assumption that increased knowledge directly leads to a greater awareness of the environment and, in consequence, proenvironmental behavior. However, research does not support this simple model for changing human behavior (e.g. Iozzi 1989; Hungerford and Volk 1990; Leeming *et al.* 1993). The American ecologist Michael Soulé pointed out that nobody can convince his father-in-law of the necessity to preserve biological diversity by simply telling him how bad the current status of the environment is. Such a 'lecture-room' way of education may actually be counterproductive, because it makes people depressed and does not motivate them to actively address the issue (Soulé 1988).

Although the antecedents of action for the environment are far too complex to be visualized through one single framework or diagram (Kollmus and Agyeman 2002), factors such as in-depth knowledge about and personal feelings towards environmental issues, and knowledge of and skills in using environmental action strategies have been identified as major forces to promote self-confidence and participation in environmental issue solving (see review in Hungerford and Volk 1990; Chawla and Cushing 2007). Moreover, environmental sensitivity, which is defined as an empathetic perspective toward the environment, has been identified as being of major significance for the development of concern about nature and a commitment to nature conservation (Tanner 1980; research overview in Chawla 1998). Environmental sensitivity has been shown to be a function of an individual's contact with nature, and is mainly developed during childhood (e.g. Tanner 1980; Palmer and Suggate 1996; Palmer *et al.* 1998). The above mentioned factors relating to willingness to act for the environment are also reflected in the more recent value-belief-norm theory of Stern *et al.* (1999). According to the is theory, people need to (1) value the protection of the environment for its own sake or because they understand its benefits for human society, (2) know enough about environmental issues to understand consequences for themselves and the people and places that matter to them, and (3) believe that they can have an effect on these issues and that social norms prescribe that they should act (see discussion in Chawla and Cushing 2007). What does this mean for conservation/biodiversity education? We suggest three approaches:

(1) Reconnecting people to nature, through relevant experiences in school, work, and recreation, is seen as one major task for conservation education (Brewer, 2002; Balmford and Cowling, 2006). For a promotion

of emotional connections with nature, value formation, and the development of an environmental ethic, conservation education should encourage people to bond with elements in nature, whether those elements are particular animals, plants, species, places, or ecosystems (Saunders 2003). Children in primary schools are an important target group, because young children are particularly interested in living organisms, and like hands-on activities and the study of plants and animals, particularly outside the classroom (Kenney *et al.* 2003; Malone and Tranter 2003; Lindemann-Matthies 2006). However, 6–10 year old children were also found to be the most exploitative, unfeeling and uninformed of all children in their attitudes towards living organisms (Kellert 1985). Thus, the transition from first to fifth grade would seem to be the most opportune time for emphasising affective, emotional concern for living species (Kellert 1985; Orr 1992; Chawla 1998).

By introducing activities that promote awe and wonder of the living world, and a sensitivity to care for organisms and their habitats, a personal association with nature can be developed (Kassas 2002). This underlines the value of field work or, in more general terms, outdoor nature education that ensures contact with organisms and their habitats. Promoting biodiversity awareness at the primary school level should include a wide range of exploratory learning activities and methods for outdoor nature education (Mayer 1992; Barker and Slingsby 1998; Barker *et al.* 2002). Such an approach has been found to be strongly appreciated by both pupils and their teachers (Lindemann-Matthies 2006).

Both children and adults are more interested in animals than in plants (Wandersee and Schussler 2001), and tend to like large animals with considerable intelligence and the capacity for social bonding (e.g. Morris and Morris 1966; Kellert 1993a) or, in the words of Kellert (1985) loveable animals'. In contrast, they tend to avoid invertebrates like insects and spiders because they are small and morphologically and behaviorally unlike humans (Morris and Morris 1965; Kellert 1993b). In view of the loss of biodiversity and the recognition of its value (Millenium Ecosystem Assessment 2005), it has been suggested that education in school should engender a greater appreciation of species other than loveable ones', and that educational efforts might best focus on the affective realm to raise emotional concern and sympathy for a broad range of species (Orr 1992; Kellert 1996). Results from an American survey suggest that conservation education is more effective by increasing general environmental concern than by providing knowledge about specific species (Hunter and Rinner 2004). However, in teaching pupils to care about biodiversity, a knowledge of at least the common organisms around them is seen as vital (Balmford *et al.* 2002; Barker *et al.* 2002; Bebbington 2005).

At present, pupils have a poor knowledge of organisms (Lock 1995; Balmford *et al.* 2002; Bebbington 2005; Lindemann-Matthies 2002, 2005), and the decrease in the importance of whole organism biology particularly at secondary school level might also result in a belief of many pupils that being able to recognize and name organisms is simply not important (Bebbington 2005). Results of a large study in Switzerland show that the more wild plants and animals children noticed in their local environment and could name, the more they appreciated these organisms. Moreover, the more additional wild plants and animals they noticed due to an educational programme, the higher the increase in their appreciation of these species (Lindemann-Matthies 2005). This supports the hypothesis that perception and preferences are closely linked (Kaplan and Kaplan 1989), and that children may appreciate animals other than pets and exotic species and even inconspicuous wild plants if they get to know them. In conclusion, both the promotion of environmental concern and the provision of knowledge about species might be valuable and complementary approaches in conservation education (see Hunter and Rinner 2004).

Effective (biodiversity) education strongly depends on the teachers and their motivation and the quality of their training (Kassas 2002). In-service fieldwork training might help to improve the environmental knowledge and skills of teachers and their ability to deliver nature-based investigations in school (examples in Brewer 2002; Bebbington 2005). Moreover, a strong methodological focus on nature-based investigations during pre-service teacher training was found to positively influence the willingness and confidence of students to apply such activities later on in school (Lindemann-Matthies and Kadji-Beltran 2006). In addition, teachers should be encouraged to make more use of easily accessible settings like school grounds or the surroundings of schools for outdoor nature education (examples in Kenney *et al.* 2003; Malone and Tranter 2003; Rowe and Humphries 2004; Lindemann-Matthies 2006). A short distance between school and study site not only saves money for transportation, but also valuable teaching time, two factors that might otherwise restrict the willingness of teachers to engage in outdoor education (Keown 1986; Lock 1998; Tilling 2004).

(2) Effective solutions to environmental problems require the active participation of scientifically literate citizens (Brewer 2002). Results of the present and related studies show that the lay public expresses general concern about environmental problems such as the loss of biodiversity, but possesses little in-depth knowledge of the issue (Turner-Erfort 1997; Ayres

1998; Hunter and Brehm 2003). However, in a large survey in the United States, the key determinant of behavioral intentions to address global warming was a correct understanding of the causes of global warming (Bord *et al.* 2000). Thus, more in-depth knowledge, i.e. an understanding of cause and probable effects of environmental problems—in our case the loss of biodiversity—with all the uncertainty and complexity included, is required (Bord *et al.* 2000; see also Hungerford and Volk 1990; Stern *et al.* 1999). It has been argued that in school education and elsewhere more graphic conceptualizations of the size of the loss of biodiversity are necessary and that more time should be spent to make numbers relevant and understandable (Dunning 1997). It is likely that an increased ecological awareness might result in more realistic conceptions about the diversity of natural habitats.

(3) An important task of conservation education is to encourage individuals or groups to act in more environmentally-friendly ways (Saunders 2003). However, simply promoting action for the environment is not enough. A distinction has been proposed between private and public actions with an emphasis on those actions which are the most strategic (Stern 2000). In terms of biodiversity conservation, private actions could be to plant a wildflower garden or to offer nesting sites for wild bees. In preschool and elementary school years, small-scale actions at the level of the classroom, the school yard and the local environment might be most appropriate (Chawla and Cushing 2007). However, an analysis of the world's most serious environmental problems suggests that the effect of private actions is limited unless they are combined with organizing for collective public change (Gardner and Stern 2002). Moreover, if people feel that their (small) actions do not have the intended effects or that they cannot implement the solutions they came up with, they feel helpless which might lead to environmental passivity (Kaplan 2000). It has thus been proposed that older students should learn how governments work and how citizens can play an active role in responsible decision making (Van Weelie and Wals 2002; Chawla and Cushing 2007).

Conservation implies active management of human–nature interactions, and is thus as much about people as it is about species or ecosystems (Kaplan *et al.* 1998; Horwitz *et al.* 2001; Mascia *et al.* 2003). However, people value nature for different reasons—intrinsic, economic, emotional, spiritual, or psychological (Trombulak *et al.* 2004). These values are not mutually exclusive, but may vary both within and among cultures, which must be taken into account to achieve conservation (Mascia *et al.* 2003; Trombulak *et al.* 2004; Saunders *et al.* 2006). Fostering environmental literacy is an essential objective for environmental educators. Central to that goal is the belief that imparting a body of environmental science knowledge to students leads to specific types of decision making and active citizenship (Cole 2007). However, as the author critically discusses in her paper, it is a culturally specific body of knowledge that fosters particular ways of thinking and acting in the world. Educators should thus look critically at the ways in which the dominant, western tradition of scientific knowledge, inquiry methodologies, and decision-making behaviors shape environmental education methods and practices. In our view, the highly controversial and value-loaded issue of biodiversity (Van Weelie and Wals 2002) makes it an excellent topic to approach through multidisciplinary frameworks and from different cultural viewpoints.

Finally, the lack of public ecological knowledge and the misconceptions related to ecological principles are major constraints on the conservation of biodiversity, particularly where state management approaches are distinct from the concerns and capacities of local people (Pilgrim *et al.* 2008). Experts such as land managers would thus be wise to be cognizant of local nonexperts' narratives and concerns (Hunter and Brehm 2003; Pilgrim *et al.* 2008). The communication of biodiversity issues should be related to people's everyday life experiences and should be done in more popular terms. Reconnecting people and nature is a major challenge for future conservation biology (Balmford and Cowling 2006). To achieve this, more use should be made of people's personal experiences: what does biodiversity mean for their lives, e.g. for their health and quality of life? At present hardly anything is known about what lay people (both youth and adults) consider meaningful contributions to preserve biodiversity and what they are actually willing to contribute.

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References

Ayres, E. (1998). Worldwatch Report: Fastest Mass Extinction in Earth History. *Environmental News Network*, 16. September 1998.

BAFU (2006). *Red Lists*. http://www.bafu.admin.ch/artenvielfalt/01010/index.html?lang=en (release 22.04.2007).

Balmford, A., Clegg, L., Coulson, T., and Taylor, J. (2002). Why Conservationists Should Heed Pokemon. Science 295: 2367.

Balmford, A., and Cowling, R. M. (2006). Fusion or Failure? The Future of Conservation Biology. Conservation Biology 20: 692–695.

Barker, S., and Slingsby, D. (1998). From Nature Table to Niche: Curriculum Progression in Ecological Concepts. International Journal of Science Education 20: 479–486.

Barker, S., Slingsby, D., and Tilling, S. (2002). Ecological Fieldwork: Is There a Problem? Environmental Education 71: 9–10.
Bebbington, A. (2005). The Ability of A-Level Students to Name Plants. Journal of Biological Education 39: 62–67.
Bord, R. J., O'Connor, R. E., and Fisher, A. (2000). In What Sense Does the Public Need to Understand Global Climate Change? Public Understanding of Science 9: 205–218.
Brewer, C. (2002). Conservation Education Partnerships in Schoolyard Laboratories: A Call Back To Action. Conservation Biology 16: 577–579.
CBD (Convention on Biological Diversity) (1992). Article 2. Use of Terms. http://www.cbd.int/convention/articles.shtml?a=cbd-02 (release 07.09.2008).
CBD (Global Convention on Biodiversity) (2002). Global Strategy for Plant Conservation, Secretariat of the Convention on Biological Diversity, Montreal, Canada.
Chawla, L. (1998). Significant Life Experiences Revisited: A Review of Research on Sources of Environmental Sensitivity. Environmental Education Research 4: 369–382.
Chawla, L., and Cushing, D. F. (2007). Education for Strategic Environmental Behavior. Environmental Education Research 13: 437–452.
Cole, A. G. (2007). Expanding the Field: Revisiting Environmental Education Principles through Multidisciplinary Frameworks. The Journal of Environmental Education 38: 35–44.
Colton, T. F., and Alpert, P. (1998). Lack of Public Awareness of Biological Invasions by Plants. Natural Areas Journal 18: 262–266.
Crawley, M. J. (2005). *Statistics. An Introduction using R*. Wiley, Chichester.
Crawley, M. J., and Harral, J. E. (2001). Scale Dependence in Plant Biodiversity. Science 291: 864–868.
Dunning, J. B. (1997). The Missing Awareness, Part 2: Teaching Students What A Billion People Looks Like. Conservation Biology 11: 6–10.
FSC (Field Studies Council), BES (British Ecological Society) (2002). *Teaching Biology Outside the Classroom. Is it Heading for Extinction?* A report on biology fieldwork in the 14–19 curriculum compiled by S. Barker, D. Slingsby, & S. Tilling. FSC Occasional Publication 72. Montford Bridge, Shrewsbury, Field Studies Council.
Gardner, G. T., and Stern, P. C. (2002). *Environmental Problems and Human Behavior, 2nd edition*. Pearson, Boston, MA.
Gigliotti, L. M. (1994). Environmental Issues: Cornell Students' Willingness to Take Action, 1990. The Journal of Environmental Education 26: 34–42.
Greene, H. W. (2004). Organisms in nature as a central focus for biology. Trends in Ecology and Evolution 20: 23–27.
Groombridge, B. (1992). Global Diversity: Status of the Earth's Living Resources. Chapman and Hall, London.
Hanski, I. (2005). Landscape fragmentation, biodiversity loss and the societal response. EMBO Reports 6: 388–392.
Hershey, D. R. (1996). A historical perspective on problems in botany teaching. The American Biology Teacher 58: 340–347.
Heywood, V. H. (1995). Global Biodiversity Assessment. United Nations Environment Programme. Cambridge University Press, Cambridge.
Hines, J. M., Hungerford, H. R., and Tomera, A. N. (1986). Analysis and Synthesis of Research on Responsible Environmental Behavior, a Meta-analysis. The Journal of Environmental Education 18: 1–8.
Hooper, D. U., Chapin, F. S. III, Ewel, J. J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J. H., Lodge, D. M., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A. J., Vandermeer, J., and Wardle, D. A. (2005). Effects of Biodiversity on Ecosystem Functioning. Ecological Monographs 75: 3–35.
Horwitz, P., Lindsay, M., and O'Connor, M. (2001). Biodiversity, Endemism, Sense of Place, and Public Health: Inter-Relationships for Australian Inland Aquatic Systems. Ecosystem Health 7: 253–265.
Hungerford, H., and Volk, T. (1990). Changing Learner Behavior Through Environmental Education. The Journal of Environmental Education 21: 8–21.
Hunter, L. M., and Brehm, J. (2003). Qualitative Insight into Public Knowledge of, and Concern with, Biodiversity. Human Ecology 31: 309–320.
Hunter, L. M., and Rinner, L. (2004). The Association Between Environmental Perspective and Knowledge and Concern with Species Diversity. Society and Natural Resources 17: 517–532.
Iozzi, L. A. (1989). What Research Says to the Educator. Part One: Environmental Education and the Affective Domain. The Journal of Environmental Education 20: 3–9.
IUCN (2006). Red List of Threatened Species. http://www.iucnredlist.org/ (release 21.04.2007).
IUCN, UNEP, & WWF (1991). Caring for the Earth. A Strategy for Sustainable Living. IUCN, Gland, Switzerland.
Junge, X., Lindemann-Matthies, P., and Matthies, D. (2004). People's Perception and Appreciation of Plant Diversity Along Waysides. Verhandlungen der Gesellschaft für Ökologie 34: 420.
Kaplan, S. (2000). Human Nature and Environmentally Responsible Behaviour. Journal of Social Issues 56: 491–508.
Kaplan, R., and Kaplan, S. (1989). The Experience of Nature. A Psychological Perspective. University Press, Cambridge.
Kaplan, R., Kaplan, S., and Ryan, R. L. (1998). *With People in Mind*. Island Press, Washington DC.
Kassas, M. (2002). Environmental Education: Biodiversity. The Environmentalist 22: 345–351.
Kellert, S. R. (1985). Attitudes Toward Animals: Age-Related Development Among Children. The Journal of Environmental Education 16: 29–39.
Kellert, S. R. (1993a). Attitudes, Knowledge, and Behaviour Toward Wildlife Among the Industrial Superpowers: United States, Japan, and Germany. Journal of Social Issues 49: 53–69.
Kellert, S. R. (1993b). Values and Perceptions of Invertebrates. Conservation Biology 7: 845–855.
Kellert, S. R. (1996). *The Value of Life*. Island Press, Washington DC.
Kenney, J. L., Price Militana, H., and Horrocks Donohue, M. (2003). Helping Teachers to Use Their School's Backyard as an Outdoor Classroom: A Report on the Watershed Learning Center Program. The Journal of Environmental Education 35: 15–21.
Keown, D. (1986). Teaching Science in U.S. Secondary Schools: A Survey. The Journal of Environmental Education 18: 23–29.
Kollmus, A., and Agyeman, J. (2002). Mind the Gap: Why Do People Act Environmentally and What Are the Barriers to Pro-Environmental Behavior? Environmental Education Research 8: 239–260.
Lauber, K., and Wagner, G. (2001). *Flora Helvetica, 3rd. edition*. Verlag Paul Haupt, Berne, Switzerland.
Leeming, F. C., Dwyer, W. O., Porter, B. E., and Cobern, M. K. (1993). Outcome research in environmental education, a critical review. The Journal of Environmental Education 24: 8–21.
Leeming, F. C., Dwyer, W. O., Porter, B. E., Cobern, M. K., and Oliver, D. P. (1997). Effects of Participation in Class Activities on Children's Environmental Attitudes and Knowledge. The Journal of Environmental Education 28: 33–42.
Lindemann-Matthies, P. (2002). The Influence of an Educational Program on Children's Perception of Biodiversity. The Journal of Environmental Education 33: 22–31.
Lindemann-Matthies, P. (2005). 'Loveable' Mammals and 'Lifeless' Plants: How Children's Interest in Common Local Organisms can be Enhanced Through Observation of Nature. International Journal of Science Education 27: 655–677.
Lindemann-Matthies, P. (2006). Investigating Nature on the Way to School: Responses to an Educational Programme by Teachers

and Their Pupils. International Journal of Science Education 28: 895–918.

Lindemann-Matthies, P., and Bose, E. (2007). Species Richness, Structural Diversity and Species Composition in Meadows Created by Visitors of a Botanical Garden in Switzerland. Landscape and Urban Planning 79: 298–307.

Lindemann-Matthies, P., and Kadji-Beltran, C. (2006). Biodiversity as an Issue in Pre-service Teacher Training. Teaching Ecology Newsletter 34: 10–12.

Lock, R. (1995). Biology and the Environment—A Changing Perspective? Or 'There's Wolves in Them There Woods!'. Journal of Biological Education 29: 3–4.

Lock, R. (1998). Fieldwork in the Life Sciences. International Journal of Science Education 20: 633–642.

Malone, K., and Tranter, P. J. (2003). School Grounds as Sites for Learning: Making the Most of Environmental Opportunities. Environmental Education Research 9: 283–303.

Mascia, M. B., Brosius, J. P., Dobson, T. A., Forbes, B. C., Horowitz, L., McKean, M. A., and Turner, N. J. (2003). Conservation and the Social Sciences. Conservation Biology 17: 649–650.

Mayer, J. (1992). *Formenvielfalt im Biologieunterricht* [Biological Diversity in Biology Education]. IPN, Kiel.

McLeish, E. (1997). *Educating for Life. Guidelines for Biodiversity Education*. Council for Environmental Education, Reading.

Meffe, G. K. (1994). Human population control: the missing awareness. *Conservation Biology* 8: 310–313.

Millenium Ecosystem Assessment (2005). *Current State and Trends*. Island Press, London.

Morris, R., and Morris, D. (1965). *Men and Snakes*. Hutchinson, London.

Morris, R., and Morris, D. (1966). *Men and Pandas*. Sphere Books, London.

Moser, D. M., Gygax, A., Bäumler, B., Wyler, N., & Palese, R. (2002). *Rote Liste der gefährdeten Arten der Schweiz: Farn- und Blütenpflanzen* [Red List of Threatened Ferns and Flowering Plants in Switzerland]. Swiss Agency for the Environment, Forests and Landscape (SAEFL), Berne, and Centre du Réseau Suisse de Floristique (CRSF).

Orr, D. W. (1992). *Earth in Mind*. Island Press, Washington, DC.

Palmer, J. A., and Suggate, J. (1996). Influences and Experiences Affecting the Pro-environmental Behavior of Educators. Environmental Education Research 2: 109–121.

Palmer, J. A., Suggate, J., Bajd, B., and Tsaliki, E. (1998). Significant Influences on the Development of Adults' Environmental Awareness in the UK, Slovenia and Greece. Environmental Education Research 4: 429–444.

Pilgrim, S. E., Cullen, L. C., Smith, D. J., and Pretty, J. (2008). Ecological Knowledge is Lost in Wealthier Communities and Countries. Environmental Science & Technology 42: 1004–1009.

Purvis, A., and Hector, A. (2000). Getting the Measure of Biodiversity. Nature 405: 212–219.

Rowe, S., and Humphries, S. (2004). The outdoor classroom. In Braund, M., and Reiss, M. (eds.), Learning Science Outside the Classroom. Routledge, London, pp. 19–34.

Saunders, C. D. (2003). The Emerging Field of Conservation Psychology. Human Ecology Review 10: 137–149.

Saunders, C. D., Brook, A. T., and Myers, O. E. Jr (2006). Using Psychology to Save Biodiversity and Human Well-Being. Conservation Biology 20: 702–705.

Soulé, M. E. (1988). Mind in the biosphere; mind of the biosphere. In Wilson, E. O. (ed.), Biodiversity. National Academic Press, Washington DC, pp. 465–469.

Stern, P. C. (2000). Toward a Coherent Theory of Environmentally Significant Behavior. Journal of Social Issues 56: 407–424.

Stern, P. C., Dietz, T., Abel, T., Guagnano, G. A., and Kalof, L. (1999). A Value–Belief–Norm Theory of Support for Social Movements: The Case of Environmental Concern. Human Ecology Review 6: 81–97.

Tanner, T. (1980). Significant Life Experiences: A New Research Area in Environmental Education. The Journal of Environmental Education 11: 20–24.

Thomas, C. D., Cameron, A., Rhys, E., Green, M., Bakkenes, L. J., Beaumont, Y., Collingham, C., Erasmus, B. F. N., Ferreira de Siqueira, M., Grainger, A., Hannah, L., Hughes, L., Huntley, B., Van Jaarsveld, A. S., Midgley, G. F., Miles, L., Ortega-Huerta, M. A., Peterson, A. T., Phillips, O. L., and Williams, S. E. (2004a). Extinction Risk from Climate Change. Nature 427: 145–148.

Thomas, J. A., Telfer, M. G., Roy, D. B., Preston, C. D., Greenwood, J. J. D., Asher, J., Fox, R., Clarke, R. T., and Lawton, J. H. (2004b). Comparative Losses of British Butterflies, Birds, and Plants and the Global Extinction Crisis. Science 303: 1879–1881.

Tilling, S. (2004). Fieldwork in UK Secondary Schools: Influences and Provision. Journal of Biological Education 38: 54–58.

Trombulak, S. C., Omland, K. S., Robinson, J. A., Lusk, J. J., Fleischner, T. L., and Domroese, M. (2004). Principles of Conservation Biology: Recommended Guidelines for Conservation Literacy from the Education Committee of the Society for Conservation Biology. Conservation Biology 18: 1180–1190.

Turner-Erfort, G. (1997). Public Awareness and Perceptions of Biodiversity. Transactions of the Illinois State Academy of Science 90: 113–121.

UN (United Nations) (2002). Report of the World Summit on Sustainable Development. Johannesburg, South Africa, 26 August–4 September 2002. A/Conf.190/20.

UNEP/CBD/COP/8/14 (2006). Global Initiative on Communication, Education and Public Awareness. Conference of the Parties to the Convention on Biological Diversity, 8th meeting Curibita, Brazil (20–31 March 2006).

Van Weelie, D., and Wals, A. (2002). Making Biodiversity Meaningful Through Environmental Education. International Journal of Science Teaching 24: 1143–1156.

Wandersee, J. H., and Schussler, E. E. (2001). Toward a Theory of Plant Blindness. Plant Science Bulletin 47: 2–9.

Wilson, E. O. (1988). *Biodiversity*. National Academic Press, Washington, DC.

WRI (World Resources Institute), IUCN (The World Conservation Union), UNEP (United Nations Environment Programme) (1992). Global Biodiversity Strategy. Guidelines for Action to Save, and Use Earth's Biotic Wealth Sustainably and Equitably. WRI, IUCN/UNEP.

Yore, L. B., and Boyer, S. (1997). College Students' Attitudes Towards Living Organisms: The Influence of Experience & Knowledge. The American Biology Teacher 59: 558–563.