2016

Biological diversity in the biology classroom: teachers' approaches, attitudes, and knowledge

Krystal Rachelle Wikstrom
Iowa State University

Biological diversity in the biology classroom: Teachers' approaches, attitudes, and knowledge

by

Krystal Rachelle Wikstrom

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Ecology and Evolutionary Biology

Program of Study Committee
James T. Colbert, Major Professor
Joanne K. Olson
Thomas W. Jurik

Iowa State University

Ames, Iowa

2016

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGMENTS

I sincerely thank my major professor, Jim Colbert, and my committee members, Thomas Jurik and Joanne Olson, for their continuous guidance and support throughout this research endeavor.

I also offer my appreciation to my friends and family for their constant optimism and encouragement. Additionally, I thank the many Iowa teachers who were willing to take time out of their busy schedules to participate in my survey.

ABSTRACT

Many biological scientists agree that our planet is experiencing a loss of biological diversity, and the available data provide support for the conclusion that the Earth may be facing a sixth mass extinction event. It is essential that the people of the world understand the threats that we face as a result of the loss of biodiversity. An important place to improve understanding is in our secondary school classrooms, as tomorrow's conservation-minded citizens are today's students. Before we can reach out to the students with this information, it is important to understand the current state of biodiversity education in secondary school biology classrooms. To do this, an anonymous survey was created and administered to Iowa secondary school biology teachers. The survey included a number of questions designed to examine and understand teacher approaches, knowledge, and attitudes regarding biodiversity.

The responses of 92 secondary school biology teachers were analyzed using SPSS statistics software. The data revealed that Iowa teachers have similar, positive, attitudes towards teaching biological diversity, but they are not approaching the topic in a consistent way. The respondents scored a mean of 74% on the biodiversity knowledge section of the survey. There was a significant difference in knowledge of biodiversity between middle school and high school teachers. Considering the global significance of the topic of biodiversity, it is vital that we strive to continue, and improve, biodiversity education.

CHAPTER I: INTRODUCTION

Many experts agree that that our planet is currently facing a sixth mass extinction event, with biodiversity losses occurring at an alarming rate [1-3]. Most now agree that rather than worrying about whether we are or are not currently in an extinction event, we should instead focus on protecting the biodiversity we currently have remaining [4]. It is not only the Earth's biological diversity that is threatened but also the proper functioning of affected ecosystems and in turn, the services that those ecosystems provide to humanity [5] The economic toll of these collapsing networks is vast and potentially daunting, and so it is no wonder that we now see an increased focus on disciplines such as Agronomy and Forestry, which are dedicated to the study of how we will deal with the practical issues of feeding, clothing, and housing the world's inhabitants in the years to come [6]. While these researchers are dealing directly with the economic dilemma brought about by decreasing biodiversity, we must not forget the more personal moral dilemma that decreases in biodiversity represent. Human activities (e.g., habit destruction, overharvest, introduced species, pollution) have clearly led to decreases in biodiversity [7]. To the extent that human actions are affecting climate change (i.e., CO_2 pollution impacting habitat availability), our current day-to-day lifestyles are linked with the extinction of species around the globe. Conservation efforts have been sprouting up with increasing frequency for many years [8]. While these efforts are critical to protect particular endangered species, in order to better protect the biological diversity of the entire planet it is critically important to focus efforts on providing quality biodiversity education to increase support for the protection of threatened and common species alike. We need to educate people on what is happening and what we stand to lose, and how quickly we may lose it if corrective actions are not taken soon. What is the state of biodiversity education in the secondary school classroom? This work is dedicated to trying to begin to answer that question.

The knowledge gained from this study is intended to inspire more informed efforts to improve the teaching of biodiversity. We need effective methods to introducing biodiversity and its significance in the classroom as a way to combat what is currently happening to biological diversity on Planet Earth.

CHAPTER II: REVIEW OF LITERATURE

Biological Diversity

The available evidence leads to the conclusion that there have been five mass extinction events on Earth which occurred at the ends of the Ordovician, Devonian, Permian, Triassic, and Cretaceous Periods [1]. A mass extinction is defined as a global and rapid biodiversity loss occurring across taxonomic groups within a relatively short period of geological time [9]. Further, and as is true for the "big five" mass extinction events, paleontologists characterize a mass extinction event as having higher than expected extinction rates, with a loss of over 75% of estimated species within a geologically short time interval [1]. Concurrently, biodiversity is a broad concept that is not so easy to concisely define. The Convention on Biodiversity (CBD) defines biological diversity as "the variability among living organisms from all sources including . . . 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" [10] In this work, I will use biodiversity as it is defined by the CBD.

Each of the five mass extinction events had particular causes and outcomes. Occurring during an alternation of glacial and interglacial episodes, the end of the Ordovican Period occurred around 443 million years ago, and was characterized by an estimated 86% drop-off in global species numbers within 1.9 - 3.3 million years [1]. The Devonian Period ended around 359 million years ago, with an estimated loss of 75% of species within 2 - 29 million years. The cause of the Devonian Extinction, like the Ordovican, is commonly thought to be a global thermal transition, in this case a round of global cooling followed by global warming [1]. The Permian concluded approximately 251 million years ago with an estimated loss of 96% of species within 160,000 years - 2.8 million years. The cause is thought to be related to global warming [1] resulting from massive volcanic explosions in current day Siberia. Recent evidence suggests that these explosions may have been triggered by a large meteorite impact in Antarctica [11]. The Triassic Period ended around 200 million years ago and within 600,000 years – 8.3 million years; a loss of 80% of species is estimated. Elevated atmospheric CO_2 levels, and in turn global warming, are proposed to have caused this event [1]. Finally, the Cretaceous concluded approximately 65 million years ago and, somewhere within 1 year and 2.5 million years, approximately 76% of species were lost. Rapid cooling is ultimately what caused this event, thought to be triggered by the impact of an asteroid in the Yucatan Peninsula [1]. Species losses observed in these events are shocking. One may be just as shocked to find themselves asking if this could really be happening now, and whether humans are impacting biodiversity on a scale previously achieved only by massive geological events.

The natural world has been greatly altered from its state 10,000 years ago, the approximate point in human history at which agriculture was developed. This alteration is largely attributed to human activities, including the fragmentation of habitats, introduction and globalization of invasive species, the stripping of vital resources from ecosystems, encouraging the spread of pathogens, directly killing organisms to the point of extinction, and having an overall impact on the global climate [1,4,12]. Perhaps the greatest threat due to these activities is the staggering loss of biodiversity we are currently observing. Clearly scientists are viewing the biodiversity losses as detrimental and alarming, but does it qualify as a mass extinction? Many notable scientists are convinced that, in fact, we are currently in a sixth mass extinction. When considering species loss estimations, it is believed that the results of these studies may even be gross underestimates, as the majority of species on the planet have not been scientifically described yet and as such, their losses can't be estimated [1]. The most recent large meta-analysis on the sixth mass extinction was completed in 2015 by Gerardo Ceballos and team [3]. In this work, the authors aimed to determine whether the current extinction rate is significantly above the background rate. Due to criticism [13] of overestimation of species loss in previous works, the authors used highly conservative assumptions. As stated by the authors, highly conservative assumptions means that they avoided using assumptions in the analysis that, in previous works, were associated with overestimates of extinction rates [3]. To calculate the modern extinction rate, the authors used data from extinct, and possibly extinct, vertebrate species from the 2014 IUCN Red list. They only used vertebrates because this is the group for which we have the most robust and reliable data [3]. For the background extinction rate, the authors used the number 2 E/MSY, or 2 extinctions per 10,000 vertebrate species per 100 years. This rate is considered to be highly conservative when compared to previous estimates [1,3]. Comparing these estimates, the authors found that the number of vertebrate species going extinct in the last 100 years would have taken 800 to 10,000 years to go extinct at the background extinction rate [3]. These estimates are alarming and support the conclusion that a sixth mass extinction is underway, and even more worrisome, these estimates are thought to be quite conservative. If data were available for other taxonomic groups, the results might be even more alarming.

Despite the mounting evidence that we are entering a sixth mass extinction, there are some critics. Among the most prominent of these is Bjørn Lomborg, a Danish author and Adjunct Professor at the Copenhagen Business School. He has written books and contributed to conversations with the view that scientists are making use of assumptions that are overestimating species loss, which leads to conclusions that are making the extinction crises appear more ominous than they actually are [13]. After the more conservative report of Ceballos et al. (2015) was published, Lomborg only took issue with the authors' discussion of future implications and was otherwise in agreement [2]. More specifically, Lomborg was in agreement that it is a problem but predicted that the richer countries would respond with concentrated conservation efforts before it would become a real threat to the natural world [2]. This prediction, however, may not be well founded. This assumption that richer countries will provide conservation efforts is predicated upon such countries being aware of the problem and being committed to a solution. Unfortunately, awareness in wealthy countries such as the United States is quite low, as evidenced by the Convention on Biological Diversity, that indicates we have a lot remaining to learn and do in terms of addressing the critical issue of biodiversity conservation [14].

Ecosystem Services Are Under Threat

From both an ecological and anthropocentric perspective, one of the greatest threats caused by biodiversity loss is the decreased productivity of ecosystems, and in turn a decreased ability for these ecosystems to provide goods and services to people [12]. Ecosystem functions refer to the ecological processes involving the biotic and abiotic factors in an environment that govern the fluxes of carbon, energy, and nutrients through the environment [12]. Ecosystem services are then defined as the benefits that organisms, be they human or otherwise, receive from ecosystems as they perform their functions [12]. Scientists agree that there are four categories of ecosystem services [15]. The first category is referred to as provisioning services which are the services that are directly acquired from ecosystems, and include energy, food, water, and other raw materials [15]. The second category is regulating services which are the benefits that humans receive from the proper functioning of an ecosystem [15]. These can include the decomposition of waste materials, flood regulation, pest control, and disease control [15]. The third is cultural services which are services that are nonmaterial but rather the experiences that humans benefit from interacting with nature, and include spiritual connections, recreational experiences, and the aesthetic beauty of the natural world [15]. The fourth and final category is supporting services which are related to all other categories and are defined as those services that are required for the other ecosystem services to exist [15]. Some examples include nutrient recycling and soil formation [15]. Since the 1980s, there has been a rising concern about what effect the sudden loss of biodiversity will have on Earth's various ecosystems and the services that they provide [12]. The 1992 Earth Summit in Rio de Janeiro increased focus on this concern [12]. Since the 1992 Earth Summit, extensive research effort has been focused on understanding how the productivity and dynamics of ecosystems will change in association with the predicted biodiversity losses. To highlight a few of the international initiatives that were spurred by this issue: The Scientific Committee on Problems of the Environment released a book about biodiversity and ecosystem functioning [12,16], The United Nations Environment Program produced the Global Biodiversity Assessment [12,17], and a biodiversity science international program called DIVERSITAS developed a global research agenda [12,18]. During the last two decades, we have compiled a number of lines of evidence that address how biodiversity loss impacts ecosystem functioning. In their review paper published in 2012 in *Nature*, Bradley Cardinale et al. developed six consensus statements regarding this topic using the available evidence. The first consensus states that as a general rule, biodiversity losses negatively impact the efficiency of biological communities at capturing nutrients, water, light and prey items as well as the ability to convert those resources into biomass [12]. The second consensus states that an increase in biodiversity leads to the stability of ecosystem functioning through time. The third consensus states that change in any given ecosystem process accelerates as biodiversity loss increases. The fourth consensus states that due to the presence of keystone species, diverse communities are more productive. The fifth consensus states that the loss of biodiversity across trophic levels impacts ecosystem functioning more than loss within trophic levels. Finally, the sixth consensus states that functional traits of organisms impact ecosystem functioning. From the extensive research on this topic, it is clear that biodiversity loss impacts ecosystem functioning at multiple levels, but what effect does this have on humans?

There are three main ways that humans are impacted by biodiversity loss: ecosystem services are impacted, there is a loss of biological information, and, perhaps most tragic in the poetic sense, there is the loss of natural beauty as well as the familiar bond to the natural world which has long been a part of the human experience. As former US President and ardent conservationist Theodore Roosevelt opinioned, "The conservation of natural resources is the fundamental problem. Unless we solve that problem it will avail us little to solve all others" [19].

In order to assess our current knowledge about the effects of biodiversity loss on the outcomes of ecosystem services, Cardinale et al. (2012) reviewed over 1,700 papers on the topic. While the results are complex, there is clear evidence that biodiversity levels, either directly or indirectly, influence ecosystem services in many instances [12]. While biodiversity wasn't linked to ecosystem services in every case, including those with mixed results or insufficient data, this in no way suggests that we should not continue to examine the relationship between biodiversity loss and ecosystem services; it is simply an indication that more work needs to be done to get a clearer picture of a complex relationship.

The second way biodiversity loss impacts humans is the loss of biological information. Tucked inside the DNA and proteins of organisms around the world are clues to cure human diseases, solve world human hunger issues, and many more human problems [20]. When you lose a species, you are losing all of the genetic information from that species. Once we lose this information due to an extinction event, it is quite likely that we will never be able to get it back.

Thirdly, a decrease in biodiversity can severely diminish much of this world's natural beauty and the human bond with it. Humans interact with the natural world, and have done so since the beginning of humanity. Humans, as described by E. O. Wilson in his book *Biophilia* [21], have a tendency to want to form connections with the natural world and the other organisms that are a part of it. In his book *The Diversity of Life*, Wilson (1992) notes that there is a recent delusion by humans that they can exist separate from the natural world, and that it is a delusion because of the existence of many identifiable examples where humankind's interactions with the natural world have had a predictable and repeatable effect on our own behavior as a species [22]. Human phobias are one such example. Phobias, Wilson argues, are more typically associated with elements of the natural world as opposed to human made objects [22]. Two pervasive phobias which cross cultural boundaries are a fear of snakes and spiders, likely due mostly to an association that has been honed over our shared evolutionary history [22]. Another example of how the natural world shapes human activities in this text is humans' desire to spend leisure time in the natural world [22]. He notes that in North America, more people visit zoos, natural parks, and aquariums than regularly frequent athletic events [22]. The reason for this seems to be related to the desire to connect with the natural world and the non-human organisms that make it up. In fact, it has been noted that when children are separated from nature there are cascading social and psychological effects [23]. In this way, the relationships individuals have with the natural world can be quite personal. It is important to note that separation from nature can occur both through a geographic inability to reach natural areas as well as the ever-growing reliance that younger generations have on their technology. If we continue to experience high rates of biodiversity loss, we stand to lose aesthetic pleasures as well as our connection with the natural world, which does not appear to be in humankind's best interest.

State of Biodiversity Education

Biodiversity loss has been of concern both nationally and internationally for some time [24]. In fact, the Convention on Biological Diversity (CBD), since the 1990s, has existed with the global goal of biodiversity conservation [25]. Despite the 20 years of existence of the CBD, biodiversity threats are only increasing. What is the reason for this? There are many, but one that is of major significance and yet is less frequently discussed [14] is a lack of public education, awareness, and understanding [24]. Without these things, there will be little initiative by citizens to change their daily habits and politics associated with biodiversity loss [14].

Biodiversity education is occurring, but faces many challenges [24]. In Navarro–Perez and Tidball's study, they list four main challenges to biodiversity education [24]. The first challenge they posit is that a clear approach to biodiversity education has yet to be defined [24]. The second challenge that they put forth is that biodiversity as a concept is complex and somewhat difficult to define, and they argue that this poses difficulties for both the teacher and the student [24]. The third challenge discussed is improper communication strategies when trying to reach the wider public [24]. They argue that the methods employed thus far have been too simple, and to be more effective, there needs to be a consideration of context as well as the attitudes and values of the target populations we are attempting to reach [24]. The fourth challenge the authors offer is a fundamental disconnect between humans and the natural world, which they argue is increasing due to a larger proportion of people living in urban environments [24]. The authors [24] assessed 70 articles addressing the topic, and found less than 20 articles that included the exact phrase of "biodiversity education." Of these articles, the majority addressed the topic through an Environmental Education (EE) or Education for Sustainable Development (ESD) lens [24].

Some efforts in biodiversity education have focused on field-based biodiversity courses such as Sebastian Kvist et al.'s course in a North American marine environment at Passamaquoddy Bay (2011) as well as Stam M. Zervanos and Jacqueline S. McLaughlin's field courses on biodiversity and evolution (2003). The field approach is the primary focus of these studies [26-29]. Additionally, there are a number of programs with biodiversity components that exist and are developed for schools [30]. Some examples are *Project Wild* [30] and *Windows on the Wild* [30]. A more local example comes from Project WET Iowa, which is an aquatic ecology education program developed to supplement existing curriculum [31]. There seems to be a prevailing belief in these works and programs that biological diversity needs to be experienced first-hand by the students in order to be fully appreciated and understood. While obviously beneficial to the students that have these opportunities, a focused emphasis on field-based techniques is not always appropriate, however, since there are many schools in which the resources are limited for such a course. McCoy et al. addressed this in their 2007 paper which focused on teaching biological diversity in inner city and under-resourced classrooms. They developed in-class activities and a seven-part presentation to introduce the topic of biodiversity in response to a lack of non-field approaches. The presentation introduced students to the concept of biodiversity as well as ecosystem services with an additional aim to encourage students to gain an appreciation of biodiversity. Following the presentation, they had discussions about causes of biodiversity losses, in addition to steps that can be taken to slow these losses. While there have been a small number of studies focusing on these types of accessible approaches, there have certainly been fewer studies published on alternatives to the field approach as there are classrooms that could benefit from them.

Internationally, works on this topic are similarly lacking. Most of these studies have been conducted in a small region of the world using open-ended interviewing techniques with teachers [30,32]. Typically, the focus of these studies is upon teachers' conceptions of biodiversity and how it should be taught in the context of their curriculum. From these works, it appears that teaching biodiversity is typically addressed as it relates to other issues such as evolution and the environment [30,32]. It should be noted that even in some of the bigger studies, the sample sizes of teachers is typically small, and the studies are typically restricted to a particular area of the world. For instance, Chris Gayford completed a study regarding teachers' attitudes and approaches to biodiversity education in a region of Southern England by meeting with five separate focus groups consisting of four to five teachers from the area [30]. Another key study was completed by Paloma Rodrigues da Silva et al. in the Bauru region of São Paulo in Brazil, however they were more interested in teachers' notions of biological evolution instead of focusing upon biodiversity alone [32].

Given the importance of biodiversity with respect to ecosystem services and the human condition, and taken together with the relative lack of studies from the US and international groups, it appears that our understanding of how biological diversity is addressed in the pre-college classroom is currently understudied and requires exploration.

Biodiversity Education in Iowa

To date, there are no studies that directly attempt to describe how biodiversity is addressed in the secondary school setting in Iowa, this study is the first of its kind. This research was completed in Iowa and therefore using an Iowa sample of teachers was convenient and the primary reason why the research was restricted to this state. It is a hope that this research will inspire more works like it in the future.

CHAPTER III: MATERIALS AND METHODS

Research Questions

The study was conducted in order to answer the following questions regarding biodiversity education in the Iowa pre-college biology classroom.

1. How is biodiversity approached in the course curriculum?
2. What difference, if any, exists in biodiversity knowledge between middle school and high school teachers?
3. What difference, if any, exists in the biodiversity knowledge across different sizes of participants' schools?
4. What relationship, if any, exists between biodiversity knowledge and the number of years of science teaching experience?
5. What relationship, if any, exists between a teacher's biodiversity knowledge and the length of time that the teacher has taught a biology related course?
6. Do teacher attitudes differ between middle school and high school teachers?
7. Do teacher attitudes differ based upon the size of the participants' school?
8. Do teacher attitudes differ based upon the amount of time that the participant has taught secondary science?
9. Do teacher attitudes differ based upon the amount of time that the participant has taught their biology related course?

Research Design

An anonymous survey (Appendix Biodiversity Teacher Survey) was developed and administered to Iowa secondary school biology teachers using Qualtrics, an online survey software (Qualtrics, Provo, UT). The survey includes questions regarding (1) teacher demographics, (2) how biodiversity was approached in the classroom, (3) biodiversity knowledge, and (4) attitudes towards biodiversity. The survey was designed to take 10-15 minutes to complete in order to recruit a maximum number of participants, and included 27 questions. There were five questions regarding demographics. These questions were a mix of multiple choice and fill in the blank. There were 13 questions designed to assess teachers' understanding of biodiversity. These 13 questions had correct and incorrect answers. A biodiversity knowledge score was calculated based upon the number of questions correct for each participant. Each question was worth two points, with a total of 26 possible points. The teachers could receive a zero if completely incorrect, a one if the answer was partially correct, and a two if completely correct. These questions were multiple-choice or select all that apply questions. An additional biodiversity knowledge question was open-ended, however, this was not used in the calculation for the biodiversity knowledge score. 9 of the 13 knowledge questions were considered "General Knowledge" while 4 were considered "Advanced Knowledge." Two questions were designed to collect information regarding how teachers approach biodiversity in the classroom. One was multiple-choice and the other was open-ended. Six questions were included using a Likert scale in order to collect information regarding teacher attitudes towards biodiversity [33].

Recruitment of Participants

Participants were recruited via an e-mail sent to all 1,119 secondary principals in the state. The e-mail included information regarding the survey, a link to the survey, and a request that the e-mail be sent to all teachers with experience in teaching a secondary school biology-related course. There were only two principals who replied that their school would not participate. How many of the remaining principals forwarded the request to their secondary biology teachers is unknown. A total of 116 teachers responded to this survey, however, only 92 met the selection criteria to be included in the analysis. Of that 92 total, there were 33 middle school teachers and 59 high school teachers. If we assume that each of these teachers has three classes of biology per day, with approximately 20 students per class, then we estimate that these 92 teachers would be impacting in excess of 5,000 students each academic year.

Summary of Methodology and Data Analysis

In summary, the goal of this study was to gather information regarding Iowa secondary school biology-related teachers' attitudes, approaches, and knowledge of biodiversity. The participants' responses were also compared based upon school size, teaching level (middle school versus high school), years teaching secondary school science, and years teaching the biology-related course that they selected to answer their survey questions. IBM SPSS Statistics was used to complete the statistical analysis for this study. There were some limitations to this study. The first being the relatively low number of respondents who participated in this survey. Considering there are a total of 1,119 principals in the state of Iowa, there are likely even more Iowa biology or life science teachers. This exact number could not be determined, however, 92 is likely to be a small percentage of the total. An additional limitation was the use of a survey. Others have noted some of the weaknesses of using surveys such as the rate of responses [34] and it is likely that these weaknesses impacted the data collected for this study.

CHAPTER IV: RESULTS AND DISCUSSION

Introduction

As outlined previously, the study was conducted in order to answer nine broad questions regarding biodiversity education in the Iowa secondary school biology classroom. Before each of the questions is addressed separately, a summary of the statistical analyses is required. To answer the questions, there are a total of four independent variables. The first is *school level*, or whether the participant teaches a middle school or high school level course. The second is *school size*, based upon the approximate number of students per graduating class at the teacher's current institution. The third is *course years*, or the number of years the teacher has taught the course they are using to answer the survey questions. The fourth is the *number of years* the teacher has taught secondary school science. To complete the statistical analyses, questions from the survey were pooled to create two dependent variables, a biodiversity knowledge score and an attitudes score. The biodiversity knowledge score included all questions that had a correct/incorrect answer. The attitudes score included all questions that used the Likert scale. The third and final dependent variable was based on a single, open-ended question that required the participants to describe how biodiversity is currently addressed in their course curriculum. We used an alpha level of 0.05 for all statistical analyses.

Results

Attitude questions

In order to assess the teachers' general attitudes towards the ideas surrounding biodiversity, there were 6 questions that were answerable using the Likert Scale (Strongly Agree,

Agree, Disagree, and Strongly Disagree). The mean for the group as a whole was 18.87 with a standard deviation of 3.3. The maximum number of points possible for the attitude questions was 24.

Attitudes: middle school versus high school

An independent samples t-test was run in order to compare the attitude scores for middle school and high school teachers. There was no significant difference in scores for middle school (Mean= 19.06, sd= 2.24) and high school (Mean= 18.76, sd= 3.78; $t(90)= .413$, $p = .68$, two-tailed).

Attitudes: participants' school size

In order to examine the influence of school size on the attitude scores, a one-way between-groups analysis of variance was conducted. Participants were divided into three groups according to the size of their school, which was determined from the survey question asking the participants to approximate the number of students per graduating class at their current institution (Group 1: 50 students or fewer; Group 2: 51-120 students; Group 3: 121 students or greater). There was no statistically significant difference in attitude scores for the three size groups: $F (2, 87) = .075$, $p= .928$.

Attitudes: years teaching K-12 science

A one-way between-groups analysis of variance was conducted to explore what relationship, if any exists between the number of years teaching K-12 science and their attitude scores. Participants were divided into three groups according to the number of years reported for teaching K-12 science (Group 1: 8 years or less; Group 2: 9-18 years; Group 3: 19 years or more). There was no statistically significant difference in attitude scores for the three groups based upon the years teaching K-12 science: $F(3, 87) = .257$, $p = .856$.

Attitudes: years teaching a biology related course

Examining the effect of years teaching the biology related course used to answer the survey on the attitude scores involved completing a one-way between-groups analysis of variance. Participants were divided into three groups according to the number of years reported for teaching the biology related course (Group 1: 5 years or less; Group 2: 6-11 years; Group 3: 12 years or more). There was no statistically significant difference in attitude scores for the three groups based on years teaching the biology related course: $F(3, 88) = 2.465$, $p = .068$.

Approaches to biodiversity in the course curriculum

An open-ended question was used to assess how biodiversity is currently addressed in a teacher's course curriculum. For the most part, teachers responded with the specific unit where they addressed biological diversity. From the data, eight categories of approaches were identified including (1) A separate biological diversity unit, (2) the evolution unit, (3) the ecosystem unit, (4) it was addressed across multiple units, (5) the ecology unit, (6) the genetics unit, (7) that it was addressed but no provided answer for how, and (8) it was not addressed at all. Examining the results reveals no consistent pattern for how biodiversity is addressed in the classroom (Table 1).

Table 1. Comparison of percentages of middle school teachers and high school teachers for each unit in which biological diversity is addressed.

Unit	**Percent of Total Teachers**	**Percent of Middle School Teachers**	**Percent of High School Teachers**
Separate	25	27.3	23.7
Evolution	8.7	0	13.6
Ecosystem	16.3	18.2	15.3
Multiple	27.2	21.2	30.5
Ecology	9.8	6.1	11.9
Genetics	2.2	6.1	0
Not addressed	8.7	18.2	3.4
No information provided	2.2	3	1.7

Additionally, some interesting similarities and differences exist in the approaches selected by middle school and high school teachers (Table 1). 18.2% of middle school teachers do not address biodiversity at all whereas only 3.4% of high school teachers claimed to not address biodiversity. Out of all of the units, the unit that the majority of middle school and high school teachers are using to address biodiversity is throughout multiple units; in other words, there is typically no single unit is dedicated to biodiversity. For both middle school and high school teachers, there is no single, common way that teachers are using to approach biodiversity, but instead teachers tend to find space in a multitude of units.

Knowledge questions

The survey included 13 questions designed to assess the teachers' biodiversity knowledge. 9 of these 13 questions were considered "General Knowledge" while the other 4 questions were considered more "Advanced Knowledge."

Knowledge: middle school versus high school

An independent samples t-test was completed to compare the biodiversity knowledge scores for middle school and high school teachers. There was a significant difference in scores for middle school (N=33, Mean= 17.94, sd= 4.34) and high school (N=59, Mean= 20.12, sd= 4.33); t (90)=2.31, *p*=.02, two-tailed), with high school teachers outperforming middle school teachers. The mean for the whole group is 19.3 with a standard deviation of 4.44. The total possible score for the biodiversity knowledge score was 26.

Due to a concern that these results could be due to the presence of questions that are too advanced for a pre-college teacher to be expected to know, an additional independent samples t-test was conducted including only the "General Knowledge" questions. When considering only the 9 "General Knowledge" questions, there was still a significant difference in scores for middle school (Mean= 13.31, sd= 2.75) and high school (Mean= 14.67, sd= 2.78); t (90)=1.11, *p* =.03, two-tailed). The total possible score for the general biodiversity knowledge score was 18.

Knowledge: participants' school size

A one-way between-groups analysis of variance was conducted in order to examine the relationship between school size and the biodiversity knowledge scores. Participants were divided into three groups according to the size of their school, which was determined from the survey question asking the participants to approximate the number of students per graduating class at their current institution (Group 1: 50 students or fewer; Group 2: 51-120 students; Group 3: 121 students or greater). There was no statistically significant difference in biodiversity knowledge scores for the three size groups: $F (2, 87) = .116$, $p = .89$.

Knowledge: years teaching K-12 science

A one-way between-groups analysis of variance was completed. This was done to examine the relationship between the number of years teaching secondary science and the biodiversity knowledge scores. Participants were divided into three groups according to the number of years reported for teaching secondary science (Group 1: 8 years or less; Group 2: 9-18 years; Group 3: 19 years or more). There was no statistically significant difference in biodiversity knowledge scores for the three groups based upon the years teaching K-12 science: $F (3, 87) = .373$, $p = .773$.

Knowledge: years teaching a biology related course

In order to explore the relationship between the number of years teaching the biology-related course used to answer the survey on the biodiversity knowledge scores, a one-way between-groups analysis of variance was conducted. Participants were divided into three groups according to the number of years reported for teaching the biology related course (Group 1: 5 years or less; Group 2: 6-11 years; Group 3: 12 years or more). There was no statistically significant difference in biodiversity knowledge scores for the three groups based on years teaching the biology related course: $F (3, 88) = 1.84$, $p = .145$.

Discussion: Teacher Attitudes

Although there were no significant differences between the groups when comparing attitudes for middle school and high school teachers, the size of schools, the length of time teaching secondary science, and the length of time teaching a biology-related course, overall patterns were observed that occurred across both groups. When asked if biodiversity education is a significant component of their course curriculum, teachers most frequently selected Agree from the Likert scale (Table 2). When asked if biodiversity education is a significant component to the field of biology, teachers selected only Agree and Strongly Agree from the Likert scale (Table 3).

Table 2. Number of teacher responses and the associated percentages for the statement 'Biodiversity education is a significant component of your course curriculum.'

Likert Scale Response	Number of Responses (%)
Strongly Disagree	4 (4.4%)
Disagree	24 (26.4%)
Agree	46 (50.6%)
Strongly Agree	17 (18.6%)

Table 3. Number of teacher responses and the associated percentages for the statement 'Biodiversity education is a significant component to the field of biology.'

Likert Scale Response	Number of Responses (%)
Strongly Disagree	0
Disagree	0
Agree	45 (49.5%)
Strongly Agree	46 (50.5%)

These findings are quite interesting. While all teachers surveyed stated that biodiversity was a significant component to the overall field of biology, 28 teachers that indicated that biodiversity was not a significant component of their course curriculum (24 disagree, 4 strongly disagree). Due to the fact that many of the middle school and high school biology courses taught by the participating teachers involve learning about organisms scattered over the tree of life and their interactions, it is notable that over 25% of the respondents did not feel that biodiversity held a significant position in their curriculum.

Discussion: Teacher Approaches

Teachers were asked to provide how biodiversity information was being presented in their classrooms with an open-ended response, and all teachers responded by giving the names of classroom units where they addressed biodiversity (Table 1), which for this study we refer to as "Approach."

The Iowa Core [35] references biodiversity directly in five distinct sections of courses, which appear in both Middle School (8th grade) and High School (9th grade) standards (Table 4). Reviewing the responses from the teachers, it appears that biodiversity information is being presented in multiple, different units, some in line with the Iowa Core Standards, and some in units where biodiversity is not specifically noted in the standards.

Table 4. Recommended Iowa Core science standards regarding biodiversity related content for each grade.

Subject	Grade	Course	Section	Standards in the section
Science	8	Life science	Ecosystems: Interactions, Energy, and Dynamics	Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
Science	9	Earth and Space Sciences	Earth and Human Activity	Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.
Science	9	Life Science	Biological Evolution: Unity and Diversity	Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.
Science	9	Life Science	Ecosystems: Interactions, Energy, and Dynamics	Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
Science	9	Life Science	Ecosystems: Interactions, Energy, and Dynamics	Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

36

Biodiversity is being presented in a majority of the courses taught by the participating teachers, as only 8.7% of respondents indicated that it was not addressed in their course. While teachers indicated where in the course biodiversity was addressed (curriculum approach), no teachers provided any information about how that information was being disseminated (pedagogical approach i.e., hands-on activities, classroom discussions, videos). Due to the lack of information received regarding the pedagogical approaches used by the surveyed teachers, a discussion of the different ways in which teachers are disseminating that information would require an explicitly worded follow-up study.

Discussion: Teacher Knowledge

The only significant difference regarding the teachers' biodiversity knowledge was between middle school and high school teachers. As stated in the results section, the mean biodiversity knowledge score for both middle school and high school teachers was 19.3 with a standard deviation of 4.44. The maximum score a teacher could receive in this section was 26. This means that the middle school and high school teachers together on average were receiving about a 74% score on the biodiversity knowledge section. On average, the middle school teachers received a 69% and the high school teachers received a 77%. There were, however, teachers who received high scores on this section. For instance, a total of 19 teachers composed of 6 middle school and 13 high school teachers received a 90% score or higher, indicating that it was in fact possible to score highly on this assessment. Being educators in charge of biodiversity learning for many students, the average scores are lower than one may have hoped for. Because teachers impact the learning of their students, these findings are supported by the work of Chafee et al. (2014), who studied first year college students entering an introductory biology course. They observed that only 20% of the students (N= 923, ~ 75% high school graduates from Iowa) correctly recognized that mammals have low species diversity compared to other groups of animals and only about 40% of these students correctly recognized that insects are exceptionally speciose compared to other groups of animals.

The questions in this section were designed to reflect general concepts key to a basic understanding of biological diversity, but one possibility for the relatively low scores is that some of the questions were too advanced to reasonably expect a pre-college teacher to know. Therefore, an additional analysis was completed using only the most general questions. All questions that could be considered too advanced for a pre-college teacher to know were removed from the biodiversity knowledge score analysis. The general biodiversity knowledge score, with only 9 general questions, was compared for middle school and high school teachers. There was still a significant difference in scores for middle school teachers. The total possible score for the general biodiversity knowledge score was 18. This means that the middle school and high school teachers together on average were receiving about a 79% score on the general biodiversity knowledge section. On average, the middle school teachers received a 74% and the high school teachers received an 82%. Although the mean scores improved slightly, there was still a significant difference between middle school and high school teachers.

A question that emerges is why middle school teachers are performing worse than high school teachers on the knowledge questions. One possibility is that high school teachers are receiving more comprehensive training and preparation to teach biology than middle school teachers. Previous research [37] has shown that the process to become a certified teacher varies widely. Different states and different universities often have variable certification requirements which, while good for imparting flexibility on the process to address local needs, also allows teachers to enter schools at drastically different preparation levels. In 2012, a summary report detailed some of the major differences between middle school and high school teacher preparation [38]. Table 5 describes the coursework that secondary science teachers (middle school and high school) took during their teacher preparation. While a high percentage of both middle school and high school teachers took an introductory biology course (96% of middle school teachers, 91% of high school teachers), high school teachers were more likely to have taken any advanced, topical courses. This extra biology-related content that the high school teachers learned during their preparation could be one explanation for their higher scores on the knowledge questions.

Table 5. Percent of secondary science teachers who completed introductory and advanced coursework as part of their teacher preparation with the associated standard deviations in parenthesis.

	Percent of Teachers	
Course	Middle School	High School
Introductory Biology/Life Science	96 (0.9)	91 (0.9)
Anatomy/Physiology	36 (2.1)	54 (1.5)
Genetics	24 (1.9)	54 (1.5)
Ecology	33 (2.1)	50 (1.5)
Cell Biology	28 (2.0)	48 (1.5)
Microbiology	23 (1.7)	48 (1.4)
Botany	26 (2.0)	44 (1.4)
Biochemistry	16 (1.5)	43 (1.5)
Zoology	25 (1.8)	40 (1.4)
Evolution	14 (1.5)	27 (1.2)

Note. Adapted from "Report of the 2012 National Survey of Science and Mathematics Education," by Banilower, E.R., Smith, P.S., Weiss, I.R., Malzahn, K.A., Campbell, K.M., Weis, A.M., 2013, Table 2.8.

Another possibility to explain the difference in knowledge scores is that high school teachers are likely interacting with biodiversity content more often and at a deeper level, due in part to biodiversity's placement in the Iowa Core standards. As shown in the previous section, there are four explicit biodiversity related standards for high school teachers and only one for middle school teachers. Middle school teachers, even if prepared properly, may not have the need to review biodiversity related concepts since it is only directly addressed in the standards once, as opposed to the four instances for high school teachers. Because high school teachers are addressing biodiversity more often as specified by the Iowa Core, they and their students are being exposed to biodiversity-related information in a more detailed and interconnected fashion more regularly than middle school classrooms.

Finally, it is worthwhile to consider the reason why no significant differences existed between the other variables, such as school size, years teaching secondary science, and years teaching a biology-related course. Regarding size, the results make sense. Teachers likely gain their biological knowledge in two ways. The first is the education that they receive during their undergraduate degrees, teacher preparation programs, or graduate degrees. The second is the knowledge that they gain from interacting with the material required for their careers. Both of these sources of knowledge are anticipated to be independent of the school where they are teaching, and therefore one would not expect a difference in the biodiversity knowledge scores for the different sized schools. As for the number of years teaching a secondary science course, or the amount of time teaching a biology-related course, possible explanations include: 1) new teachers may be impacted by their more current knowledge base received schooling and teacher preparation program; and 2) the teachers who have taught for a greater amount of time have interacted with the material longer. The teachers, therefore, no matter how long they have been teaching, are not all that different regarding their overall knowledge of biological diversity. These are possibilities that would require further research to fully understand.

CHAPTER V: CONCLUSIONS AND FURTHER RESEARCH

The goal of this study was to gather information regarding Iowa secondary school life science teachers' attitudes, approaches, and knowledge of biodiversity. With respect to teacher attitudes towards biodiversity, using the data, we can infer that Iowa middle and high school teachers have similar, positive attitudes towards the importance of biodiversity education as it pertains to the field of biology (Table 3). However, as seen in Table 2, there appears to be a disconnect between the perceived importance as it relates to the field of biology and the importance of highlighting it in the courses that they teach. About 30% of teachers (Table 2) responded negatively (Disagree or Strongly Disagree) with the statement that biodiversity education is significant to their course curriculum, and these results are surprising given that all of the surveyed teachers taught introductory biology courses as opposed to advanced or specific courses (e.g. Human Osteology or Plant Physiology).

When asked how biodiversity was approached in their classrooms, teachers universally responded with the unit(s) in which biodiversity was addressed, but did not discuss the pedagogical approaches they used to present the material to students or, importantly, the amount of time they spend on this topic. From these data we can infer that Iowa teachers approach the topic of biodiversity in various places in their curricula, and it is likely that the variable placement will result in varying emphases, which can impact student learning outcomes. Given that the variability in biodiversity content focus currently appears to be at the discretion of the teacher, students could be finishing their secondary biology courses with vastly different experiences with biodiversity related content.

We also wanted to get a sense of the teachers' knowledge about biodiversity content, and developed a set of knowledge questions that contained both general and more advanced types of questions. From the data in this study, it appears that high school teachers have a stronger biodiversity knowledge foundation than middle school teachers, yet both groups performed sub-optimally on the knowledge questions. The average scores from the knowledge questions in this survey (69% middle school, 77% high school) would be high enough to pass a college course, but are they as high as one would hope for in a teacher of potential future scientists (either professionally or as citizen scientists), voters, consumers, and citizens? Data from the 2012 NSSME report [38] demonstrates that high school teachers were nearly twice as likely to have taken any advanced biology courses (as opposed to general or introductory courses) relative to middle school teachers, yet both are responsible for teaching biodiversity-related material to their students. These data, combined with the fact that the Iowa Core Standards only mention biodiversity once in middle school but four times in high school may begin to explain the disparity of scores between teachers of different grade levels. However, both groups in this survey demonstrated a clear lack of mastery of the material that they themselves are responsible for teaching.

Taken together, the knowledge, attitudes, and approaches responses collected from the teachers regarding biodiversity suggests that the current state of biodiversity education in Iowa is underwhelming. Given that both the middle school and high school teachers are performing sub-optimally on the biodiversity knowledge section, the variability of when biodiversity is addressed in the course curriculum, and that some introductory biology teachers do not even believe that biodiversity serves as a significant component of the course curriculum, some recommendations appear necessary. In order to improve both the consistency and accuracy of

Iowa teachers' biodiversity content delivery, we propose simultaneously addressing both the variable approaches towards teaching biodiversity through mandated adjustments to the Iowa Core Standards, while addressing their apparent biodiversity knowledge deficiencies by increasing the minimum content mastery required for teacher certification.

Data from the 2012 NSSME report[38] demonstrates that access to teacher workshops, teacher preparation, and the lesson plans used in the classroom are variable. The answer to addressing these issues must then come down to efforts that can be mandated. One such possibility would be through actual legislation, requiring that teachers address biodiversity consistently by amending the Iowa Core Standards. Data from this study, which suggest that biodiversity is mainly addressed as a 'tag-along' topic for other science units, appears to do a disservice to its own explicit importance. With all that students stand to gain from a strong foundational understanding of biodiversity, it should be addressed explicitly as a Section (in the parlance of the Iowa Core) in middle school and high school life science courses, and not merely as a standard associated with other units. Two challenges exist when considering such an amendment to the Iowa Core, or any related set of standards. The first is that any change to the existing standards would have to come from a consensus amongst working scientists about what biodiversity content should be highlighted in secondary biology classrooms. Given that biodiversity has a broad and complex definition, this is no easy task. If this consensus can be reached, the second challenge is of one of practicality, as enforcing any of these changes would require agreement between politicians, educators, and other education specialists.

Another possibility would be to address the issue of teacher preparation. In Iowa, in order to be certified to teach a particular course, including Biology, the Iowa Department of Education requires that the educator receive qualifying scores for the *Praxis II* test both in pedagogy and content [39]. A straightforward way to ensure that the best qualified teachers are entering the secondary biology classroom without adding new components to the certification process would be to simply increase the threshold for what is considered a qualifying score for the *Praxis II* content test. Based on the biodiversity knowledge section in this study, it is evident that our teachers are at least partially deficient in their overall content knowledge. Because this content test is already built into the certification process in Iowa, an adjustment to make the score requirement higher would add minimal complexity to the process while encouraging teachers-in-training to maximize their content preparation prior to entering the classroom.

Based on the findings of this study, there are clear areas where new research should focus. As stated previously, public understanding regarding biological diversity is low [24]. This is worrisome, because without this knowledge, people will be less likely to change the way they interact with the environment or the politics involved with the biodiversity crisis [25]. If we want to ensure that our planet is able to continue to sustain human, and other, life on Earth, it is evident that we will need to change the habits of our own species and a strong education in biological diversity is the foundation for change. As none of the teachers provided any examples of pedagogical approaches for teaching biodiversity, a follow-up study of the range of teaching tools currently being implemented in Iowa classrooms, as well as nationally and internationally, may yield valuable information regarding what is most effective in the classroom.

When faced with the distinct possibility that we may be entering (or we may in fact already be in) a sixth mass extinction event, it becomes important to find ways to recruit as many people, both scientists and non-scientists, to help offset the damaging effects that our species is having on biological diversity. Firstly, we must encourage learning in children and adults alike, both in and out of schools, about how biodiversity losses and ecosystem services interact with each other, and how those effects can impact our lives even if the damage may not be obvious in our backyard.

It was Theodosius Dobzhansky who stated, “Nothing in biology makes sense except in the light of evolution,” [40] however, one could make the argument that biodiversity may be an equally important foundational idea for anyone who wants to understand how complex biological systems operate. The study of biodiversity provides for students a sense of a place amongst all living things, an appreciation for the seemingly boundless ways in which different organisms solve unique and shared challenges, and how no species’ place on this planet is ever guaranteed.

It is our hope that as a society we will continue to work towards a better understanding of biodiversity loss and its impact on society, as well as biodiversity education, so we can put our students in a position to make informed choices for a better future not only for our species, but also for all of the species with whom we share this amazing planet.

APPENDIX BIODIVERSITY TEACHER SURVEY

Demographic Questions:

1. How long have you taught the following course(s)? Select all that apply and enter the number of years spent teaching the course(s):
a) Biology (HS-level) [enter number of years]
b) AP Biology or Honors Biology (HS-level) [enter number of years]
c) Environmental Science (HS-level) [enter number of years]
d) Life Science (Middle School or Junior High) [enter number of years]
e) Foundations of Science (Middle School or Junior High) [enter number of years]
f) Other (enter the title of the course not listed) [enter number of years]
g) Other (enter the title of the course not listed) [enter number of years]
h) Other (enter the title of the course not listed) [enter number of years]

2. Approximately how many students per graduating class are at your institution?
[enter number]

3. Your survey responses are based on (which course? choose one):
a) Biology (HS-level)
b) AP Biology or Honors Biology (HS-level)
c) Environmental Science (HS-level)
d) Life Science (Middle School or Junior High)
e) Foundations of Science (Middle School or Junior High)
f) Other (enter the title of the course)

Biodiversity Questions

1. What is your understanding of the term "biodiversity"?
[Open-ended]

2. Is biodiversity addressed in your course curriculum?
Yes No

3. Biodiversity education is a significant component of your course curriculum:
Strongly Disagree Disagree Agree Strongly Agree

4. If you answered "Yes" to question #2, please describe how biodiversity is currently addressed in your course curriculum. [open-ended]

5. The study of biodiversity is significant to the field of biology:
Strongly Disagree Disagree Agree Strongly Agree

6. Observational science is significant to the field of biology:
Strongly Disagree Disagree Agree Strongly Agree

7. Observational science is a significant component of your course curriculum:
Strongly Disagree Disagree Agree Strongly Agree

8. Experimental science is significant to the field of biology:
Strongly Disagree Disagree Agree Strongly Agree

9. Experimental science is a significant component of your course curriculum:
Strongly Disagree Disagree Agree Strongly Agree

Knowledge questions with the distribution of responses for each answer

10. Biological diversity refers to, select all that apply: (General biodiversity question)
a) The genetic variability existing within species. (65%)
b) The genetic variability existing among species. (68%)
c) The variety of species living on Earth. (90%)
d) The variety of biological communities and their associated processes. (65%)
e) Please comment in the provided space if none of the above. (2%)

11. Members of a particular species, e.g., white-tailed deer, are usually: (Advanced biodiversity question)
a) genetically identical to each other. (4%)
b) genetically distinct from each other. (49%)
c) genetically identical to each other when living in the same habitat. (9%)
d) genetically identical to each other only when they are members of the same family. (18%)
e) Please comment in the provided space if none of the above. (20%)

12. Individuals of which species are most genetically distinct from each other (Select all that apply)? (Advanced biodiversity question)
a) Robins. (52%)
b) Channel catfish. (56%)
c) Cottontail rabbits. (54%)
d) Garter snakes. (55%)
e) Humans. (81%)
f) Please comment in the provided space if none of the above. (13%)

13. In your estimation, what percentage of all the species on Earth are "known to science," that is, they have been assigned a scientific name? (General biodiversity question)
a) More than 90%. (5%)
b) 75% to 90%. (16%)
c) 50% to 75%. (25%)
d) 25% to 50%. (22%)
e) 2% to 25%. (22%)
g) Please comment in the provided space if none of the above. (10%)

14. Which of the following is an animal (select all that apply)? (General biodiversity question)
a) Rabbit. (95%)
b) Trout. (87%)
c) Grasshopper. (84%)
d) Shrimp. (86%)
e) Snail. (87%)
f) Please comment in the provided space if none of the above. (7%)

15. Which of the following is a plant (select all that apply)? (General biodiversity question)
a) Mushroom. (9%)
b) Sponge. (10%)
c) Coral. (11%)
d) Tulip. (99%)
e) Mold. (5%)
f) Please comment in the provided space if none of the above. (2%)

16. A lichen is (Advanced biodiversity question)
a) A plant. (9%)
b) A fungus. (5%)
c) A composite organism resulting from a symbiotic relationship between fungus and a photosynthetic alga or cyanobacterium (62%)
d) A composite organism resulting from a symbiotic relationship between a fungus and a bryophyte. (13%)
e) A composite organism resulting from a symbiotic relationship between a fungus and a plant. (9%)
f) Please comment in the provided space if none of the above. (2%)

17. Which of the following groups of organisms has the greatest number of species on Earth? (General biodiversity question)
a) Mammals. (4%)
b) Birds. (1%)
c) Reptiles. (1%)
d) Flowering plants. (29%)
e) Beetles. (65%)

18. Biologists define species based on which criterion (Select all that apply). (General biodiversity question)
a) The ability of two groups of organisms to interbreed, or not (71%)
b) The structural (morphological) similarity or dissimilarity of two groups of organisms (42%)
c) The DNA sequence similarity or dissimilarity of two groups of organisms (53%)
d) Please comment in the provided space if none of the above. (8%)

19. The activities of humans that can lead to decreases in biological diversity include: (General biodiversity question)
a) Introduction of non-native species. (1%)
b) Removal of natural habitats. (3%)
c) Overharvest for food / commercial purposes. (0%)
d) Chemical pollutants. (0%)
e) All of the preceding. (96%)
f) Please comment in the provided space if none of the above. (0%)

20. What biome includes the greatest biodiversity? (General biodiversity question)
a) Coniferous Forest. (1%)
b) Tundra. (1%)
c) Tropical Forest. (90%)
d) Desert. (0%)
e) Temperate Grassland. (4%)
f) Please comment in the provided space if none of the above. (4%)

21. Which of the following is true? (General biodiversity question)
a) Extinction is a natural event that is unaffected by human actions. (0%)
b) Although human activities are known to have caused the extinction of a few species, the vast majority of species are at no risk of going extinct. (15%)
c) Extinction is not really a problem because these particular species will re-evolve. (1%)
d) Extinction is a minor problem because new species evolve at about the same rate as species go extinct. (5%)
e) 99.9% of species to ever live on earth are extinct. (79%)

22. Which group of organisms has the smallest number of species in Iowa? (Advanced biodiversity question)
a) Mammals (42%)
b) Birds (3%)
c) Fish (19%)
d) Flowering plants (2%)
e) Lichens (34%)
f) Please comment in the provided space if none of the above. (0%)

REFERENCES

1 Barnosky, A. D. *et al.* Has the Earth/'s sixth mass extinction already arrived? *Nature* **471**, 51-57 (2011).

2 Boyle, A. *Scientists Build Case for 'Sixth Extinction' ... and Say It Could Kill Us*, <http://www.nbcnews.com/science/environment/scientists-build-case-sixth-extinction-say-it-could-kill-us-n378586> (2015).

3 Ceballos, G. *et al.* Accelerated modern human–induced species losses: Entering the sixth mass extinction. *Science Advances* **1**, e1400253 (2015).

4 Kareiva, P. & Marvier, M. Conserving Biodiversity Coldspots Recent calls to direct conservation funding to the world's biodiversity hotspots may be bad investment advice. *American Scientist* **91**, 344-351 (2003).

5 Hassan, R. M., Scholes, R., Ash, N., Condition, M. E. A. & Group, T. W. *Ecosystems and Human Well-Being: Current State and Trends: Findings of the Condition and Trends Working Group*. (Island Press, 2005).

6 Lichtfouse, E. *et al.* in *Sustainable Agriculture* 1-7 (Springer, 2009).

7 Wood, A., Stedman-Edwards, P. & Mang, J. *The root causes of biodiversity loss*. (Earthscan, 2000).

8 Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A. & Kent, J. Biodiversity hotspots for conservation priorities. *Nature* **403**, 853-858 (2000).

9 Jablonski, D. & Chaloner, W. Extinctions in the fossil record [and discussion]. *Philosophical Transactions of the Royal Society B: Biological Sciences* **344**, 11-17 (1994).

10 Convention on Biological Diversity. *Article 2. Use of Terms* <https://www.cbd.int/convention/articles/default.shtml?a=cbd-02> (2011).

11 von Frese, R. R. B. *et al.* GRACE gravity evidence for an impact basin in Wilkes Land, Antarctica. *Geochemistry, Geophysics, Geosystems* **10**, doi:10.1029/2008gc002149 (2009).

12 Cardinale, B. J. *et al.* Biodiversity loss and its impact on humanity. *Nature* **486**, 59-67 (2012).

13 Lomborg, B. *The skeptical environmentalist: measuring the real state of the world*. Vol. 1 (Cambridge University Press Cambridge, 2003).

14 Convention on Biological Diversity. *Aichi Biodiversity Target 1 and CEPA* <https://www.cbd.int/cepa/> (2011).

15 Assessment, M. E. *Ecosystems and human well-being: biodiversity synthesis*. (Island Press, 2005).

16 Schulze, E. D. & Mooney, H. A. *Biodiversity and Ecosystem Function: With 22 Tables*. (U.S. Government Printing Office, 1994).

17 Watson, R. T. & Programme, U. N. E. *Global Biodiversity Assessment: Summary for Policy-makers*. (Cambridge University Press, 1995).

18 Loreau, M., Naeem, S. & Inchausti, P. *Biodiversity and Ecosystem Functioning: Synthesis and Perspectives*. (Oxford University Press, 2002).

19 Congress, U. S. *Congressional Record, V. 149, PT. 4, February 25, 2003 to March 10, 2003*. (U.S. Government Printing Office, 2006).

20 Landweber, L. F. & Dobson, A. P. *Genetics and the Extinction of Species: DNA and the Conservation of Biodiversity*. (Princeton University Press, 1999).

21 Wilson, E. O. *Biophilia*. (Harvard University Press, 1984).

22 Wilson, E. O. *The Diversity of Life*. (Belknap Press of Harvard University Press, 1992).

23 Louv, R. *Last Child in the Woods: Saving Our Children From Nature-Deficit Disorder*. (Algonquin Books, 2008).

24 Navarro-Perez, M. & Tidball, K. G. Challenges of biodiversity education: A review of education strategies for biodiversity education. *International Electronic Journal of Environmental Education* **2** (2012).

25 Convention on Biological Diversity. History of the Convention. (2011).

26 O'Neal, L. & Skelton, J. A field trip to the rocky mountains to teach undergraduate ecology. *The American Biology Teacher*, 233-237 (1994).

27 Beiersdorfer, R. E. & Davis, W. E. Suggestions for planning a class field trip. *Journal of College Science Teaching* **23**, 307-311 (1994).

28 Zervanos, S. & McLaughlin, J. S. Teaching Biodiversity & Evolution Through Travel Course Experiences. *The American Biology Teacher* **65**, 683-688, doi:10.1662/0002-7685(2003)065[0683:tbettc]2.0.co;2 (2003).

29 Kvist, S., Montanari, S. A., Yi, H., Fuks, B. & Siddall, M. E. Teaching Biodiversity & Evolutionary Biology in a North American Marine Coastal Environment. *The American Biology Teacher* **73**, 72-77, doi:10.1525/abt.2011.73.2.4 (2011).

30 Gayford, C. Biodiversity education: A teacher's perspective. *Environmental education research* **6**, 347-361 (2000).

31 http://www.scienceiniowa.org/project-wet. *Project WET*, <http://www.scienceiniowa.org/project-wet> (2014).

32 da Silva, P. R., de Andrade, M. A. B. S. & de Andrade Caldeira, A. M. Biology Teachers' Conceptions of the Diversity of Life and the Historical Development of Evolutionary Concepts. *Journal of Biological Education* **49**, 3-21 (2015).

33 Likert, R. A technique for the measurement of attitudes. *Archives of psychology* (1932).

34 Goyder, J. Surveys on surveys: Limitations and potentialities. *Public Opinion Quarterly* **50**, 27-41 (1986).

35 https://iowacore.gov/about-iowa-core. *About Iowa Core*, <https://iowacore.gov/about-iowa-core> (2015)

36 https://iowacore.gov/iowa-core/subject/science. *Subject,* <https://iowacore.gov/iowa-core/subject/science> (2015)

37 Olson, J. K., Tippett, C. D., Milford, T. M., Ohana, C. & Clough, M. P. Science Teacher Preparation in a North American Context. *Journal of Science Teacher Education* **26**, 7-28, doi:10.1007/s10972-014-9417-9 (2015).

38 Banilower, E. R., Smith, P.S., Weiss, I.R., Malzahn, K.A., Campbell, K.M., Weis, A.M. (ed Inc. Horizon Research) (Chapel Hill, NC, 2013).

39 Education, I. D. o. *Practioner Preparation*, <https://www.educateiowa.gov/pk-12/educator-quality/practitioner-preparation#Required_Test_and_Qualifying_Scores> (2015).

40 Dobzhansky, T. Nothing in Biology Makes Sense except in the Light of Evolution. *The American Biology Teacher* **35**, 125-129, doi:10.2307/4444260 (1973).