EDUCATIONAL TECHNIQUES THAT FOSTER CREATIVE SOLUTIONS AND GOOD DATA IN FIELD BIOLOGY: EXAMPLES FROM 3 CONTINENTS

by

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submitted in accordance with the requirements for
the degree of

DOCTOR OF PHILOSOPHY IN MATHEMATICS, SCIENCE, AND TECHNOLOGY EDUCATION

in the subject

LIFE SCIENCES EDUCATION

at the

UNIVERSITY OF SOUTH AFRICA

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JANUARY 2007

CURRICULUM VITAE

I was born Derek Scott Madden in Lawrence Kansas in the USA in 1955. After schooling at the primary and secondary level, I entered school at California State University Fresno (CSUF) where I earned a bachelor's degree in geography in 1980, and a bachelor's degree in biology in 1984. I continued my education by conducting graduate research in Kenya for two years. I earned a master's degree in biology through CSUF in 1988. At this time, I also earned a California State Teaching Credential for my two years of coursework and teaching internships. From 1988 to 1990, I was employed as a Laboratory Coordinator and Professor of Biology at CSUF.

In 1991, I accepted a tenure-track professorship at Modesto Junior College in the Yosemite Community College District. I have been employed in this college system for the past fifteen years as a Professor of Biology, Interim Dean of Instruction, and Dean of Science, Math and Engineering. Over the past fifteen years, I have also been involved with field biology projects, which included work with the University of California Research Expedition Programs in Costa Rica, and the School for Field Studies programs in Ecuador, Costa Rica, and Africa. These field experiences, and resulting publications, helped me to earn the California College International Education Award in 1994, and led me to establish field biology programs in the Yosemite Community College District. My college prefers that their upper-level administrators possess earned doctorates. This policy of the college, along with my involvement in college leadership and student field studies, has motivated me to pursue this doctoral degree.

ABSTRACT

One of the principles regarding our knowledge about life on earth is that no organism can be fully understood without taking into account its surrounding environment. This study examines the extent to which ecosystem-focused field studies may be associated with students' academic performance and potential to contribute to the advancement of science and conservation. Pilot studies conducted in Panama and California established methods used in this project from 1993-2003. Two hundred and sixty-seven students conducted field studies in either Kenya or Costa Rica. Students worked in cognitive apprenticeships, in which research staff trained each student to conduct field research. At the conclusion of their fieldwork, the research staff assessed the students written field reports. The students' reports were then sorted according to the extent to which their studies were ecosystem-focused. Data analysis through nonparametric, Kruskal-Wallis statistical tests revealed no significant difference in academic performance on field study reports, in regards to whether the studies were narrow in scope (species-specific) or broad (ecosystem-focused). Marginal significance was revealed between ecosystem-focused studies and the potential for students' fieldwork to contribute to the advancement of science and conservation. Also addressed in the data were injuries, disease, and potential hazards, which were influenced by prudent and decisive leadership. Successful field studies require consideration of the content, context, and design of the intended field projects. Many of the solutions to environmental problems on the planet will come from the working hands of teachers and students that conduct explorations in the field.

KEY WORDS

Field studies

Ecology

Environmental education

Field biology

Situated cognition

Cognitive apprenticeship

Conservation

Wildlife ranching

Sea turtle ecology

Giraffe ecology

DECLARATION

Student number: 3426-374-8

I declare that

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is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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SIGNATURE DATE

(Mr. D Madden)

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ACKNOWLEDGEMENTS

I am grateful for the encouragement and crucial guidance from professor Diane Grayson of the University of South Africa. I can say that if not for professor Grayson's help and her faith in me, I would have dropped this research project a year ago and would have never looked back at it again. I am now glad that she firmly drove me onwards so that I might share my work with others. I am proud of what we have accomplished. It was not an easy task to finish this work! I am also grateful for assistance from Mrs. Maree and Dr. Carol Summers who helped me to wrap up this marathon of a dissertation.

I am grateful for the YCCD Board of Directors and Dr. Bill Scroggins of Modesto Junior College who awarded me a sabbatical for completing this important work. Dr. Harrison Madden and Dr. Richard Haas, Emeritus Professors of California State University at Fresno, both provided valuable guidance and profound advice. Professor Cathy Snyder provided editorial work that I badly needed in the final writing of this lengthy document. The Registrar at Unisa, Professor Molamu, was one of my reliable contacts with the university for which I was often grateful.

I am also thankful for the involvement of David Hopcraft of Game Ranching Ltd., the Office of the President of Kenya, and the Kenya Wildlife Service that provided approval for my research. The School for Field Studies provided support and capable students in Costa Rica, Ecuador, Panama, and Kenya. The School for Field Studies staff members that were helpful included: Toni Milewski, Truman Young, Jorje Ballestero, Rocio Alacar, and Elaine Christains. Sea turtle work in Ostional, Costa Rica was conducted under the appropriate permits and animal care protocols according to the Association of Integral Development of Ostional, and as described in Wildlife Conservation Law 4551.

ABBREVIATIONS

A	*A*., when followed by the scientific names *seyal* or *drepanolobium* in this paper, refers to *Acacia* tree species native to arid regions of East Africa.
B	*B*., when followed by the scientific name *glabra* in this paper, refers to a spiny tree known as the Desert date, *Balanites glabra*.
GRL	Game Ranching Ltd. is an operational wildlife ranch situated in Kenya. This ranch has a meat production operation that conserves wildlife by making it economically valuable.
HUI	Herbivore Use Index refers to a tree's relative browsing pressure, measured by counting dung pellets within 5 m of a tree's canopy.
M	Meter
N	Number
SE	Standard Error of the statistical mean
SFS	The School for Field Studies is an educational institution that organizes student field studies in biology and environmental science. Students are awarded university credit for completion of SFS field study courses.
STDEV	Standard Deviation of a statistical mean or average
WRR	Wildlife Ranching and Research is the former title of Game Ranching Limited in Kenya.
X	Statistical average or mean

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Chapter 1

INTRODUCTION

The first section of this chapter presents an overview of basic principles of ecology, as these principles are associated with the major thrust of this study. This section launches into a discussion of keystone species, the niche, predation, and other concepts of ecology that are relevant to this study. Ecology is also addressed as a theory with applications to our everyday world and to the instruction of science. The chapter moves on to a section that introduces the motivation behind this study, and provides sources of published literature that support the rationale for conducting this study.

According to the literature that was reviewed for this study, there is a need for establishing guidelines for apprenticeship field studies, in which students learn by working alongside a master in the field of study. There is also a need for students' fieldwork to generate information that may benefit the planet. In the section on motivation, the importance of the place in which instruction occurs is discussed, as it is associated with situated cognition. Students may benefit when a context (the situation or setting) is appropriately matched with the instructional content that is being considered for an academic lesson. Information acquired by students through contextual experiences may be transferred to other areas of a student's life. There is evidence that situations in which students are involved in studying real problems in nature, may provide information upon which resource management decisions can be made.

Following a discussion of the factors that motivated this study is a section on the research questions that this study addressed. These questions arose as a result of field studies that I had conducted with students in California and Panama. A supporting theoretical framework for each research question is based upon a review of published literature in ecology, resource management, science education, and situated cognition. A research design is presented in this section, in which each of the research questions and the proposed methods is supported through reference to the published work of others.

Following the research questions is a section in which some of the basic, underlying theories and methods that were applied to my study are summarized. Cognitive apprenticeships were arranged in remote research sites in Costa Rica and Kenya, in which students earned university credits by working under the guidance of experts in field biology. These apprenticeships were structured so that some students examined one type of organism, while other students studied several aspects of an organism's environment. The latter type of study is referred to as ecology-focused, and is the major independent variable being investigated in the study.

The final section of this chapter provides an outline of the entire thesis, in which a brief description is given of the Introduction, Literature Review, Methods, Results, Discussion, and Conclusion chapters of this study. In the final pages of the Conclusion, a framework is presented that suggests ways in which academic field studies in biology might be effectively conducted with first year college students. Evidence in support of this framework is provided through reference to figures in the Results chapter, and through reference to pertinent published articles that are listed in the Bibliography of this study.

1.1

INTRODUCTION

One of the basic principles governing our understanding of life on this planet is that no organism can be fully understood without taking into account the specific environment in which it lives. In order to understand one organism, we must understand the organism's ecology, which refers to the relationships and interactions between an organism and its environment (Smith and Smith 2002). How can an eagle, cheetah, oak, or coral be fully known in the absence of specific details of the objects and events with which it interacts? We recognize the importance of ecology in human behavior. Anthropology, sociology, and psychology, among other disciplines, have provided a wealth of data on how our environments influence what we think, feel, and do. As is true for humans, an organism cannot be fully understood apart from the detailed knowledge of its ecology (Huston 1994).

When attempting to understand an organism, various factors need to be taken into account besides those of ecology. Such factors as the organism's molecular, behavioral, and anatomical features are also basic components of what they are. These factors are widely recognized for their importance, and so have received extensive study (Starr 2005). There has been an increasing awareness given to the importance of understanding the impact that the environment has upon organisms. Many of the advances in this area of science have progressed through the mounting attention being given to the study of ecology (Orr 1999). It has become increasingly apparent that without attention to ecological elements, our knowledge of any particular organism is severely limited (Smith and Smith 2002).

The interactions that the science of ecology deals with may include associations such as predation, competition, parasitism, and mutualism (Wallace et al. 1997). Also examined in many ecological studies are parameters such as meteorology, hydrology, geology, and other factors of the physical environment that influence the livelihood of organisms. Interactions are what ecology is truly about, and interactions are the platform upon which effective cross-curricular education in this discipline may rest.

When considering the ecology of an organism at its most fundamental level, there are many interactions that take place at the molecular and biochemical level, as energy flows from one organism to another. Much of the energy in an ecological situation is lost, as is described in the First Law of Thermodynamics (Smith and Smith 2002). According to this law, energy is neither created nor destroyed. Energy merely changes form as it is transferred in various reactions, or moves from one source to another. Typically more than 90% of the potential chemical energy in a reaction is lost as heat or through some other route that does not directly benefit the organisms involved in an interaction (Starr 2005). Much of the generalized knowledge about the ecology of an organism, such as is depicted in food chains and food webs, has its roots in the thermodynamics of reactions at the molecular level.

An increasing awareness of the implications and potential applications of ecology has brought about an escalating involvement of people working with the land in ways that improve the fertility of landscapes without excessive use of toxins (Morrison et al. 2002). In a process called biomagnification, organisms may serve as reservoirs for toxins that they absorb in small quantities when they feed. Each time these organisms are consumed by another creature, a small dose of toxin is transferred into the tissue of the consumer (Primm 1991). Certain toxins are not expelled or secreted after having been absorbed in the living tissues of an organism. Over a period of months or years, the consumer may acquire relatively heavily loads of toxins. Such processes of biomagnification may take place in the food chains of a variety of habitats (Primm 1991). Even in places such as our backyard, toxins and various forms of energy flow through living and nonliving components of the landscape in ways that may influence our daily lives (Fig. 1.1).

Figure 1.1 An example of a backyard ecosystem, illustrated by the author.

1.2

MOTIVATION FOR THE STUDY

Learning can be enhanced by the appropriate use of field activities in which students experience learning in a contextual setting. In this way, the content of the lesson becomes a part of the physical setting (Castillo et al. 2002). An appropriate contextual setting can stimulate the participants to learn when a teacher has planned, designed, and tested the contextual lesson thoroughly (Hirsch 1996). Biological field studies are one method in which teachers may embed the content of a lesson in the appropriate context. Field study, in general terms, refers to the exposure of participants to a setting in which an item can be studied as it naturally occurs (Schatzman and Straus 1973).

Field studies have been used successfully in many types of instruction, in which the students learn by working directly with the objects that they are studying (Dresner 2002). Both the teachers and students in a field study are likely to develop a sense of personal accomplishment in being able to observe and understand organisms operating in their natural habitats (Manner 1995). Moreover, field studies can provide teachers with opportunities in which they can share their personal fascination about science with their students (Richmond and Kurth 1998). By having students learn by doing, field studies may also connect students to the real world (Richmond and Kurth 1998).

The introductory statements in this section on motivation provide several of the reasons why I selected field studies as the platform upon which to answer several questions. Although the information described above suggests that field study is an excellent way to stimulate students to learn, there are many difficulties that teachers may face when selecting such an instructional strategy. Exposing students to the bewildering array of creatures and interactions in nature can sometimes lead to confusion (Aubusson 2002). It is the complexity of nature that often drives teachers to use packaged science curricula for instructional units on environmental education (Barab and Hay 2000). Natural environments are often difficult settings to predict when planning field trips, and unexpected shifts in weather or other factors may completely disrupt a field endeavor (Deng et al. 2002). Furthermore, it is difficult to design a lesson that involves context because there are relatively few guidelines that show teachers how to approach such nontraditional instructional strategies (Young 1993).

In field studies that I was conducting with students in California, I found it necessary to construct instructional strategies based on my trials and errors rather than on published guidelines. This is a situation many teachers face when providing contextual learning experiences for their students (Young 1993, Barab and Hay 2000). I found it difficult to conduct field studies with students, and there were few guidelines that provided me with the information that I needed to experience success. It would be easier to use packaged curricula than to undertake the enormous work and responsibility required for conducting academic field studies. This led me to the major aim of this study, namely, to establish guidelines that would provide teachers with effective ways to design and conduct field studies in biology.

In an effort to improve my ability to lead field studies, I had explored the application of constructivism as a theory of learning to an instructional strategy in which students constructed their own ideas about the information that resulted from a field project (Hirsch 1996). I had explored drill-and-practice instruction, in which students learned through repeating various activities involved in a field project (Madden and Grayson 2003). After examining constructivist, drill-and-practice, and various other instructional strategies, I selected cognitive apprenticeships as an appropriate way to introduce students to field research. Cognitive apprenticeships, as the name suggests, allow students to learn from experts in authentic contexts the component cognitive skills and complex tasks involved in a specific cognitive domain.

Another motivating force for this study came about through a review of published articles in science education that emphasized the potential for teachers to have contribution to be one aspect of the students' lessons (Cleary and Benson 1998, Wellniz et al. 2002). There has been a growing need for colleges to be a source of solutions to social and environmental problems (Cleary and Benson 1998). Expanding the integration of academic learning with community service can do this. There is increasing pressure in higher education for faculty to leave the ‘Ivory Tower’ and to use their expertise to help solve practical problems in their communities, and to facilitate desired developments (Wellniz et al. 2002).

The changing attitudes about the importance of applying academic research and scholarship to the many aspects of community life come at a time when there is increasing attention being given by science educators to improving the effectiveness of field activities (Bentley et al. 2000, Marques et al. 2003). Field explorations have resulted in scientific discoveries that addressed serious environmental problems (Burgess et al. 1999). These explorations take many forms. At one extreme, there are rigorous field research projects focused on arriving at new discoveries. At the other extreme, there are exploratory types of field trips designed to entertain students as they are exposed to various environmental settings.

Project-based instruction is one educational strategy that uses projects that are completed by students as graded assignments. There are difficulties in arranging and conducting such instruction because projects may expose students to situations that they are emotionally unprepared to tackle. Projects are also complicated in that they may not be adequately assessed through standard examinations (Hirsch 1996). However, project-based inquiries have great potential to expand a student's personal experience and awareness of a topic (Wimmers 2001). Yet, there is no single recipe that describes the way in which such project-based endeavors should be conducted to maximize student success (Young 1993).

From an ecological perspective, much can be learned about one organism by investigating the environment in which that organism is found (Meffe and Carroll 1997, Wallace et al. 1997, Barnes 1998). Such an ecological approach to understanding an organism may involve the study of many parameters, since there are nearly an infinite number of associations that each living creature has with its surroundings (Smith and Smith 2002). Is it effective to have college students in an entry-level biology course focus their investigations in field biology upon one organism? Such one-topic explorations are referred to in this study as species-specific field studies. Or, is it more effective for instructors to design an alternative to such species-specific field studies, in which students learn about an organism by studying the environment in which that organism naturally occurs? Explorations in which an organism's ecological connections are examined are referred to in this study as ecology-focused field studies.

Investigating several ways in which to teach biological field studies was of primary importance in this study; however, I also wanted to know how field projects might be designed so that the information generated by students would contribute to science and conservation. This second aim of the study addressed the potential for ecology focused academic field studies to make meaningful contributions outside of the classroom. Rather than being focused on student success, as was the first goal described in this section, the results of students' field studies were examined in light of their potential to provide meaningful information in the area of resource management and conservation. This aim was of secondary importance in my study, and was primarily addressed in appendices and in manuscripts that were submitted for publication in scientific journals.

Prior to the study reported in this thesis, I explored ways in which academic field studies could be improved during a project that was based in a remote rainforest in the country of Panama (Appendix A). Many of the student teams studied primate ranging behavior, foraging behavior, and interactions among other primates at the field site. Primates moved rapidly and frequently from tree to tree in the dizzying heights of massive rainforest trees. I was perplexed about how to direct my team of students to collect data on these mobile and elusive animals. Fear of failure in my first academic field study drove me to scramble through the rainforest while maintaining visual contact with a species of primate known as the Panamanian tamarin (*Seguinus oedipus geoffroyi*). Many of the species in this family are no larger than a squirrel, and a great many of them are endangered due to habitat destruction and the pet trade (Garber 1984).

By the end of the first month in the field, when each research team gave its reports, I observed several unexpected results from the various student field studies (Madden 1987). Some of the students that originally arrived at the project site having a poor understanding of biology proceeded to conduct successful field research. Conversely, a student team, composed mostly of biology majors, ended up conducting a rather pathetic study, resulting in little meaningful data. Both student groups worked under a researcher that had tested the methods and had a history of success in producing data for publication. There were no obvious indications, such as interpersonal conflicts or sickness, which would explain the one student team's failure. Why did one team of poorly prepared students perform so well, while simultaneously a team of biology students did so poorly in producing results in the field study? This question would plague me for years as I conducted further field studies.

Following the study in Panama, I began to conduct field studies with my students at Modesto Junior College, where the topic was the ecology of local riparian (river-side) habitats (Appendix B). I found that student performance in field studies in the Modesto area was often unpredictable. Students that scored high on exams sometimes performed poorly on their field studies. As was the case in my Panama studies, I wondered why students that seemed prepared to conduct research were often out-performed by students that were not as well prepared in regards to their background in science. It has been nearly two decades since I began to explore ways in which biological field studies can be used in project-based instruction. I am now prepared to propose that there are indeed ways in which academic field studies in biology may be designed and conducted so that student performance is affected.

Student Contributions, Solutions, and Understanding

Ecological research conducted by students has the potential to provide important scientific information upon which future environmental management decisions can be made (Castillo et al. 2002). Students that work as novice researchers can help make important discoveries. Furthermore, undergraduates with little preparation in the sciences have proven that they can be a great source of enthusiasm, and may also provide ideas for creative approaches and practical solutions to real-world scientific endeavors (Walls

1996). This has been demonstrated many times, in situations in which students that are completely new to a specific area of study find unique ways to contribute new information (Bentley et al. 2000). Students working in the field are apt to have unique perspectives that are not tainted by the lengthy and formal training the expert usually receives. Students may develop a personal understanding through directly working with the topic of a lesson (Greengrove and Secord 2003). For example, students from a variety of classes over several years undertook a complex project involving the establishment of a native prairie. Many of the students in that project experienced a deep connection to the natural environment. Also, and especially important, they came to more fully understand the implications of conservation and restoration programs (Burgess et al. 1999).

Turning Point

Many research scientists regard their undergraduate research experiences as a turning point that led them to pursue research careers. Such scientists were influenced in unexpected ways by the context and content of what they at first thought would be dreary experiences in classroom science (Whiteacre 2003). There is also value for those students who are not interested in pursuing science as a career. Furthering their understanding of ecology helps prepare students to make intelligent decisions about many complex environmental issues, as the students become future decision-making members of their communities (Hogan 2002).

Direct experiences in problem solving in the context of real-world situations can help students understand the complexity of decision-making. (Jime’nez-Aleixandre 2002). For example, students reading about the destruction of rainforests may arrive at very simplistic solutions to the problem. Few such solutions, in reality have much likelihood of being reasonable to implement. Most issues in conservation are complicated enough to require a multi-perspective approach that takes into account the various parameters involved in the situation (Cambell 1998).

Through direct exposure to field studies, students may become enlightened enough to understand that there is a web of interactions involved with most problems in the environment. Direct experiences, in which students learn by doing something in a natural setting, may help students to sort through the noise of information that they are exposed to in some academic settings. Such students may be able to arrive at viable solutions. There is growing evidence that students may transfer this contextual knowledge to other aspects of their life in which they might learn by doing or being part of something worthwhile (Brody 2002).

Importance of the Physical Setting

The importance of an organism's place (the specific location) has been woefully neglected in biology education. This is in part because of the unpredictability of nature and the logistical challenge of matching learners with an appropriate physical setting (Orr 1992). The location and specific situation in which learning occurs has powerful implications in the study of biology. For example, viewing organisms in their natural habitat can become a source of inspiration that rarely occurs in the classroom (Walls 1996). Research on various forms of instruction that have been experimented with over the past few decades reveals a bewildering number of different ways in which people learn new information (Hirsch 1996).

Although the ways in which people effectively learn are highly variable and may change during the lifetime of an individual, there is mounting evidence that the place in which learning occurs is important for students and teachers (Orr 1992). There is a beneficial association between learning about a topic organism and having such learning occur while the participants are physically present in the location and situation in which such a topic organism naturally occurs (Manner 1995). What I saw in the actions and expressed attitudes of students that took part in the field research projects in Panama and California, motivated me to work towards providing contextual instruction in which the students directly experienced biology in the field.

1.3
RESEARCH QUESTIONS

This investigation of academic field studies focuses upon two instructional approaches that teachers typically use when deciding what each student will study in a field project. One approach involves the selection of a study topic organism that is convenient, locally accessible, or is one that the teacher feels will interest the students (Greengrove and Secord 2003). In such an approach, students are instructed to focus their fieldwork on the selected topic. The students typically locate, observe, and record the movements and behaviors of this single subject in the field. If the major topic is an inanimate object, such as a tree, then the students measure such factors as distribution patterns, growth habits, size, and other features that lend themselves to simple data gathering activities (Burgess et al. 1999). In the study that I am conducting, such one-topic instructional designs are referred to as species-specific.

An alternative approach to a species-specific field study is to have students examine various aspects of the environment in which an organism lives or travels through (Gibbs 1998). In this paper, this instructional approach to designing a field study for students is referred to as ecology-focused. The major organism being investigated in such a study needs not be present when students are working in the field, for the environment alone may provide much information about this organism (Morrison et al. 2002). Such a field study focuses on the ecological connections between an organism and the surrounding environment (Wallace et al. 1997). The activities involved with this type of field study may include the investigation of physical features such as climate and geology.

Each research question that was addressed in this study originated from my personal experiences of designing and leading academic field studies. Each research question was selected after careful examination of the daily instructional agendas and the end-of-course student reports for academic field studies that I had conducted in Panama, Ecuador, and California. Research questions that I generated from these academic field studies were examined in regards to the published work of experts in disciplines such as education, ecology, and resource management. After a literature review had been used to screen out many of my original queries, I was left with three major research questions upon which to base my study. Both a literature review and details from my pilot studies in California and Panama, as these were associated with my research questions, are addressed in the Methods chapter, and are summarized in Table 1.1

Table 1.1 The research questions, and the major sources of theory and methods that were used in the academic field studies that were conducted for this study.

Research Question	Parameter Measured	a) Theoretical Framework b) Research Methods
Will students' contribution to science and conservation be associated with the diversity of species that the students examined in the field, after cognitive apprenticeship fading had ended and the students were trained to complete their fieldwork?	Species diversity was measured as the number of different species that were examined in the field by each student, based on the entries made in the student's field data and related to student performance.	a) Smith & Smith (2002) a) Bruner (1986) b) Gibbs (1998) b) Choi & Hannafin (1995)
Will students' contribution to science and conservation be associated with the ecological trophic levels that the students examined in the field, after cognitive apprenticeship fading had ended and the students were trained to complete their fieldwork?	Trophic levels were measured as the number of major ecological links of a food chain that were examined in the field by a student, based on the ecological role of each subject that a student recorded in his or her field data and related to student performance.	a) Smith & Smith (2002) a) Bruner (1986) b) Gibbs (1998) b) Choi & Hannafin (1995)
Will a student's contribution to science and conservation be associated with an ecosystem approach of study, after cognitive apprenticeship fading has ended and the student has been trained to independently complete the assigned fieldwork?	Ecosystem approach was measured by the extent to which the following parameters were addressed in his or her field data sheets: 1) Physical (temperature, topography, humidity, etc.) 2) Biological (organisms) 3) Anthropocentric (humans)	a) Smith & Smith (2002) a) Bruner (1986) b) Gibbs (1998) b) Choi & Hannafin (1995)

In the basic research design of this study, no single literary source or single research endeavor provided all of the information required for each major aspect of the study. For example, I applied the basic concept of cognitive apprenticeships based upon the work of Bruner (1986), but I found many of the ideas for constructing the actual design of my study in the work of Choi and Hannifin (1995), and Collins et al. (1991). In addition to the theoretical framework upon which my research was based, the work of these authors sometimes provided me with methods for the design of my study. Other ideas for appropriate research methods that I employed came from the work of Gibbs (1998), and several other sources that are described in Appendices B through I.

My selection of parameters to be measured was influenced by the ecological principles presented in the work of Smith and Smith (2002), whose work was ultimately based on the primary research papers of others in the field. The latter source of information presented a review of ecological principles, which I used to screen out some of my original research questions. I used the work of Gibbs (1998), Milewski et al. (1991), and Cornelius et al. (1991) to determine the details of what students would actually be doing in the field.

What this approach to the review of literature achieved was to begin at broad concepts in general survey literature, and advance to reviewing specific topics in journals dedicated to narrowly defined disciplines. By identifying broad parameters to measure that could be broken down into precise steps and concepts, a logical set of procedures could be established that was based on broad, well-accepted theories. My pilot studies in California and other locations also provided structure for the research design of this study (Madden 1987, Madden and Young 1992, Madden and Grayson 2003, 2004).

Many factors may influence how well students perform in their field studies; however, many of these factors are not within the instructor's means to control. For example, whether students come to the course committed to work hard and to achieve success is something that the instructor has little influence over. There were several factors in my sample that represented uncontrolled variables. Such variables could have had the potential to influence data, but could not be controlled because of the use of convenience sampling, which is described more completely in the Methods chapter.

In my use of a convenience sampling strategy, some randomness was achieved because the students that attended the field courses came from various locations in the world, their academic and cultural backgrounds differed, and there were no prerequisites to enrollment beyond admission fees and a high school diploma. Opportunities for financial aid helped to rule out economic status as a major factor that might influence the type of sample found in this study. However, financial issues probably influenced the sample to some extent since transportation costs were not covered in the assistance programs. There are a considerable number of uncontrolled variables, such as age, gender, motivation, and several other factors that may be associated with the performance of a student (Hirsch 1996, Bell and Bromnick 1998, Chall 2000). Several of the major uncontrolled variables that I identified in my study appear in Table 1.2.

Table 1.2 Factors that may influence performance in academic field studies. These items were not examined in the current study.

1.	Gender
2.	Age
3.	Academic background
4.	Health: physical, emotional, and mental
5.	Attitude
6.	Ethnicity
7.	Economic status
8.	Motivation
9.	Family background
10.	Responsibilities
11.	Expectations
12.	Prior experience

1.4

RESEARCH METHODS

The study was predominantly quantitative, although it did not conform to a standard experimental design in that there were no control or experimental groups. Quantitative data were obtained in the form of student grades on their projects. Each project was analyzed in terms of the extent to which three biological features were present, which were used to indicate the extent to which the project was organism or ecology-focused. Statistical tests were then carried out to explore the relationship between these features and student grades. Cognitive apprenticeship determined the instructional strategy used during the field trips. The primary content to be learnt comprised various biological field techniques. Student assessment was by means of a project.

Throughout the study, there was a constant effort at maintaining consistency and integrity. In ways that are described more fully in the Methods section of this study, the research design addressed the potential for experimenter bias and other sources of confounding variables. Subjects worked in double-blind situations. The experts that assessed student outcomes were unaware of the independent variables (the three biological features) being investigated in this study. Mathematical statistics were applied appropriately, and the study progressed as per the scientific method of investigation. In this manner, the results of this study could be objectively examined, and an empirical interpretation of the data was made possible.

Cognitive Apprenticeships

A form of contextual instruction, referred to as cognitive apprenticeship, was one of the major strategies used in my field studies. This instructional strategy is addressed in the Literature Review chapter. A summary of cognitive apprenticeship is provided here to introduce the reader to this concept of contextual instruction. Situated cognition is a theory of learning which emphasizes the role of context on what is learnt and how that learning can be used later on (Vygotsky 1978, Bruner 1986, Choi and Hannafin 1995).

Although situated cognition is a theory of learning, it has implications for structuring a learning experience. One way that teaching can be done through the application of situated cognition is by arranging lessons in which the participants acquire knowledge by doing something in a specific context rather than by passively listening to the lectures provided by an instructor. One application of situated cognition is referred to as cognitive apprenticeship, in which students are exposed to a master that performs a set of activities to help to train each student and monitor his or her progress (Collins et al. 1991). The term ‘authentic’, as it is used in this study, implies that the work being conducted by students is similar to the activities that would be done by professionals in the field.

I conducted cognitive trial studies in Costa Rica and Panama, where I was a research assistant that taught biological research methods in the field to first year college students. During my leadership role in Kenya and Costa Rica, upon which the data in this study are based, I was a co-director and a staff member in charge of designing, guiding, and assessing the work of students in their academic field studies.

Biological Field Techniques

This study involved the application of biological field techniques that were appropriate to the specific setting and research topic of each academic field study. In the studies in Kenya and Costa Rica, field methods were based upon literature regarding the use of biological field techniques for accurate acquisition of data, interpretation of data, and application of these data. Biological field methods described by Gibbs (1998) and Morrison et al. (2002) were employed as default methods to be used when more specific literature was not sufficient. For example, the methods described by Cornelius et al. (1991) were used extensively in the field studies students’ conducted in Costa Rica because these authors’ work involved the same location and population of sea turtles that my students’ academic field studies were focused upon.

In situations where the published work of Cornelius et al. (1991), and Milewiski et al. (1991) did not provide guidance, such in the sampling of flies in beach sand, I then turned to Gibbs (1998) and Morrison et al. (2002) as the default volumes that contained generalized guidelines for field study techniques. These methods involved acquiring information in the field through use of the type of equipment and techniques that an expert would utilize in a true scientific investigation. Students were trained in the field by experts, and were guided so that their fieldwork was conducted with a high degree of accuracy.

Project-based Assessment

Cognitive apprenticeship provided the instructional framework for structuring the field studies, and techniques of biological field study provided the strategy used for designing student activities. A third tool was required for assessment of the students' work. The primary sources of information that I used in designing the assessment of student performance came from the work on cognitive apprenticeship as described by Bruner (1986), Collins et al. (1991), and the work of Choi and Hannafin (1995).

In cases where the work of these authors did not provide an appropriate method for assessment in my study, the default source of assessment information came from the work of The National Science Foundation (1994), and Tomari and Borich (1999). These sources of information were employed in several instances because the work of Bruner (1986) and Collins et al. (1991) that were specific to cognitive apprenticeships, often failed to provide specific guidelines for how assessment of this type of contextual learning might be conducted in my particular study.

1.5

OUTLINE OF THE THESIS

In the Introduction of this study there is a summary of basic principles of ecology as these principles are associated with the aspects of science education that I am exploring. In this summary are described various aspects of a species that refer to its niche, its many connections with organisms and physical features of the environment, and its role in the planet's energy cycles. Also discussed is the importance of considering the ecology of an organism when attempting to fully understand that organism. This concept provides the foundation of my investigation, in which I measure student performance on their field research reports as this performance is associated with organism focused or ecology-focused field studies.

In the Introduction, I present information that suggests there are relatively few guidelines for designing and conducting academic field studies. Information is also presented about the potential for students' field studies to provide information that addresses real environmental problems. There exists in the literature a large body of information about ecology and environmental education. There is a limited amount of published information that describes how biological field studies might be optimally conducted so that students and the environment benefit from such endeavors. Many teachers that lead biological field studies with their students typically draw from their own experiences rather than from published guidelines for field studies.

The Introduction in this thesis provides a brief introduction to a theory of learning referred to as situated cognition in which the learning that occurs is context-dependent. An application of situated cognition, called cognitive apprenticeship, is a contextual approach to learning that is based on the premise that students may benefit when the content of what they are learning is embedded in an appropriate contextual setting.

Pilot field studies in Panama and California are presented as events that initially gave rise to the research questions that this study addresses. Also important in establishing the questions and aims of this study was a review of literature regarding science education, conservation, and ecology. Biology field techniques, as presented by several authors of this topic, were selected for designing the actual field activities that students would be conducting. Student performance was evaluated through a nontraditional method referred to as project-based assessment, in which students were ranked on their field studies through the grading of the students' written, end-of-course field report.

In Chapter 2, Literature Review, a review of the published literature that is pertinent to this study is summarized. Theoretical information about situated cognition as a contextual form of learning is presented. Some of the ways in which this theory might be applied as a cognitive apprenticeship are addressed. Several potential problems and values of cognitive apprenticeship as an instructional strategy are presented, as well as the rationale for choosing the type of cognitive apprenticeships that were used in this study. The pressing need for students to serve as sources for solutions to environmental problems is addressed in this chapter, as is the concept that ecology is a science with far-reaching applications to real-world situations.

Chapter 3, Methods, begins by describing how the research questions were examined in this study. This chapter describes the environmental setting of the study sites where the Kenya and Costa Rica student research projects took place. This section was written to acquaint the reader with the physical and biological settings, infrastructure, cultural aspects, and various other factors that influence the operation of a field camp for students in remote situations. Structure of the field camp in regards to the financially responsible institutions, the resident goals for conservation, problems to be overcome, and the potential for improvement regarding the management of species is also described here and in several appendices.

In addition, in the Methods chapter the detailed steps of each aspect of the study are described, from the planning and preparation to the final methods used for assessment. Methods are based on pre-established techniques for cognitive apprenticeship, biological field studies, and student assessment. Rationale is provided in this chapter that describes why each method was selected, and how that method was managed for extraneous variables that might influence the acquired data. Participants of various backgrounds were involved, and the studies were designed and carried out in two different study sites with a variety of professional evaluators.

Chapter 4 contains the results. Following the biological data section in the Results is the crux of my study in which species-specific studies are compared with ecosystem-focused field studies in regards to the scores entered on students' end-of-course reports. Data were grouped to the extent to which students' reports addressed: 1) species diversity, 2) trophic levels, and 3) site-habitat conservation. A statistical mean score of students' end-of-course field report is compared for each of the categories (1 - 3 described above). Tables and graphs provide information about each of the three categories. Examples of the students' work are included in each category to demonstrate how sections of the actual reports appear in regards to the parameters being measured.

Chapter 4 presents quantitative analyses of the students' field reports that were generated in Costa Rica and Africa. Nonparametric statistical analysis included a Kruskal-Wallis test and Chi-square test. Statistical significance was determined at a minimum of a 95% confidence level, and was obtained through an analysis of variance by rank used on subcategories of the students' reports (Kruskal-Wallis statistical test), and through a Chi-square test of the extent to which students' work contributed to science and conservation. Student reports were sorted with respect to each of the parameters being measured. Also addressed in the Results chapter are data on student attrition, and a summary of the risk management data entries for the various student field studies. Student attrition due to non-medical issues was less than 2%, and was attributed to emotional distress that was referred to as homesickness. There were several cases in which an injury or hazardous situation occurred that reduced instructor and student time in a field study. The most frequently encountered hazards were plant bristles, thorns, and other inanimate irritants that frequently caused lesions. Humans that were not officially associated with the academic field studies also became hazards in several situations. Humans caused few direct injuries, but their presence caused problems relating to student safety.

In Chapter 5, Discussion, I interpret the results of this study, and make suggestions about how academic field studies might best be conducted so that students and natural environments benefit. Information that originally appeared in the Introduction and Literature Review of this study is addressed briefly in the Discussion to support the recommendations of the study with a body of relevant literature. The data presented in this study suggests that there is an association between the potential for students' field studies to contributed to scientific understanding of nature and conservation, and the extent to which species diversity, trophic levels, and the ecosystem is examined in the field endeavors. Student projects that minimally addressed these parameters had relatively low field report scores, and little potential to contribute something meaningful to conservation efforts on our planet.

In the final chapter, Conclusion, I provide a framework for academic field studies that is supported by published literature and by the results of this study. Students that explore the ecology of an organism may acquire the data and experiences they require in order to make meaningful contributions to science and conservation. There may be a link between such contributions and the number of different parameters a student examines in a field study. Sufficient data may in itself serve as a motivating factor, since students may perceive data to have a crucial value in determining the fate of their graded report. The precise mechanisms that might explain this link between the number of parameters being investigated and the potential for contribution to science and conservation to occur is unclear even at the conclusion of this study.

In addition to designing field studies in which student are exposed to the ecology of an organism, it is also important for instructors of field studies to consider the emotional status of the students. By scheduling events that foster interpersonal interactions among the members of an academic cohort, students may be less likely to experience homesickness or related forms of separation anxiety. In this framework for academic field studies, I also suggest that students work in a true cognitive apprenticeship, in which they learn by working with experts. This method of instruction is based on the theory of situated cognition, in which content of the lesson may be appropriately matched with context to provide a positive learning situation. Such apprenticeships may lead students to make discoveries through their own actions in the field of study.

Cognitive apprenticeships may lead students to suggest plausible solutions to problems. If solutions to many environmental problems are to come from future students, then science educators that conduct field biology projects with their students may wish to address factors such as emotional stability, hazards, and ecology in their academic field study endeavors. In addition to the benefits that students may experience through the application of my framework for field studies, teachers may also benefit as they conduct field studies alongside their students in the search for solutions to real problems.

Chapter 2

LITERATURE REVIEW

This chapter begins with a review of literature on ecology, in which organisms are described as having distinctive roles in the environment. The ecology of an organism refers to its interactions with other creatures, and with climate and other non-living factors of an ecosystem. These interactions provide information about how an organism survives, for each species' survival is dependent upon specific features of its preferred environment. Conversely, many environments are molded by resident species, such as the American bison that historically influenced vegetation of the vast American prairie.

Following the discussion on ecology is a review of education and field studies. Academic field studies may serve to support and expand on information that students received through lectures and reading. Field studies may provide students with knowledge that is not easily acquired in a classroom setting. One type of field studies, in which students learn by becoming part of the process of searching for answers, is referred to as cognitive apprenticeship. This strategy of learning is based on the theory of situated cognition, in which the mental processes involved with learning are enhanced when the proper set of conditions (context) is provided as part of the learning experience.

This chapter concludes by addressing the potential for contextual learning experiences to lead students to believe that science and the environment is connected to their reality. Through contextual experiences such as field studies, students may contribute meaningful information that has the potential to improve some aspect of the natural world. Conversely, it is pre-fabricated, non-contextual learning experiences that may hinder the advancement of environmental education in many schools throughout the world.

2.1

ECOLOGY AND THE ORGANISM

Ecological Paradox

When studying an organism, one paradox of its ecology is that it can be incredibly complex and full of chaotic parameters, yet an organism's ecology can simultaneously be highly structured and stable (Primm 1991). The latter characteristics are often dictated by patterns of energy flow that are in turn influenced by stable physical and biological processes (De Vries et al. 1997). The result is that an organism’s ecology consists of many identifiable biochemical pathways and routes of flowing energy through food chains. These routes can be understood and often predicted. Associations among species that result in natural communities, also bring about stability in natural ecosystems. Within a community there is typically a fairly consistent species composition, uniform general appearance of the landscape, predictable flow of nutrients, and regular pattern of succession and transition (Huston 1994).

Organismal Theory of Communities

The organismal theory of ecological communities suggests that associations are so powerful that each species represents an interacting and integrated part of the whole. Scientists have suggested that this is especially true for colonial insects, such as bees and ants, in which each living member serves as one part of a functioning organ of the colony (Primm 1991). Naturalists in the American West have often stated that when we look closely enough at a creature, we find it attached in some way to nearly everything else on the planet (Orr 1999). From an ecological perspective, such an all-encompassing approach to the study of nature is the most logical approach to take in order to develop a full understanding of how biological processes work. However, rarely can all of the connections in a creature’s ecology be visualized at a single glance, such as the way an ecological scene is often portrayed in habitat profiles (Fig. 2.1).

Figure 2.1   The author's illustration of a heron’s complex ecology.

Many of the connections in an organism's environment frequently change or are easily overlooked. This can be illustrated by the unexpected discovery of a new species of parasitic mite, which was discovered living in the skin of parasitic louse flies, which were discovered living in the feathers of hawks that were the original focus of one study (Madden and Harmon 1998). This illustrates the many connections in nature that exist beyond the familiar perceptions of species interactions, such as those that involve food chains and other obvious sorts of interactions. An interaction between a hawk, a fly, and a mite at first glance appear to be an unlikely association; however, the existence of the latter two organisms is completely tied to the hawk (Fig. 2.2). Such discoveries in nature emphasize the value of searching for answers, while also remaining open to ways in which external factors may be connected in subtle ways to the topic being investigated.

Figure 2.2 The author's illustration of a species of hawk, mite, and fly that interact.

Not only is one organism supported by many other factors in the environment, but the organism's existence may also support its environment. Besides drastic and rather obvious examples, such as the way herds of American bison affected the American Prairie, there are cases in which organisms influence their environment in powerful and yet very subtle ways. For instance, the Northern flying squirrel (*Glaucomy sabrinnus*) helps sustain vast boreal forests in Canada. These small rodents disperse spores of subterranean fungi that many trees require for root efficiency (Stolzenburg 2004). If not for the feeding activities of flying squirrels, great tracks of forested lands would gradually change over time in response to the limited distribution of crucial root-dwelling fungi.

There are many examples in which a single species helps to create and maintain entire ecosystems. Such organisms are what ecologists refer to as keystone species (Primm 1991). These species play a major role in stabilizing many ecosystems. Often the keystone species in an area fosters the growth and maintenance of a landscape's native vegetation. For example, California's Sierra foothill vegetation is maintained to some extent by woodpeckers that gather acorns before these nuts become infested by beetles (Madden et al. 2005). The birds never recover all of the acorns that they hide as a food cache for lean times. From such forgotten acorns sprout vast woodlands that foster acorn woodpeckers and hundreds of other species in California's interior (Fig 2.3). Other examples abound, where an organism's existence is closely tied to the stability and maintenance of an ecosystem. From an ecological perspective, no organism is truly alone in nature, for each living creature is connected in a nearly infinite number of ways to its surrounding environment (Meffe and Carroll 1997).

Figure 2.3 The author's illustration of an oak’s ecology.

Another example of how a single species helps to create and maintain entire ecosystems is evident in the studies on sea turtles described later in this thesis. Not only does the environment influence how a sea turtle lives, but also the activities of these reptiles impact the environment in various profound ways. A sea turtle spends nearly its entire life at sea, yet it makes a major contribution to the ecology of a beach during the brief hour that the reptile comes ashore to lay its eggs. It is common for most of the eggs laid by a sea turtle to never hatch (Cornelius et al. 1991). However, the abundant turtle eggs in the beach foster complex food webs that help maintain the ecology of sea turtle nesting beaches in much of the world (Bouchard and Bjorndal 2000).

The Ecological Niche

An organism's niche consists of all elements, whether living or not, that the organism interacts with in some way during its lifetime. The niche of an organism changes from season to season, and from place to place in such a way as to make definitive predictions of an organism's potential interactions nearly impossible (Starr 2005). The numerous parameters of an organism's ecology are largely a result of the vast multidimensional space that the organism's niche occupies (Aubusson 2002). For this and other reasons, the niche exists as a theoretical space in time, as described by the ecological niche theory (Smith and Smith 2002).

A vast array of possible interactions inherent in a creature's ecological niche can make ecological field studies a daunting task for a scientist (Castillo et al. 2002). Yet, the myriad interactions that are possible in nature may also provide new topics to be explored as scientists attempt to understand an organism's natural lifestyle. Based on the ecological niche theory, much about an organism can be understood through examining its interactions in nature (Smith and Smith 2000).

From an ecological perspective, the chemical energy that flows through an ecosystem originates from the trophic level comprised of what are identified as primary producers. In most terrestrial habitats, plants with the green pigment chlorophyll are the primary producers (Smith and Smith 2002). As a group, green plants capture solar energy and convert that energy into bonds that bind inorganic atoms of hydrogen, carbon, and oxygen into an organic nutrient called glucose (Starr 2005). Primary producers are at the base of most food chains and pyramids of biomass. Plants collectively provide the chemical energy upon which most ecological food webs are based (Primm 1991).

Immediately following the primary producers, in a classic scenario of trophic level sequence, are the primary consumers. These organisms are the herbivores that feed in various ways upon green plants. Predators and scavengers often comprise the next trophic level because they feed on the primary consumers (Madden et al. 2005). The food of predators is usually living prey, while the food of scavengers is typically dead organic matter. In nature, there is not always a clear separation between which organisms are predators and which are scavengers (Wallace et al. 1997). Predators may sometimes be scavengers, and scavengers may become predatory when the opportunity arises (Letrourneau et al. 2004). Such role reversals have been observed for lions and hyena of the Serengeti, and in many other less obvious sorts of interactions (Gibbs 1998).

To some extent, an organism’s surroundings contain ecological information about the organism’s lifestyle (Barnes 1998). This study emphasizes the value of acquiring information about the ecology of an organism in order to understand that organism. While such an approach to the study of organisms living in nature seems appropriate and logical, it requires specific instructional strategies when the study of an organism is an educational lesson for entry-level students. Also being considered in this study is how academic field studies might be conducted so that the ecological information that is acquired by students may be applied in practical ways to the management and preservation of species in the wild.

Trophic Cascades

The term trophic cascade refers to a theory suggesting that carnivores are ecologically crucial in maintaining the relative amounts of biomass in ecosystems. Biomass refers to the collective relative weight of living factors in an area. In pyramids of biomass, plants and algae often comprise the greatest biomass. This trophic level (or step in a food chain) is followed by herbivores, which as a group are characterized as having relatively high biomass (Smith and Smith 2002).

Carnivores occupy the top trophic levels in a biomass pyramid, and their biomass seems trivial when compared to the enormity of the underlying levels that are comprised of plants and herbivores. In most settings, predators are a tiny part of an area's ecological biomass; however, the role of predators in influencing the ecology of an area can be immense (Letrourneau et al. 2004). If not for carnivores that control the hordes of leaf-eating organisms that are inherent in most natural systems, herbivores would overgraze and disrupt most ecosystems on earth (Fig 2.4).

My first major exposure to academic field study of trophic cascades took place in a vast rainforest reserve in Costa Rica that goes by the Spanish name of La Selva (Appendix C). Students were randomly assigned to study different aspects of plants in the genus *Piper* (family piperaceae). Some students focused on the plants themselves by measuring growth, location, morphology, and situation. Other students conducted field studies on various types of invertebrate organisms found to be interacting with the plants.

Figure 2.4 The author’s illustration of a trophic cascade.

When predatory species of ants were experimentally excluded from natural swollen growths within *Piper* plants, the students observed extensive destruction of plant tissues. To some extent, the existence of several species of *Piper* appeared to be linked with ants that either fed upon leaf-eating insects or attacked and drove off insects that were too large to eat (Letrourneau et al. 2004). Such information supports the concept that plants are ecologically linked to carnivores, and that plants are not only linked to animals that eat or pollinate plants. In many indirect ways, predators may have ecological connections with plants that affect the overall stability of an ecosystem. Such predators include ants, which are easily overlooked as being major factors influencing an ecosystem.

Species Diversity

Species diversity refers to the number of different types of species that exist in a specific area. In most systems that have routes available for immigration and emigration, species diversity is a dynamic situation that changes seasonally, daily, and even hourly in some situations (Primm 1991). For example, DeVries et al. (1997) found that species diversity for some butterflies might be dramatically influenced by the vertical tiers of a tree, especially at the borders between tiers. Not only is species diversity highly variable at any one place or time, but also species diversity is difficult to calculate because of varying degrees of available nutrients that cycle through an ecosystem (Svenning 1999).

The inherent complexity of nature suggests that for some organisms, species diversity is unlikely to be more than a theoretical estimate that is based on a small and inappropriately obtained sample size (Smith and Smith 2002). Yet, species diversity provided one platform with which to separate organism-focused from ecosystem-focused field studies in my investigation. In applying species diversity as a parameter for examining students' work in my study, several questions emerged. Does it really matter whether a student examines one or many species during a field study? Will students perform at a high level in their field studies if they examine numerous different species that are associated with the species that is the major topic of a study? These questions on species diversity were addressed by examining the association between the number of different species being investigated in a student's field project and the student's performance on his or her end-of-course research report.

Trophic Levels

Most natural ecosystems are comprised of various trophic levels. Each of these levels represents links in a food chain or one step in an ecological pyramid of biomass (Letrourneau et al. 2004). In one classification of trophic levels, organisms are grouped according to their niche, and how this niche relates to the flow of food and energy through an ecosystem (Wallace et al. 1997). Ecological trophic levels may not address scientific classification of organisms, in which each living creature fits within a taxonomic scheme based on assumed shared ancestry. For example, giraffe and leaf-eating insects are capable of causing extensive damage to plants, regardless of their taxonomic status. Thus, giraffe and such insects are both considered as being herbivores that are situated at a similar ecological trophic level. Based on the concepts presented in this section, I identified plants, herbivores, and predators as representing the three major tiers of trophic levels in this study.

Ecosystem Approach

The concept of an ecosystem is an expansive one, taking in every minute quality of a landscape or waterscape. As described by Smith and Smith (2002), ecosystems are complex systems that are comprised of the sum of all interactions that occur within an area. Each ecosystem is comprised of various microhabitats that may contribute to the biological and physical character of the entire ecosystem (Svenning 1999). Some of the major factors in an ecosystem include 1) all of the living organisms and their organic wastes, 2) the various physical factors such as topography, geology, weather, and climate, and 3) the cycling of nutrients and energy, which serve as the ‘glue’ that binds an ecosystem into a functioning unit (Huston 1994).

Species diversity and trophic levels had been identified as measurable parameters for use in my study, yet neither of these parameters fully addressed the large-scale workings of ecosystems. Based on Smith and Smith (2002), and Primm (1991), organisms cannot be fully understood without an appreciation of the abiotic (nonliving) aspects of the environment in which they live. Temperature, wind and water currents, inorganic parent rock material, cyclonic storms, and numerous other features of the non-living landscape drastically influence the biological character of that piece of land. Furthermore, according to Huston (1994), the anthropocentric aspects of a landscape, which are features modified by the action of *Homo sapiens* and their predecessors, may have a profound affect on the biology of that landscape.

An ecosystem approach was established as the third and final parameter to be used for discerning ecology-focused from organism-focused field studies. Students' projects that addressed species diversity, trophic levels, and ecosystems only minimally were identified as organism-focused field studies in my investigation. In contrast, student projects that incorporated several different aspects of each of these three parameters were identified as ecology-focused field studies. The precise ways in which these parameters were organized, used, and evaluated are described in the Methods chapter.

2.2
ECOLOGY EDUCATION

As an academic discipline at many universities in the US, the study of ecology attempts to address the constraints that govern the flow of energy and nutrients on the planet (Orr 1992; Starr 2005). So vast and complex is this potential body of information, that university courses in ecology typically are at the upper division level, and require a thorough understanding of the principles of calculus, physics, and chemistry. It is also typical for educational considerations of ecology to partition this discipline into units that focus upon distinct aspects within an ecosystem, such as the behavioral and energetic aspects of interactions (Starr 2005). Ecology is not entirely relegated to the biological sciences at many universities. Engineering departments may address hazardous waste ecology, agriculture departments may offer courses in agricultural ecology, and earth science departments may offer courses in physical ecology (Orr 1992). Universities may also offer ecological courses in social and behavioral departments in which the activities of humans are examined as interactions.

The ecological study of life typically addresses units of the landscape that are technically known as ecosystems (Smith and Smith 2002). Ecosystems are places with specific characteristics that are often molded by the physical environment, such as water, topography, and weather patterns. Other important physical shaping forces in an ecosystem are biochemical and inorganic factors such as the levels of hydroxyl and hydrogen atoms that influence pH. Nutrient cycling also influences ecosystems (Huston 1994). One example of nutrient cycling involves the movement of nitrogen through ecological food webs. When an organism dies, decomposer organisms dismantle the organism's proteins into inorganic nitrogen, which is ultimately reformed into organic substances by plants (Primm 1991).

Although the science of ecology is highly technical when taught as a core area of study in many US universities, ecology is approached at a more general level when the instruction of biology is intended for non-science majors. In the study of ecological concepts for these entry-level students, the focus tends to be upon major principles that do not require complex mathematical calculations. Introductory ecology education tends to focus upon interactions in the natural world and our role as humans in influencing the environments we inhabit (Orr 1992). Science educator Cecie Starr takes the following approach to inviting students to investigate the natural world (Starr 2005):

> "What it boils down to is this: For a couple of million years, we humans and our immediate ancestors have been trying to make sense of the natural world and what we're doing in it. We observe it, come up with ideas, and then test the ideas. But the more pieces of the puzzle we fit together, the bigger the puzzle gets... You could walk away from the challenge and simply not think. You could let others tell you what to think. Or you could choose to develop your own understanding of the puzzle... No matter what your focus might be, you can deepen your perspective. You can learn ways to sharpen how you interpret the natural world, including human nature."

2.3

FIELD STUDIES

Field Studies and Education

Field study is a concept with rather nebulous meaning, since the use of the term varies according to its specific application. For clarification of the term, as it is used in this study, field study refers to the direct exposure of participants to a setting in which an item can be studied as it naturally occurs (Schatzman and Straus 1973). Field studies involve more than mere place, because the term also implies a process by which learning can occur through experiences. The concept of place implies that some integration of information can occur through learning activities in which participants arrive at some ideas on their own accord (Mittermeyer et al. 1997). The term ‘place’ is often replaced with the word context when most educators deal with this concept of site or location.

Evidence for the success of field studies in education has been obtained across a variety of cultures and ages of the participants (Schatzman and Straus 1973). Learning is nearly always enhanced by the appropriate selection of field activities where students directly experience learning in a real-world setting (Castillo et al. 2002). Selection of an appropriate contextual setting is nearly as crucial as the overall design of how learning will take place. Contextual settings can stimulate the participants to effectively learn. However, inappropriate instructional situations that increase the number of distractions and discomforts experienced by students may derail attempts to instruct (Deng et al. 2002).

The timing and planning of field studies is one area that teachers find difficult (Bentley et al. 2000). Even those teachers that are able to effectively conduct field studies are often not prepared for situations that may arise in natural settings. Fairly rigorous or repetitive and directed activities may reduce distractions that students experience in field studies (Madden and Grayson 2003). Such a regimen has been used successfully in the instruction of forestry, in which the students monitored woodlands as part of their learning experience (Dresner 2002). In this situation, students were responsible for making decisions about how a forest might best be managed. When these students made their decisions about forest management, they needed to incorporate the information from several academic disciplines, since the biological and social aspects of forestry had to be addressed.

Environmental field studies are often planned in a catch-as-catch-can manner, and it is common for students to receive very little detailed information on how to study an organism or topic in the field. Such students find themselves working in collaborative settings for which they are basically unprepared (Marques et al. 2003). One challenge in planning environmental field studies is in the basic design of what and how students will study. Since time in the field is at a premium for most public schools, efficient field study design is of paramount importance. The latter condition emphasizes the need for teachers to know how to create an effective field study. Grace and Ratcliffe (2002), in their work on students' perceptions on conservation, suggested that contextual instruction requires completely different pedagogical guidelines than those used for traditional learning situations that are removed from the place in which the contents being studied naturally occur.

Service learning, in which students perform a service that benefits others, can be another form of academic field studies. In one such instance, college students conducted their field studies by visiting various elementary schools. At these field sites, the college students were challenged as they learned how to convey information about conservation to children. One result of this outreach field study was that the college students benefited from the experience at least as much as did the group that was being served (Wellnitz 2002).

Field Studies, Teachers, and Students

Field studies are a practical tool for supporting and extending information obtained from lectures and laboratories. This is especially true when students are given first-hand experiences with an organism's environment (Dresner 2002). Students are not the only ones to benefit from exposure to real-world situations. Instructors working under these conditions are often exposed to unique learning experiences that enrich their own understanding. Such situations can excite teachers about their academic discipline. Both teachers and students in field studies are likely to develop a sense of personal accomplishment in being able to observe and understand organisms operating in their natural habitats (Manner 1995). Moreover, field studies can provide teachers with opportunities in which they convey some of their interests and ideas about science in meaningful ways to their field study students (Richmond and Kurth 1998).

To understand the research, principles, and methods presented later in this thesis, it is important to introduce concepts in this chapter that describe the context in which this examination of field studies was made. These concepts include situated cognition, cognitive apprenticeship, and conservation. Many instructors that teach in field settings may utilize various instructional concepts to some degree without fully understanding the underlying theories (Dresner 2002). Each of the three concepts that I have selected for this study can be a powerful educational tool if used effectively, while inappropriate use can result in problems. The appropriate use of situated cognition, cognitive apprenticeship, and resource management, as these theoretical concepts apply to field studies, is addressed in the following three sections of this chapter.

2.4

SITUATED COGNITION

According to the work of Collins et al. (1991), the context in which learning occurs affects what and how learning takes place. Situated cognition describes the mental processes that are involved in learning when the situation (context) is taken into consideration. Situated cognition is a theory of learning that can be applied to instructional methods. Learning is often enhanced when the subject matter of a lesson for a student is associated with direct interactions involving a real world situation (Brown et al. 1989).

In their review of situated cognition, Choi and Hannafin (1995) revealed extensive evidence that individuals think and behave differently in real-life versus controlled and created settings. When participants are involved in active forms of learning, in which they become part of the process of searching for answers to questions, then they are likely to development personal commitment to the task of problem solving. Physical involvement in situated cognition, in contrast to passive involvement where the participants listen to lectures or read to gain knowledge, is likely to stimulate learning and to engage students in collaborative activities (Young 1993).

Situated cognition has its roots in some of the early work on experiential learning by Dewey (1938). This educator had his students design and build a clubhouse in order to acquire knowledge about such construction projects. Dewey demonstrated that students learned more effectively when they worked together on a project rather than when they simply read about such activities. Through this early example of situated cognition, Dewey was able to observe the profound affect that active involvement in problem solving had upon his students.

The American Naturalist, Henry Thoreau deliberately went to live in the rustic setting in a rural environment near Walden Pond. This experience of co-inhabitation with denizens of the natural world resulted in a literary masterpiece on the workings of nature (Orr 1992). Thoreau did not limit himself to the use of books, but instead researched Walden Pond through direct experience. Rather than remotely study this environment, Thoreau lived his study as he went about noticing the subtle rhythm of the natural world in his daily existence at Walden Pond (Richardson 1986). Thoreau took the time to watch one bird forage for food, and compared this activity to a different species of bird. He paused to watch an ant crawl past, and followed it to discover the tiny insect's destination.

Thoreau's discoveries were subtle put powerful, and he was exposed to a number of scientific principles that would have taken tedious study if his activities had been restricted to the classroom (Orr 1992). His work demonstrated the importance of context when acquiring knowledge in an area that is new to the learner. The contextual exposure to information that was experienced by Thoreau at Walden Pond was an early example of situated cognition.

There is ongoing debate among some educators, concerning the effectiveness of situated cognition to address the long list of goals and objectives that comprise the curricula of many educational institutions (Hirsch 1996). Situated cognition has challenged traditional approaches that emphasize memory rather than perception and manipulation as the means for learning (Gibson 1986, Brown et al. 1989). Some researchers suggest that students can benefit from situated cognition when they use the process of science to solve problems or improve the world (Orr 1999). Studying content within the context of an authentic task fosters integrative thinking skills that prepare students to make principled and intelligent decisions about the world (Cocoran and Siervers 1994, Jensen and Schnack 1997).

Situated cognition can also bring about solutions to real-world problems, arrived at by students working as novice researchers (Burgess et al. 1999). Students represent a virtually untapped source of solutions for many of our environmental problems. Students that are new to an area of study can observe it without the bias of a seasoned researcher. Sometimes students notice crucial factors in a field study that the researcher does not see or at least does not consider worth examining. Also important is the collaboration that takes place among students, which may not occur to the same extent among professional scientists (Castillo et al. 2002).

As students work toward solutions in situations in which the students are actively engaged in the process of problem solving, their motivation and interest in learning science increases. Such a situation was found in a project at the University of Wisconsin-Madison. Students here developed botanical skills as they worked to restore a natural plot of earth (Greengrove and Secord 2003). Parts of the success from such endeavors in learning stem from the way participants acquire information as part of a stimulating activity. Rather than memorizing the names and botanical features of native prairie vegetation in a classroom setting, students in this study learned gradually as they encountered their leafy subjects growing in a sod of rich soil.

The instructional design associated with the theory of situated cognition follows various organized schemes that enhance the participants' acquisition and transfer of information. There are many ways in which situated cognition may be applied in learning situations. For example, one procedural method that is sometimes used is to have students repeat a process until they become extremely proficient at what they are doing (Hirsch 1996). Such repetitive experiences, which are sometimes referred to as drill and practice learning, may develop a degree of confidence as students gradually learn the subtle processes involved with an activity (Chall 2000).

Typically the first task in planning a contextual experience is the selection of a situation that has the potential to provide a desired set of student learner outcomes (Shaw et al. 1982). Since the potential tasks to be considered are as vast and nearly infinite as the real-world situations available, there are rarely specific guidelines for a particular contextual experience (Young 1993). It is the open-ended and potentially vague aspects of this first step of applying situated cognition that can cause problems later if the tasks or direction of the planned experiences are inappropriate. Young (1993) emphasizes the crucial nature of the planning of an activity that is based upon the theory of situated cognition. Effective planning must take into consideration various aspects of the learning environment and the participants that will be involved. After the situation has been selected, an instructional framework is designed so that students can operate within a real-world context while being assisted by an instructor or other expert in the field (Vygotsky 1978, Bruner 1986).

As is the case with many types of non-traditional instructional strategies, applications of situated cognition have their skeptics. From a practical perspective, most situations where students must leave the classroom create additional paperwork and planning for the teacher. Teachers are also discouraged from providing situated cognition experiences for their students due to institutional pressures. Situated experiences may not conform easily to curriculum standards nor adequately prepare students for standardized tests (Hirsch 1996). Furthermore, learners may encounter conditions that require them to develop control or metacognitive strategies for which they are not yet prepared (Bruner 1986). There are also uncertainties about how much and what type of supervision is appropriate for contextual learning situations (Chang 2003).

Decisions that students must make about how to proceed in an authentic task can be daunting, but such challenges may also prepare students for the real world (Schoenfield 1985). While applying situated cognition may create additional work for a teacher, when compared with traditional forms of instruction, such a contextual experience has the potential to foster a sense of accomplishment in all of the personnel involved with a project. Positive experiences can have powerful implications for the future perceptions and actions by both teacher and student (Hidi 1990). Students in one program frequently reported that they valued their contributions largely because they were doing the real stuff, and they were helping scientists to make real decisions (Barab and Hay 2001).

2.5

COGNITIVE APPRENTICESHIP

Situated cognition is a theory of learning in which the context within which learning occurs affects what and how learning takes place. A teaching approach that takes cognizance of this theory of learning is called cognitive apprenticeship (Collins et al. 1991). Cognitive apprenticeship in education has some parallels with traditional apprenticeships, but also some important differences. Traditional apprenticeships are usually focused on helping the apprentice develop specific manual and/or technical skills. Cognitive apprenticeship, in many situations that are used in more formal education, focuses on helping the student develop certain cognitive skills relating to the acquisition and application of content knowledge.

Many types of cognitive apprenticeships in education involve nontraditional activities such as the construction of a project. As the students work to complete the physical requirements of their task, they are also building a conceptual idea of the processes required to complete the task. One way that students may accomplish the construction of such conceptual ideas in a cognitive apprenticeship is by observing a model in action (Collins and Smith 1982). Often times, the model in action is an instructor or other expert in the field.

Coaching may follow modeling, as the instructional scaffolding progresses in an apprenticeship experience (Collins et al. 1991). Coaches may provide initial training, and later may provide reminders and guidance as the student develops the skills necessary to emulate the actions of the coach. In a process called fading, the coach gradually reduces guidance, and allows the apprentice to conduct a task on his or her own (Collins et al. 1991).

Coaching is one step in scaffolding, which provides an organized way in which cognitive apprenticeship may proceed under the guidance of a teacher or expert. The concept of scaffolding was introduced by Bruner (1986) and is based on the notion of the zone of proximal development, as described by Vygotsky (1978). The proper application of organized, guided steps to cognitive apprenticeship, such as scaffolding may provide, encourages a collaborative interaction between students and instructor, and enhances progress toward the desired goal (Bruner 1986). It is unclear just how much instructional time should be devoted to coaching and to a student's independent, constructive learning in a contextual learning experience (Hirsch 1996).

Cognitive apprenticeships often include stages of assessment that require a different set of criteria than found in traditional classroom evaluation strategies (Tombari and Borich 1999). Terminal examinations that address content are not always an appropriate method for testing accomplishments of students that have been engaged in cognitive apprenticeships. Contextual assessment in an apprenticeship is typically embedded within the instructional design as an integrated and ongoing part of the learning experiences rather than being simply a terminal exam (Case 1985).

Cognitive apprenticeship can involve real-world problem-solving strategies, and the acquisition of knowledge similar to what is done by experts. Applying scientific principles to practical problems in their communities often stimulates scientists. By applying knowledge gained through active involvement in the search for solutions, scientists often clarify or modify those principles, and help to solve everyday difficulties for others (Castillo et al. 2002). Lave and Wenger (1991) state that practice, or the practical application of principles, in the search for knowledge allows the content of these principles to be embedded in the activity itself rather than being separate from it. Such an approach is in contrast to instructional settings in which principles are studied without reference to practical applications (Bransford et al. 1986). Situated cognition is likely to expose students to realities of their world. Assessment of situated cognition is typically imbedded in the learning experience, and is fairer to minorities and verbally challenged students than are many types of standard evaluations that are typical of content driven instruction (Hirsch 1996).

Besides the benefits students receive from cognitive apprenticeships, instructors may also experience satisfaction and professional development when their students become involved in situations in which they are engaged in working toward solutions with applications to real problems. Much of the general focus of pedagogical studies has been on the student. However, the ways in which teachers benefit from their instructional experiences in field studies is also important (Manner 1995). The way that teachers feel about a lesson after its conclusion has a powerful influence upon the teachers' future decisions about which lessons to teach (Shepardson et al. 2003). The tendency is for teachers to repeat not only the lessons in which student experience success, but also those lessons in which the teacher also acquires some sense of satisfaction.

Teachers of cognitive apprenticeships are likely to feel that what they know really matters, and that they are in a position to communicate to others about the true relevance and importance of the scientific method. Apprenticeships may also serve as an outreach mission, whereby teachers communicate their own interests and achievements to students and the community (Wellnitz et al. 2002). By physically conducting environmental studies in the field, students and teachers often move beyond mere assimilation of the usual targeted instructional goals.

Possible Problems with Cognitive Apprenticeships

There are many potential problems in apprenticeships that cause the prospect of planning an ecological field study to be a daunting task for many instructors. Part of the difficulty in designing field studies relates to heuristic strategies, which are the tricks of the trade acquired by experts through trial and error (Schoenfeld 1985). Such strategies help scientists in their search for solutions, but can create chaos when a teacher attempts a trial and error field experience with students. Young (1993) suggested that only a limited number of well-tested teacher guidelines exist for student apprenticeships.

The conversion of domain knowledge into operational knowledge can be increased through exposure to environmental settings where teachers work alongside their students (Orr 1992). Domain knowledge, which refers to the personal experience a person has with the theoretical aspects of content, is not sufficient for good field studies. Teachers typically spend the majority of their college years involved in the acquisition of domain knowledge (Hirsch 1996). This content-driven curriculum is intended to prepare students to understand information, and is built upon previously covered academic material. As a house is constructed, brick-by-brick, so the acquisition of domain knowledge is expected to build towards enlightened understanding (Schoenfeld 1985).

Student field studies are one way teachers may be able to make the transition from domain to operational knowledge, as they assist their students in a contextual setting. Yet, in this role, teachers may find themselves unprepared for the unforeseen problems that typically arise in field studies.

2.6
CONSERVATION AND ENVIRONMENTAL EDUCATION

There is a body of published information suggesting that some traditional forms of learning in the sciences that do not involve contextualized experiences, can lead students to conclude that science and the environment are disconnected from their reality (Richmond and Kurth 1998). There is evidence that restricted educational experiences, in which students are not exposed to an appropriate context, are a common part of the packaged science curricula that is typical for many instructional units on environmental education (Barab and Hay 2000).

It is the various types of worksheets and pre-fabricated experiences that students are exposed to in the investigation of nature that tends to hinder the advancement of environmental education in schools around the world (Barab and Hay 2000). Through convenient kits and plans, many teachers lead their students through environmental education curricula that fail to address interesting and controversial issues in the local environment. The importance of such a contextual exposure to the environment was addressed in a study in which visitors were questioned at Yellowstone National Park in the state of Wyoming (Brody et al. 2002). Here, the unique natural settings provided environmental information for visitors to directly experience, and provided indirect opportunities for visitors to learn about social and cultural disciplines associated with Yellowstone. Exposure to a model village of Native Americans in a realistic setting may lead park visitors to consider learning about early human cultures. Through learning about such cultures, park visitors may learn about various plants that Native Americans used, thus increasing the visitor's exposure to botany.

Novel places may illicit extra-ordinary openness in people to explore new information, and may enhance learning through the powerful effect that some environments have upon people. Such a perception has been well documented, and has been successfully applied by various agencies that rely upon the captivating aspects of natural settings in order to draw visitors (Deng et al. 2002). Visitors to such novel environments may become motivated to search for solutions that may improve the condition of the landscape or preserve its species for the future (Worboys et al. 2002).

Novelties afforded by the environment itself can produce some of the biggest challenges and rewards for students and teachers working in the field (Dillon 2002). Again, this was observed in Yellowstone National Park where natural features of the landscape attracted the interests of visitors and made possible the inclusion of human history, sustainability, and other topics that might not be given attention in areas of less marvelous magnitude (Brody et al. 2002).

Constraints within most environmental study units often create situations in which students lack the time and opportunity to allow complex issues to be contextualized and discussed (Grace and Ratcliffe 2002). This aspect of time is crucial when planning field studies, for it is common for teachers to devote most of the student time and effort toward the actual field experiences. The analysis and integration phases, which follow the field study, are typically relegated to a classroom discussion or a summary report produced by the students. This results in a lost opportunity for students to incorporate their field experience with appropriate content (Aubusson 2002).

In the field studies that were conducted with my students, I used appropriate instructional scaffolding in order to foster a solid working relationship between the student and teacher and enable the student to acquire the requisite skills. The study was organized so that students were exposed to the theory and application of methods that demonstrate how a scientist proceeds systematically toward a meaningful goal. Such an apprenticeship is in contrast to the traditional instructional situation in which students in a field study rush through the motions of a field project in which the students function more like spectators than like authentic researchers. It was in this spirit of careful observation and lengthy field studies that the research described later in this thesis was conducted.

2.7
SYNOPSIS

A basic tenet of our understanding of life on earth is that no organism can be fully understood without consideration of the environment in which it exists. Niche is a term that refers to the ecological role an organism has in the environment in which it lives. This role includes the many interactions an organism has during its life in regards to both biological and physical aspects of its environment. No organism is truly solitary, for every ecological niche is linked to numerous factors in the environment. It is necessary to comprehend an organism's relationships, known more technically as the organism's ecology, in order to understand its role in an ecosystem.

Historically, many college curricula relegated field studies to specific circumstances that serve serious graduate studies or serve to expand the experiences of non-science students. More recently, field studies in many college curricula have been applied in a vast number of ways with far-reaching potential (Burgess et al. 1990).

Field studies can serve as an application of situated cognition in which course content is matched with the appropriate contextual setting in a physical environment. Cognitive apprenticeships are based on the theory of situated cognition, in which students learn while working at the elbows of experts. It is while working alongside an expert that a student has the potential to expand their perspectives and the knowledge that he or she acquires in the classroom.

The information that is acquired by students from academic field studies may contribute to conservation efforts that benefit the planet. Even when data from situated experiences in field studies are not directly applied to a problem, the participants come away from the experience with an improved understanding of the topic being studied. Furthermore, such students are likely to make wise decisions about environmental issues as future voting citizens and volunteers within their community.

There is a body of evidence supporting the use of field studies to educate the participants while simultaneously helping to conserve and manage our natural resources. However, there are insufficient guidelines for teachers to draw upon for such endeavors. Furthermore, the current attention being given to environmental issues in various places on earth makes it important for teachers to design instruction in which authentic field studies can result in information about how to manage and conserve organisms for the future.

Until some of the problems associated with student field studies are closely examined, and the various hypothetical solutions tested, many teachers will continue working from limited resources, personal experiences, and anecdotal information when designing field studies in nature. In doing so, there will likely be lost opportunities for the teacher and student. The potential is there for students to make meaningful discoveries that contribute something to science and the conservation of species.

Chapter 3

METHODS

AIM OF THE STUDY

One of the major aims of this study was to investigate how ecosystem-focused academic field studies might be associated with student contribution to science and conservation. My selection of three parameters would serve to differentiate ecosystem-focused field studies from studies that focused primarily on a single organism (species-specific field studies). Through conducting pilot field studies with students in California and in the country of Panama, I had confirmed the use of the following three parameters for identifying ecosystem-focused field studies. A more lengthy description of these terms appears in chapter 2, Literature Review.

1) Species diversity was observed as the number of different species that students examined in the field.

2) Trophic levels were observed as the major categories of a food chain that students examined in the field.

3) Ecosystem approach was observed as the number of different aspects of an ecosystem that students examined in the field.

In this chapter, I first suggest ways in which these three concepts of ecology might be used to discern major differences between species-specific and ecosystem-focused field studies. I then address the use of cognitive apprenticeship as an instructional strategy for carrying out academic field studies. Apprenticeships in this study were intended for first and second year college students enrolled in unit-bearing introductory biology courses. The role of conservation education, as it applies to biological field studies, is also addressed in the early sections of this chapter.

This chapter moves next to several sections which collective describe the supportive theories of the research design, and provide a rationale for the use of these theories in the study. Also provided in this account is a discussion of the sample selection, which included a description of the institutions that were involved in this study, and how specific aspects of these institutions might have influenced the sample of participants that were involved in my study.

Following the section on sample selection in this chapter is a description of the time frames and the location of each study. Information is provided about the biological, physical, and cultural aspects of the study site in Kenya and Costa Rica. A description of the structure of the academic field studies comes in the following section, in which an account is given of the types of field projects that students were involved with during my study. Various ways in which potential systematic errors were handled are addressed, along with the motivation behind the goal of each of the field research projects that the students conducted.

Following the section on systematic errors is a description of the three categories of data that I collected, with an emphasis upon data with applications in science education. Near the conclusion of this chapter is a section describing the ways in which data analysis was conducted. The analysis section provides examples of how data were managed so that organism and ecology focused field studies could be empirically assessed. This section moves onward with a description of project-based assessment as an instructional strategy for objectively evaluating student performance in field studies. The chapter concludes by briefly addressing the potential for student attrition, personal injuries, and other problems to influence academic field studies.

3.1
THEORETICAL FRAMEWORK FOR ECOSYSTEM-FOCUSED FIELD STUDIES

Three of the major steps in planning this study were to: 1) clearly define ecosystem-focused and species-specific field study strategies, 2) design the investigation so that rigor would be maintained throughout the study, and 3) establish an unbiased method of evaluating the results. In addition to the anecdotal evidence acquired in my trial studies in California, systematic research data was required in order to determine whether ecosystem-focused field studies resulted in better student academic performance than field studies in which one organism was the emphasis.

Major Parameters of the Study

The research design was based in part on ecological theories presented by Primm (1991), Huston (1994), DeVries et al. (1997), Wallace et al. (1997), Svenning (1999), Aubusson (2002), and Smith and Smith (2002). Information from these sources was used to distinguish measurable differences between organism and ecology centered field studies.

One feature that differed among the student projects in my trial studies in California was the number of species being examined in the field by various teams of students. Some student teams focused their fieldwork on a single species, while other student teams examined various factors in the environment that were associated with a single species. Another feature that varied within my California field studies was the number of different trophic levels that were examined in the field by students. Some student teams examined only one energy level, such as herbivores. Other student teams studied several energy levels, such as herbivores, predators, and plants.

A third and final feature identified dealt with major factors of the physical, anthropocentric, and biological aspects of the landscape in which the students conducted their fieldwork. Some student teams in my trial study addressed only the biological factors in the study; whereas, other teams examined physical aspects such as climate and geology, along with the biological and anthropocentric aspects of their study. The parameter regarding various aspects of an ecosystem that were examined by students is addressed in the section on ecosystem approach. This appears in the Ecology and the Organism section in this study (Section 2.1). Also in this section are described the concepts of species diversity and trophic levels which were the first and second parameters used in the methods for comparing species-specific and ecosystem-focused field studies.

3.2

COGNITIVE APPRENTICESHIP AS AN INSTRUCTIONAL APPROACH

Process of Cognitive Apprenticeship

One of the possible advantages of using cognitive apprenticeships in my methods was that the participants were in a position to develop a more personal clarity of reality, as suggested by Collins and Smith (1982). This clarity may help students propose meaningful and/or workable solutions through the guidance provided by an expert. In the cognitive apprenticeship model that I used, there was an introductory phase in which an expert or instructor trained a participant through a process that is referred as coaching. Coaching was followed by a second phase called fading in which supervision was gradually reduced as the apprentice became skilled at a task and eventually became independent of supervision (Collins et al. 1991). In the post-fading stage, students were considered to be largely independent in their fieldwork tasks.

When education of students is a priority, the use of thoroughly tested field methods can ease students into research without them having to experience delays and excessive frustration. One benefit of apprenticeships was that students could avoid some of the severe technical problems associated with novel research (Wimmers 2001). The use of new or ‘creative’ methods is typically a painstaking process for students and teachers because additional time must be added when planning such lessons, to allow for episodes of trial and error.

Through my trial studies in California, I observed that a post-fading phase was not always a clearly defined stage in the instructional sequence. Students can almost always benefit from the assistance provided by an expert or instructor (Choi and Hannafin 1995).

Yet, students can be expected in the post-fading stage to have acquired sufficient experience during their apprenticeship to be able to work through many of the problems that are typically encountered in field research endeavors.

In the major field studies that I conducted in Kenya and Costa Rica, I focused my assessment on the work that students conducted during the post-fading stage of their fieldwork. The fieldwork would not be fully conducted by students without my assistance; therefore, what I conducted with my students was a pseudo-post-fading phase. No student during the post-fading phase in my study was left entirely on their own to conduct their fieldwork, even after I felt that they were fully capable of completing their tasks without assistance.

The master-apprentice association described here was maintained throughout the study, even during the post-fading phase, and provided frequent opportunity for communication between the student and instructor. This association increased the likelihood that the students would follow the methods closely. This strategy of insuring rigor in the research methods also increased the potential for students' results to be considered for publication in peer-reviewed science journals.

3.3
OVERVIEW OF THE FIELD STUDIES

The field studies were designed so that students were in a position to make discoveries that could contribute to a body of information in biology and conservation. Rather than having only pre-fabricated learning experiences and traditional numerical scoring of performances on exams, students would collaborate in search of solutions that even I was not fully aware of at the onset of each field study. Some student teams would choose to focus their fieldwork on one or a few organisms, while other teams would focus their fieldwork on numerous factors in the environment of an organism. The classification of a project as being either species-specific or ecosystem-focused was based on the extent to which the students' fieldwork addressed species diversity, trophic levels, and the ecosystem.

By working at the elbows of experts through cognitive apprenticeships, the students would explore, in true contextual settings, ways in which their ideas and actions could make a difference in how a piece of nature was to be managed for the future. Many of the logistical considerations for the research design of this study were worked out during my field studies in California (Appendix B), and at Jatun Sacha Biological station in Ecuador (Appendix D). However, the field camps in Kenya and Costa Rica required extensive planning, and some of the lessons that I had learned in Ecuador and California could not be applied to the strategic planning that I conducted for the African and Latin American field sites.

While the financial supporting organization for the field studies posed some constraints, the general structure of students' activities, the specific research projects and related activities were identified and supervised by me. The evaluation of the students' work was conducted by various staff members that were hired by SFS to teach at the field camps in Kenya and Costa Rica. These staff members were also trained to use the evaluation tool that I implemented, as described the section on structure of the academic field studies (Section 3.8).

3.4

ASSESSMENT FRAMEWORK

A major purpose of my study was to investigate ways in which academic field studies could be effectively conducted so that students' work would contribute to science and conservation. Assessment of the outcome of the students' work involved specific problems that were worked out in the research design prior to the establishment of the actual methods that would be used in the study. Neither the activities nor the intended outcomes of my study were conducive to standard student evaluations as conducted through graded exams and worksheets. Hirsch (1996) has suggested that cognitive apprenticeship instruction is not appropriately evaluated through traditional testing. Lave and Wenger (1991) further emphasize this point, suggesting that the content of situated learning is embedded in the activity itself rather than being separate from it.

While the work of Choi and Hannafin (1995) and Collins et al. (1991) was used to establish aspects of the research design that dealt with the instructional framework of the study, project-based assessment strategies of the National Science Foundation (1994) were used for the actual assessment of the students' work. This work on project-based assessment was used in the design of the Directed Research Project Description, which was the tool used for appraising student outcomes in this study. A sample of this assessment tool that was used for the student projects in my study appears later in this chapter in Figure 3.4.

3.5

SAMPLE SELECTION

This section describes the institutions, the environments, and the participants of my study. The School Field Studies (SFS) is an educational institution that sponsors a field camp in Kenya where college students learn how to conduct research at the elbows of experts. This nonprofit institution organizes field programs that are accredited by Northeastern University and by 17 other US Affiliated Colleges and Universities. The field camp for one part of this study was at Game Ranching Ltd (GRL), which occupies 8100 km^2 of native savanna landscape situated on the Athi Plains in central Kenya at an altitude between 1600 and 1700 m (Appendix E). The ranch is approximately 40 km southeast of Nairobi, and near the equator at longitude $37^o02'$ E, latitude $010^o30'$ S. The mean annual rainfall averages 510 mm. Although temperatures fluctuate relatively little from one season to the next when there is no cloud cover, there are two distinct rainy seasons each year in this region.

Game Ranching Ltd. has hosted camps for academic field studies in a partnership with SFS since the early 1980's. Until fairly recently, GRL was named Wildlife Ranching and Research (WRR). Much of the literature regarding this operating ranch and reserve continues to use this former name. The close proximity to the major city of Nairobi has helped make the wildlife ranch possible. This is because of the many restaurants where wild game meat is served to tourists. The ranchland of GRL is one of the few local enterprises that can provide predictable quantities of game meat to these restaurants.

In addition to the Kenya field school, SFS also sponsors a field camp in the Central American country of Costa Rica. At this site, college students learn how to conduct field research by working alongside experts that are hired by SFS. The Olive Ridley Sea Turtle (*Lepidochelys olivacea*) was one of the major topics of study during several SFS field projects that I supervised in Costa Rica. These field studies were conducted at Playa Ostional on the Nicoya Peninsula in western Costa Rica at approximately 10.00^{o} N and 85.45^{o} W.

The study site in Costa Rica represents one of the last remaining major nesting areas of the endangered Olive Ridley Sea Turtle This coastal area includes a major nesting site used by several other species of sea turtle, including Leatherback, Hawksbill, and Green sea turtles. The nesting beach is in a remote region of the Guanacaste Pennisula, which was without electricity and several other forms of infrastructure during my field study (Appendix G). The total nesting area of Olive ridleys at the study site was about $28{,}000m^2$ at the time of my study. The upper beach boundary was composed of brackish sloughs, tropical scrub vegetation, and the homes of resident people. Sea turtle nesting beaches also occurred to the north and south of the main beach.

The total number of field study students that participated in academic field studies during my work in Kenya was 127 female and 78 male. There were a total of 34 female and 28 male students during my work in the Costa Rica study. The average age of participants collectively for both study sites was 19 ($\pm$ 1.3), with over 86% of them being first or second year college students. SFS had an open-door admissions policy, which allowed high school graduates from institutions around the world to be eligible to matriculate in an SFS course. SFS also offered financial support and assistance to encourage enrollment of economically deprived students and racial minorities.

There were a significant numbers of entry-level college students enrolled in each of the field studies that I conducted. According to the public information personnel at SFS, this predominance of first and second year college students is largely due to the academic course codes for field study credits (all undergraduate credits), and due to advertisement of the field courses in university catalogues. Students received three to four Carnegie units for each course, which involved 18 instructional hours per unit. The Carnegie system for determining university transfer credit is a widely accepted standard used for universities and colleges in the US. Each credit involves 18 hours of direct instruction, and assumes 52.5 hours of student involvement, mostly in the form of reading and preparation time spent outside of the required class hours.

In the SFS courses that I taught and supervised during my study, each student spent 28 days at the field site and received five university credits. These five academic credits translated as 90 hours of actual instruction and 262.5 hours of student involvement in activities such as studying, field report writing, and data analysis. These numbers of hours of instruction and student obligation were based on the Carnegie system that determines university credits. Instructors for the field study program at both sites where I conducted this study had a minimum of a MS degree in science from a US Accredited or US-recognized university. The US recognized universities included those institutions that were foreign to the US, and yet were recognized by accrediting bodies in the US. One such accrediting institution was the Western Association of Universities and Colleges, which periodically evaluates overseas colleges to determine whether their academic standards are equivalent to those standards found in accredited US universities.

The SFS payroll department paid instructors according to the number of Carnegie credits that they taught. The costs of an SFS course, which included staff payroll, logistical costs, and liability insurance, were covered through various grants from private corporations, including the Carnegie Foundation. Student tuition provided the balance of the money required to operate each of the field courses that I supervised. Each member of the field staff worked a rotational schedule, which included assigned lectures, assigned leadership on several student field projects (directed research). Personal time off was also scheduled, as were duties that related to the running of the field camp. An example of such a schedule, which was taken directly from the field camp, appears in Figure 3.1.

Center for Wildlife Management Studies

SCHEDULE FOR THE PERIOD: 03 JULY - 09 JULY

CASE STUDY ONE: LIVING WITH WILDLIFE

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	03	04	05	06	07	08	09
A.M.	SM09 [WV] SP10 [PB]	DR	Nairobi	DR	DR	DR Presentations	DR
P.M.	DR Soccer	SE10 [JR] SP10 [PB] PM Birdwalk	Nairobi SE06 [G]	DR Soccer	DR PM Birdwalk	DR Soccer	DR Due Mt. Lukenya
EVE.	SM12 [G]	Small World	OT	Study Hall	DR Presentations	DR	Study
AM	Brett	Karyl	Cath	Brett	Karyl	Cath	Bret
PM	Cath	Brett	Karyl	Cath	Brett	Karyl	Cath
OFF	Karyl	Peter	Otieno	Wayne	Janet, Cath	Derek	Brett

Lectures as indicated by their number e.g. WM05, as referenced in the revised curriculum. DR = Directed Research. SOD = Staff on Duty

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Figure 3.1 A staff summary sheet during one week of the study.

While tuition costs varied according to the study site and the year of the course, the typical range of costs for a one-month SFS course was $1,700 to 2,600 US dollars. This tuition provided students with credit for the course, and covered the costs of food, board, and transportation during a SFS course. The tuition that students were required to pay for each course did not cover the expense of travel to and from the country in which the field camp was located. Students were required to provide all of their own personal gear, such as clothing and toiletries, and were required to be at a specific location (usually an airport) at a specific date and time when the course began. Air travel combined with tuition resulted in costs of $4,000 to 2,600 US dollars, depending on the course and location of the field study.

The variation in tuition that students were required to pay for a field course were largely a result of the expenses accrued from logistics. For example, the Costa Rica field site was more expensive than the Kenya field site due to the facility fees that the University of Costa Rica charged us for use of the research station at Ostional. The university charged us an additional blanket fee for support (food, cooks, station manager). This differed from the operational costs in Kenya in which some of these services were provided for in the original contract.

Research staff salaries appear rather meager considering the costly student tuition; however, staff was provided free room and board, and SFS paid for all transportation costs during a scheduled course. As a staff member, I earned about $1,900 US dollars per month. I earned a few hundred dollars per month in addition to this amount when I had a directorship role. Typically, I was not responsible for the selection of the SFS instructional staff. Although, in some cases I was asked by the SFS office to review job applications, interview candidates for an SFS course, and to provide recommendations on whether a candidate should be considered for job placement. I did provide on the job training for new staff members. I also evaluated the staff, and in several instances I needed to mediate conflicts among the students and staff. Some of the instances required that I discipline the guilty parties, and in some cases I had to ask a staff member to leave the site due to theft or other actions for which there was a no tolerance policy that had been established for the field site.

3.6

TIME FRAMES AND INFORMATION ABOUT THE STUDY SITES

There was a range of 24 to 36 students in attendance during the 28 days of each SFS course that I supervised. Student attendance was not uniform throughout my field studies. This variation in matriculation will be addressed in the Results chapter. Students conducted their directed research projects six days a week, following an initial orientation period at the beginning of each month when new student groups arrived at a site. Attrition of students during the entire study, which consisted of 12 courses (each 28 days long), was less than 2%. The sample size of students in the various academic field studies appears in the Results section of this study.

I supervised academic field studies in Kenya in 1990, 1994, and in 2003. Field courses in Costa Rica took place in 1993 and 2002. My teaching and supervisory assignments were short term, and in many cases I only taught one or two courses during a particular year. For example, in 1994 I taught a single course in Kenya before returning home to help with the birth of my son. My involvement in SFS field courses was restricted to summers except for years when I was on sabbatical from my teaching duties at California State University at Fresno, and Modesto Junior College in California. I did not select the locations of each of the sites that I used for this study; The School for Field Studies was responsible for doing this. I had responsibilities as the instructor of record and director. SFS was the institution that was ultimately responsible and legally liable for the welfare of students during an SFS course. Although I did not select the general location of each site, I was responsible for making numerous decisions about what students could and could not do, where they could go, and various other limitations that insured some relative safety in both study sites. Such restrictions were necessary, for there were natural hazards, such as hyena in Kenya and crocodiles in Costa Rica. There were many other dangers for which I was responsible for steering students away from during each SFS course.

According to one administrator at the SFS Massachusetts headquarters in the US, academic field study site selection is based on numerous factors, which include practical logistics, student safety, and the potential for student projects to result in appropriate contextual knowledge. Another consideration for site selection was the potential for students to make meaningful contribution to the local environment where the field study took place. Decisions about site selection were also based on the previous experiences of the SFS staff, and upon eco-tourism, and relevant literature in which environments have been used for instruction or entertainment (Manner 1995, Gibbs 1998, Deng et al. 2002, Worboys et al. 2002).

Sites selected by various companies that operate eco-tourism adventures are often desirable since such companies have already worked out some of the potential hazards inherent in a specific location. The actual workability of a site cannot be fully known until an institution leads a tour of the general public, and visits the site for an extended period of time. Also important in site consideration is the degree to which the environment can withstand visitor use without losing the attractive aspects of the land or the denizens that originally attracted people to the area (Van der Dium and Caalders 2002). Risk management, local economy, and various other factors must be also be explored before a study site in a remote location is considered as a future SFS field camp.

Field Studies in Kenya

The SFS staff and I planned several studies in advance of the students' arrival for each course in Kenya. Some of the studies focused on increasing the applied information available about large animals. One example, described in detail in Appendix F, involved the weekly harvest regimen in which wildlife was used for meat production to preserve the rangeland for future herds of native animals. Increasing economical and social pressure to develop arid landscapes has focused some global conservation efforts toward appropriate technologies such as wildlife ranching. In such endeavors, the economic utilization of native animals is used to sustain savanna ecosystems (Dekker 1997).

Developing a full understanding about the various relationships between plants and large mammalian herbivores is crucial in order to properly manage wildlife. Many areas of the world cannot afford to conserve wildlife unless such animals pay their way through endeavors such as wildlife ranching in which landowners can turn a profit by allowing nature to have its way (Dekker 1997). This situation, as it related to the resident herds of hoofed animals on the Game Ranching Limited, was one of several topics that were investigated by students that participated in academic field studies in Kenya (Figure 3.2).

The selection of the Kenya field site was ideal for many reasons. Here, students were able to conduct fieldwork six days of each week, with data collection occurring sunrise to mid-morning, or late afternoon to evening. Such a wide range in times was necessary because each species of wildlife was active during specific hours of the day or night. For example, if students were to observe hyena behavior on a hot afternoon, the students would do little more than record the napping behavior of these animals. The Kenya site was also ideal because students could view wildlife in relative safety. There were no leopards or lions at the study site. There was a guard on duty 24 hours each day that restricted people without permission from entering the study area.

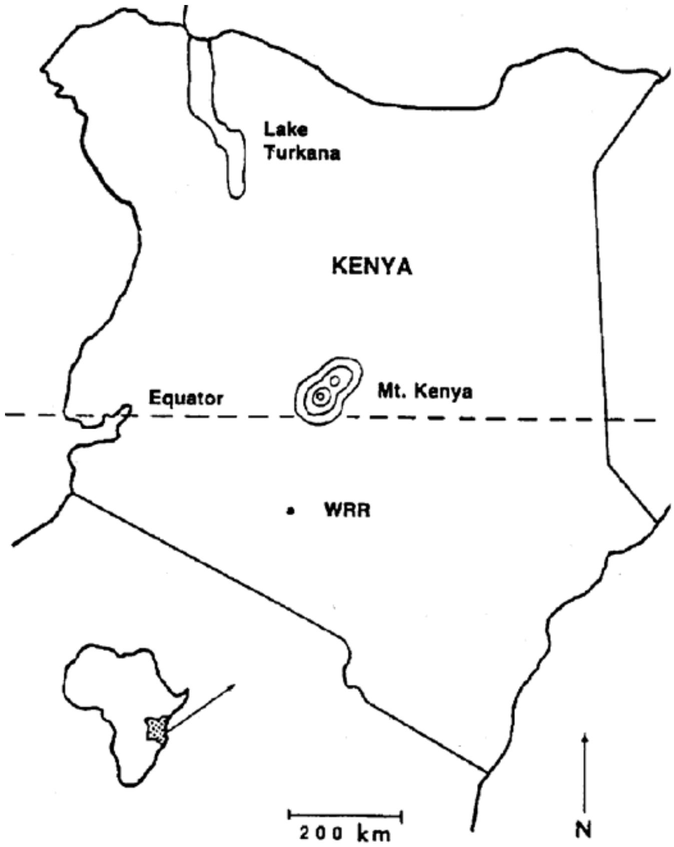

Figure 3.2 The author's illustration of the region of the Kenya field site.

Field Studies in Costa Rica

Site selection for the Costa Rica field studies was determined by conditions in which students could examine sea turtle nesting beaches in the Ostional region where legal turtle egg harvest was conducted by the local community. This area supports one of the last great nesting grounds of several species of sea turtles, and is also unique in having an experimental project whereby the local community harvests turtle eggs. Conservation through utilization was the approach used here to preserve sea turtles by making them a valuable resource for people to manage (Cambell 1998). By making an organism valuable, people are often likely to preserve it more than if no immediate incentives for preservation existed. Further information about this site and the experimental harvest of sea turtle eggs appear in Appendix G.

Many aspects of sea turtle ecology are held in balance by the manner in which the eggs are laid. The female turtle must crawl up a beach platform, select and excavate a nesting site, and cover the nest effectively before dashing back to the surf (Miller 1997). Successful nesting is often timed closely with the cycle of the moon, tides, and other environmental factors. A dramatic nesting event characteristic of the Olive Ridley Sea Turtle involves the emergence of thousands of turtles from the surf to nest on a beach over a period of hours. Nancite and Ostional Beaches in Costa Rica are considered to be crucial nesting beaches for this species. In a typical year, Olive ridleys nest on these beaches from June through December (Cornelius et al. 1991).

The selection of the Ostional field site was ideal for many reasons. Here, students were able to conduct fieldwork six days of each week, with data collection occurring sunrise to mid-morning, late afternoon to evening, and in 2-hour shifts throughout the night when female turtles typically came ashore to lay eggs. Students were able to divide their time among three different sections of beach where sea turtles came ashore to nest during the summer nesting season in this region.

At this site in Costa Rica, students were able to conduct field studies at a rural nesting beach, situated near scattered human dwellings, and students worked at a nearby beach in a remote area of Ostional. Students also conducted field studies on a beach where a legal harvest of turtle eggs by the local community took place. A map of the academic field study site in Costa Rica appears in Figure 3.3. Dark areas on this map represent dense vegetation, and clear areas indicate estuaries, marine waters, swamps and shallow pools. Ocean tides struck the three nesting beaches with similar wave action. The harvested beach had the longest and the most gradual gradient of the three beaches where the students worked in this study.

3.7

STRUCTURE OF THE ACADEMIC FIELD STUDIES

The SFS staff members and I designed academic field studies prior to the arrival of students at each study site. Prior to working out the actual field methods that the student would use, we first consulted experts and site-specific literature in determining what sorts of field activities would be appropriate for the study site and our students. Once this was established, then tasks were planned whereby instructors and students could engage in work leading toward solutions to real-world problems, as described in the work of Wilson (1993).

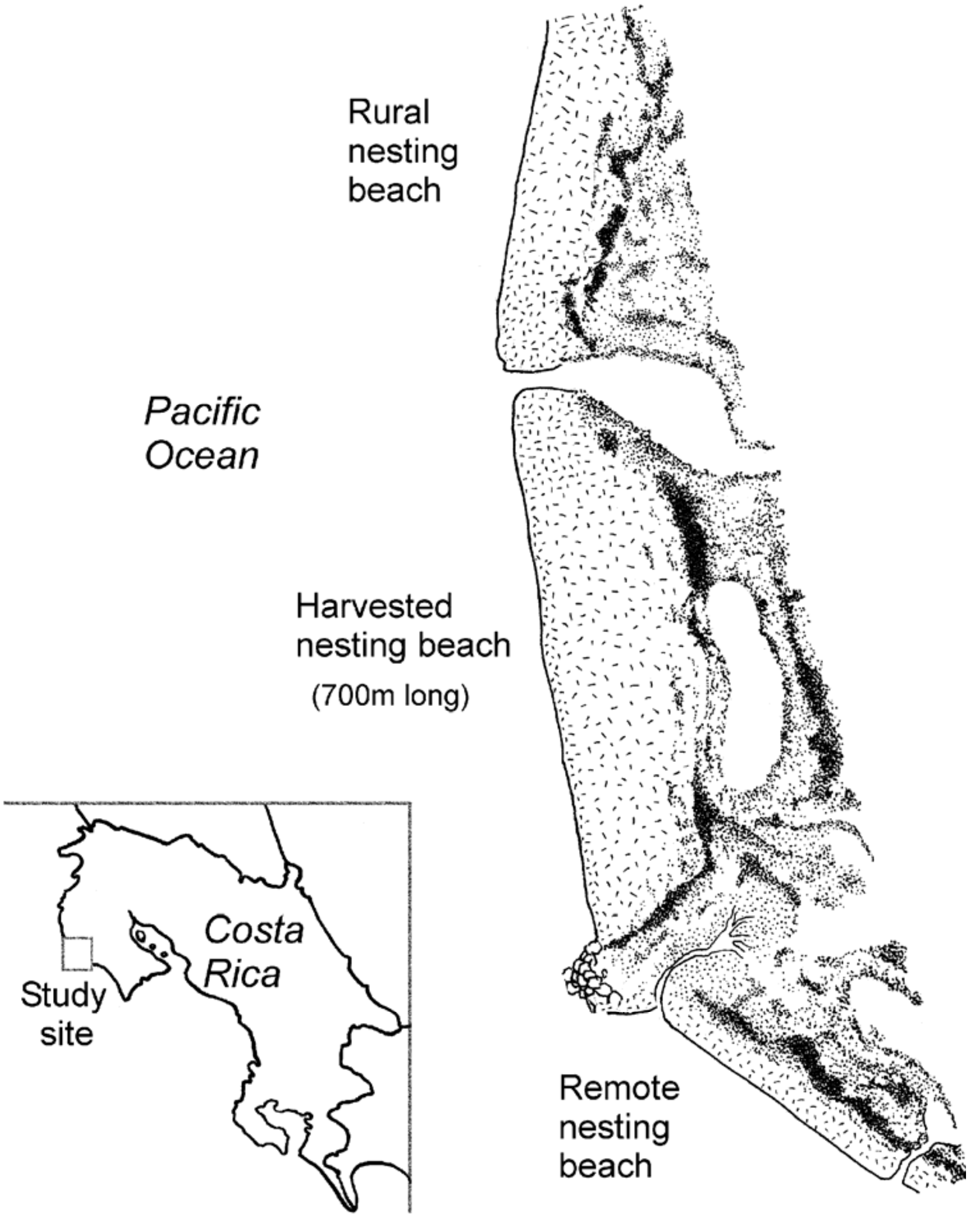

Figure 3.3 The author's illustration of the sea turtle field study site.

The staff and I experimented with these planned student tasks so that we would be prepared to assist the students in their projects. For each field research project that I designed, it was necessary to make modifications to the methods after I conducted a trial in the field. Each theoretical project description that I came up with had little hope for success with students unless I field-tested the methods first, to experience the activities as though I was a student. Thus, each of the methods that the students would be expected to use were field tested in advance of the students' arrival at the study site.

The activities that I planned for the students were based on methods that I had located in published literature. Thus the student working as an apprentice would be able to develop true skills of a scientific investigator, as suggested by Collins and others (1993). In this aspect of my study, I followed the description of cognitive apprenticeship of Barab and Hay (2001), and gave students little control over the primary research question, basic goals, and resources they would use. The apprenticeship situation, in which students were not in control of the field study design, might be considered restrictive from an educational perspective. However, such a design was necessary in order to have the students' projects follow the pre-planned methods that the SFS staff and I had field-tested. Also, such methods were necessary in order for the data to be considered for publication, if the students' study resulted in a novel discovery.

Student activities were based on a scientist-apprentice role as described in the following pages. Some of the academic fieldwork that the SFS staff and I planned was a continuation of studies conducted in a previous session. Therefore, the staff and I did not create entirely new research project descriptions for each twenty-eight day session of students. Such continuation projects are referred to as ongoing studies in this paper, and were originally presented to the students in the same manner in which the new projects had been done.

Field Research Protocol

In the SFS field studies that I conducted, each of which lasted 28 days, there was a standard agenda for how student training would proceed for their directed research projects. The first full day in which the students were at the field site was devoted to orientation. This included a number of items to be covered, each specific to the field site. Cleanliness and proper sanitation guidelines were emphasized, for illness could pose a major problem in remote field camps. In both sites, a medical doctor was not readily available. Thus nearly half of the first day of orientation involved protocols for hygiene and safety.

In each of the 12 courses in which I conducted academic field studies, student orientation to the study site was followed by a random assignment of research topics. These topics were written on a chalkboard as I verbally described some of the basic information regarding each topic. In describing the directed research projects that students would choose from, I explained to the students what sorts of field activities each topic would involve, why it was important that the research be conducted, and I explained some of the possible applications or values of the results of the study.

During the field study orientation with students, I also discussed aspects of the research that students needed to consider, according to their personal suitability for a particular project. For example, students that were not capable or physically fit enough to walk 5-7 miles a day might not want to take part in field studies where the participants must conduct extensive wandering transects by foot for each two hour research session. Students with sun-sensitive skin might wish to choose field projects that included time indoors for analysis.

Students were given about 20 minutes to ask me questions about the research topics before I asked them to commit to doing one of the projects. Some of the most common student concerns regarded safety. I took time to answer such questions thoroughly because safety was one of my greatest concerns as well. I was required by the School for Field Studies to conduct an extensive risk management assessment prior to student arrival to the study site. Each academic field study topic that students selected from had similar potential hazards. Each project had a relatively similar degree of small risk in the form of insect and tick bites, sunburn, dehydration, fatigue, and sundry other factors that are inherent in many field studies in nature. The directed research topics that students were to choose from are listed in Table 3.1 on the following page.

This table presents all of the research topics from academic field studies in Kenya and Costa Rica for the entire duration of my study. In any one course; however, the students had only three to four topics to select from. For example, a summer course in Kenya involved two student teams that examined springhare, one that examined giraffe feeding behavior, and a fourth student team that examined plant distribution. In the following summer, we investigated giraffe, impala, and plants, but did not study springhare. Students needed to choose from one of the studies that I had listed on the chalkboard for that specific session. There was not sufficient time or resources available for students to create their own field research projects if they were not interested in any of the topics that the SFS staff and I had planned in advance.

Table 3.1 Academic field studies that were planned in this study.

Title of academic project	Location	Projected students	Total months
Habitat and forage selection of springhare	Kenya	14	3
The role of Crematogaster ants in inhibiting insect herbivore.	Kenya	12	3
Vegetation census in relation to foraging habits of gazelle and giraffe	Kenya	67	9
Habitat and forage selection of gazelle and giraffe	Kenya	64	9
Behavior and flight distance of wildlife harvested for meat production	Kenya	43	6
Determining giraffe sex and age differences in daily intake of forage	Kenya	18	2
Totals for Kenya field studies:		218	
Vertebrate predators of sea turtle eggs	Costa Rica	14	2
Invertebrate predators of sea turtle eggs	Costa Rica	9	2
Nest position as a factor influencing sea turtle egg mortality	Costa Rica	10	2
Sea turtle nesting behavior	Costa Rica	9	2
The community harvest of sea turtle eggs at Ostional	Costa Rica	7	2
Totals for Costa Rica field studies:		49	

*The total months refers to the total number of 28-day field sessions that were attended by students during this study.

Steps for Preparing Each Apprentice

Each directed research topic was to be limited to a specific number of students. To indicate the desired group size for each topic, I wrote this number in parentheses next to the topic on the chalkboard. Many students did not seem to care what they did, or could not make up their minds. I assigned such students to projects that were in need of more field workers.

Following the assignment of students to the different directed research topics, I asked the students to form into their field study topic groups and become acquainted with each other briefly. Meanwhile, the SFS staff and I went around to give the students directions about what they would need to do in order to prepare for their project. This period of informal discussion followed the protocol used for contextual learning as presented in Brown and Palincsar (1989). Each group of students, that shared the same research agenda, was provided an opportunity to collaborate. This was done prior to actual field study activities such as data acquisition, data analysis, and a discussion of these data in the form of a field report.

After students were assigned a particular directed research topic, apprenticeship facilitation proceeded through a series of instructional scaffold steps designed to develop independent teams of student researchers, as described by Rogoff and Gardner (1984). The step-by-step process in which students became skilled at a task was also based on the work of Collins et al. (1991), and Choi and Hannafin (1995). In the cognitive apprenticeships conducted during my study, the research team leader was a staff member assigned to a particular group of students. This leader modeled the activities that the students would eventually need to conduct.

Modeling in the cognitive apprenticeships often involved an explanation of how equipment worked or why the staff member was conducting the activity in a certain way. The SFS staff and I performed data acquisition tasks in the field while students observed. In this initial modeling stage, students were able to observe both obvious and subtle processes in the instructor's actions. In this manner, students were beginning to integrate fieldwork activities, in a process of apprenticeship development that was described by Collins et al. (1991).

By the end of the first apprenticeship day, students were performing field study tasks, while the SFS instructors switched from being models to being coaches. Coaching followed modeling, in which the students conducted the field activity while a staff member looked on. During coaching, the staff member often needed to remind the student of missed steps and to give other forms of guidance that would reinforce the instructions given to the students during the modeling phase of the apprenticeship (Collins et al. 1991). In this role, the SFS staff and I observed, directed, provided hints, and remained close to the student groups as they conducted their field work.

Near the conclusion of the first apprenticeship day, students were expected to be able to conduct the desired fieldwork with very little input from a research staff member. For example, a student charged with observing the behavior of giraffe was able to conduct the work for 5 to 10 minutes without the supervisor of the directed research team having to say anything. Such independence was variable. The cause for variation in student independence in the fieldwork was different for each project.

Typically, the student field teams that were not expected to work completely independent of SFS staff were those that had a degree of risk involved in which a SFS staff member might be able to reduce if he or she accompanied the student research team in their fieldwork. Other types of field studies in which the students were not expected to work independently in the field were those that relied heavily upon vehicular transportation, required a translator or guide, or required assistance in the proper identification of organisms in order to for the fieldwork to be completed as originally intended.

During the two days that followed the first day of the field research, instructional input was gradually reduced for each student apprenticeship in a process called fading. Fading involved the gradual reduction of instructional guidance so that students became increasingly responsible for the work being done. Through this process, students gradually became independent in their field studies, as described by Collins et al. (1991). Fading was completed by the third day of the field research apprenticeship, when conditions of the specific research project allowed this to happen safely and effectively. After the third day of the field apprenticeship, students were considered by the supervising staff member to be on their own to complete their research tasks independent of instructional supervision

After the cognitive apprenticeship fading had been completed, I gathered together all of the research groups and handed out a grading sheet. At this time, I described how each student would be assessed on his or her research project. This information session lasted about one hour, and concluded with a question-answer session in which I made clear what the expectations of the directed research would be. A sample of the grading tool that the SFS staff and I used in the field studies in Kenya and Costa Rica appears on the following page (Fig. 3.4).

Some of the categories on the Directed Research Project Description sheet, related to problem solving competencies, were adapted from The National Science Foundation

(1994). Instructional staff at each of the field camps was required by their teacher contracts, which were issued by SFS, to arrive seven days prior to the arrival of the students. During this preparation period, the instructional staff worked together to prepare methods for students' field research projects. Also discussed during the pre-session was the assessment tool that would be used to determine grades on each student's research report. Verbal communication about what constituted a score of 1, 2, 3, etc for each subcategory of students' reports were discussed at this time. Collaboration of the SFS instructional field staff during the pre-course preparation period provided communication about the assessment tool, but inter-rater reliability was not tested, such as by having the staff grade several assignments and then exchange papers to see if each gave the same grade.

Potential for Systematic Errors

There were several features in the research design of this study that worked to eliminate some of the potential systematic errors. To address the influence of any single apprenticeship coach, instructors rotated their position as facilitator of the various field study groups. In this rotational method, as described by Aubusson (2002) and Chang (2003), rotation of instructors in a field study may lessen the 'ownership' of one particular study by one staff member, and thus reduce the impact that a single supervisor might have on the results of one student project.

School for Field Studies
Center for Wildlife Management Studies
Directed Research - Summer

PROJECT GRADING SHEET					
Name					
Project Working Title					
Section	**%**	**#**	**Category**	**Points**	**Score**
Prep. Work	15%	1	Literature Review	3	
		2	Project Proposal	3	
		3	Pilot Study	3	
		4	Hypothesis Formulation	3	
		5	Experimental Design/Equipment Design and Construction	3	
Field Work	25%	6	Personal Enthusiasm	5	
		7	Independence	5	
		8	Group Co-operation	5	
		9	Accuracy/Precision	5	
		10	Persistence	5	
Write Up	45%	11	Data Manipulation/Statistics	5	
		12	Introduction	5	
		13	Materials and Methods	5	
		14	Results	8	
		15	Discussion and Conclusions	12	
		16	Management and Research Recommendations	5	
		17	Bibliography	2	
		18	Appearance/Style	3	
Other	15%	19	Bio Illustration/Graphics	3	
		20	Oral Presentation/Defense	7	
		21	Willingness to Accept Direction/Learn	2	
		22	Problem Solving/Resourcefulness	3	
Total	100%	Research Director:		100	

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Figure 3.4 A sample of the grading tool provided to students during the introductory training on their directed research projects in this study.

Constancy of conditions, for the various study sites and topics, was achieved with the students' use of widely accepted guidelines for biological field studies. This was done by using site and topic-specific field methods, and by establishing the guidelines presented by Gibbs (1998) and Morrison et al. (2002) as the default methods to be used in the field. In this manner each student research team used current, appropriate field techniques. No student research team was left to construct its own methods or to patch together methods from various sources. Further information about the methods used by students in their fieldwork appears in Appendix G and H.

As per methods described by Tierney (1981), balancing was used in my study to reduce the impact of supervisors as sources of extraneous variables. As the term is used in this study, balancing refers to ways in which one factor might be compensated for by another factor in the field studies. One method of balancing in my study was the variable academic and ethnic background of the SFS instructors. This variability reduced the likelihood of certain student projects receiving more attention than others because of the interest and background of the supervisory staff. Rotation of staff members helped strengthen this use of balancing.

Balancing was not used in the grading of papers; however, the staff graded the reports in sessions in which all staff members were present. These grading sessions made it possible for each person that graded to communicate with his or her colleagues if there were questions. Each staff member took a paper from the top of the pile, graded it, placed it in the stack of completed papers, and turned again to take the next student paper from the stack of papers that had not been graded. In this manner, the SFS staff graded student papers randomly.

Supervisors with a background in botany might favor student research projects on botanical field studies, and zoologists might favor animal studies if balancing and staff rotation were not included in the methods of my study. Each instructional staff member for each site had a specific expertise that was not shared entirely by another staff member. In Kenya, we had one wildlife expert, one plant expert, and an expert on local culture and economics. Similarly, staffing in Costa Rica was done so that there was some overlap of expertise, but such expertise was not entirely redundant.

A relatively unbiased sample of students was obtained through the admissions policies of the School for Field Studies, and by the academic course codes of the field courses. Students that conducted fieldwork in this study were not all from any single university or from a specific academic cohort of students. The open-door admission policy of SFS, the economic incentives provided for student from low-income families, and the undergraduate credits of the SFS courses, provided a convenience sample for this study that was not comprised of a narrowly defined group of students. Further information about the institutional aspects of the School for Field studies appeared in section 3.2 of this chapter.

Having the SFS staff collaborate during the pre-course training week reduced the potential for systematic errors to influence the data gathered in this study. As previously described, the instructional staff was trained on how to evaluate student field reports through the use of a Project Description sheet. By the conclusion of the preparation week, each staff member was provided an opportunity to collaborate with his or her peers in understanding how each line of the Directed Research Project Description sheet would be used to assess students' field reports. This training addressed the need for inter-rater reliability of the assessment tool that would be used at the conclusion of the students' field research project. Each student in a research team would submit a written report and would orally present a summary of their report to the rest of the class. Each staff member graded an entire student report based on how the student performed on the various categories of that appeared on the Project Description sheet.

3.8
DATA COLLECTED

There were four different categories of data that I collected in this study. The first category was comprised of the scores from individual student field reports. The SFS field research staff assigned these field report scores during the sessions that I taught in 1990, 1993, 1994, 2002 and 2003. The scores that each student received were based on the Directed Research Project Description that each student had been provided in advance of their fieldwork. In these data, the students were considered a convenience sample, represented by college biology students who had paid to participate in field study courses in Kenya or Costa Rica. The instructional staff, which had no previous knowledge about the parameters being examined in this study, assigned the scores for each of the student end-of-course field reports.

The instructional staff was charged with teaching students how to conduct authentic field studies independently, and how to analyze, interpret, and present the information from their studies. As presented to students in the field study orientation session, which was described earlier in this chapter, and as presented in the Directed Research Project Description (Fig. 3.4), students knew in advance of their study precisely how the end-of-course field reports scores would be determined.

The second category of data that I gathered in this study was comprised of the biological field research that students conducted. This included the field data that were gathered by students working as apprentices in the field. Because my study was focused on science education, and not upon biological research, much of the data regarding scientific discoveries that my students made in field biology appear in Appendices L through O. Because of the science education emphasis of my work, the results of these studies are addressed in Appendices Q and R, but are not presented at length in the Results and Discussion chapters in my paper.

A third category of data that I gathered was comprised of the students' field reports in regards to the parameters of ecology being examined in this study. Students' field reports were sorted according to the species diversity, trophic levels, and the number of aspects of the ecosystem that were the focus of their study. Once the reports had been sorted into three separate categories, with each set of reports representing a low, moderate, or great extent to which a parameter was addressed, then a statistical mean score could be assessed for that categories. This strategy of sorting and processing data from student field reports is outlined in Figure 3.5 on the following page. Following this analysis, reports were once again gathered together and sorted for the next parameter. The parameters of ecology, which were the major focus of my study, are described more fully in the following sections on 1) species diversity, 2) trophic levels, and 3) ecosystems.

A fourth category of data that was gathered involved the potential for students' field study reports to be deemed worthy of being used in the production of manuscripts for journal publications and/or presentations at professional symposia. After the SFS instructors had assigned grades for the students' field reports, these instructors gathered to discuss the students' results. Through this conversation, the SFS staff decided which reports should be copied and set aside as potential sources of information for future publications. As described earlier, the SFS staff was an assemblage of men and women with different academic backgrounds, different interests and motivations for serving as SFS staff, and with different cultural backgrounds since it was typical to have staff members representing different countries. Their selection of student field reports with potential for publication did not follow written guidelines, but was instead based upon each staff member's expertise in being able to recognize novel results and authentic scientific discovery. Each member openly discussed their opinions, and there was no double blind or validity test involved with this subjective phase of my study. Student authors of the copied field reports were approached and asked if the staff would be allowed to use the students' work for publication. The precise way in which the selection of students' fieldwork was processed and used to provide information for my thesis is described in section 3.9, Data Collected.

Species Diversity

Species diversity, which is the number of different species in an area, was selected as one parameter for determining the extent to which a student's project was ecosystem-focused. Species diversity was selected to address the following research question. Will students that focus their time and efforts in the field study of a single species perform better in their end-of-course reports than students that focus on two or more species? One step in processing the results would involve comparing species diversity with the student's performance on his or her end-of-course research report.

Categories of species diversity in students' field reports

Example of low diversity	Example of moderate diversity	Example of High diversity
Sample A Student field report: Alert behaviors of gazelle... Major species: gazelle Species diversity: 1 Report score: **80**/100	Sample B Student field report: Invertebrates in sea turtle nests... Major species: Sea turtles, flies, crabs Species diversity: 3 Report score: **85**/100	Sample C Student field report: Foraging habits of... Major species: Springhares, Cynodon, Digitaria, Pennisetum, Themeda (plant genera) Species diversity: 5 Report score **75**/100
Sample D Student field report: Sea turtle nesting... Major species: Sea turtles, humans Species diversity: 2 Report score: **90**/100	Sample E Student field report: Feeding habits of giraffe... Major species: giraffe, acacia, balanites Species diversity: 3 Report score: **85**/100	Sample F Student field report: Vertebrate enemies of sea turtles... Major species: sea turtles, humans, dogs, raccoons, pigs Species diversity: 6 Report score: **85**/100
Low diversity score = 85	*Moderate diversity* score = 85	*High diversity* score = 80
N (A+D) = 2	N (B+E) = 2	N (C+F) = 2

Figure 3.5 A sample of how each student's report was sorted according to the number of species that were the focus of the study. This chart also indicates how the sorted reports were combined to generate a statistical mean score. The symbol 'N' refers to number of student papers in each of the species diversity categories in these fictitious data.

Species-specific studies were comprised of student research projects that focused on one or two organisms. In a like manner, an intermediate, and an ecosystem-focused category were established, based on how well the reports could be evenly distributed into sets. The following degrees of species diversity were established in order to sort student field reports into three sets comprised of relatively equitable number of reports:

Species-specific:	Populations of 1-2 species
Intermediate:	Populations of 3-4 species
Ecosystem-focused:	Populations of more than 4 species

The students' field reports were further sorted according to whether they were new studies or on-going studies in which the students were not expected to generate conclusive data. This latter action was based on the Directed Research Project Description that was filed by each SFS instructor prior to the academic field study for each topic of study. Each instructional staff member kept this form current during his or her supervisory rotation of a student research team. An example of this form appears in Figure 3.6.

Trophic Levels

A second parameter that was examined in this study consisted of trophic levels. Each of these levels represented a major category in a food chain (Letrourneau et al. 2004). In ecological trophic levels, organisms are grouped according to their niche, and how this niche relates to the flow of nutrients and energy through an ecosystem (Smith and Smith 2002). The major trophic levels considered in this study were 1) plants, 2) herbivores, and 3) predators and scavengers. Determination of where a species fit within one of these three ecological trophic levels was determined by Smith and Smith (2002), Primm (1991), and as described in Appendices B through I. A sample of how these parameters might be isolated and examined in my study appears in Figure 3.7.

Student papers were sorted according to the number of trophic levels that they had examined, as evidenced by their field data. This sorting of the field reports was in regard to trophic level, and did not address species numbers. For example, a student that studied gazelle, oryx, impala, and giraffe in the field was examining only a single trophic level, since each of these species is a primary consumer (herbivore).

As was done for the investigation of species diversity, categories of trophic levels were established in order to sort student field reports into three sets comprised of relatively equitable number of reports. This reduced the likelihood of the results from a data set being skewed by one or a few extreme scores. A quantity that represented precisely how many trophic levels a student examined as a major focus of his or her field research was established for each student field report. This number was obtained by examining the entries of a student's field data, which were attached to the back of the field report that they turned in for a grade. Entries that represented 10% or more of the entire body of data that a student gathered during a study were used in the determination of the number of trophic levels of that study. An example of such a data sheet appears in Figure 3.8.

✵ Directed Research Project Description

Aspect of Project			Details/Justification/Expectations
Proposer/Project Director			
Working Title			
Number of Students	Ideal/Minimum/Maximum		
Intern Involvement			
Nature of Project	One-off		
	On-going		
	Part of a Current Series		
	Part of a Planned Series		
Availability of Literature	At Jua Kali		
	In Nairobi		
	Elsewhere		
Necessity for Supervision	Scientific		
	Security		
Need for Night Work			
Dependence on Vehicles			
Need for Translation Services			
Need for Labour			
Need for Equipment	Existing		
	Borrowable		
	Purchaseable in Kenya		
Potential for Publication			
Necessity for Co-operation	With GRL		
	With KWS		
	Other		
Other Aspects/Notes			

Figure 3.6 A research project description form that was used in this study.

Once the determination for exactly how trophic levels could be assessed, and trials of various sorting separations were conducted, I arrived at three categories, which provided relatively equal numbers of student field reports in three separated sets. Each trophic level represents an assemblage of organisms with a single, distinctive role in converting energy in a food chain sequence, as described in the trophic level section in this chapter. The categories for sorting the field reports were:

Species specific:	1 trophic level
Intermediate:	2 trophic levels
Ecosystem-focused:	More than 2 trophic levels

Ecosystem Approach

The third category of data that was considered in this study was comprised of the aspects of ecosystems that students addressed in their end-of-course field research reports. As described by Huston (1994), ecosystems are complex systems, which are comprised of all of the living organisms, physical factors (such as geology, weather, and climate), human activities, and the cycling of nutrients and energy that occur within an area. The rationale for including this ecosystem concept in the study was based upon the importance of investigating the environment when attempting to understand one living organism.

Categories of trophic levels in students' field reports

Example of 1 level	Example of 2 levels	Example of > 2 levels
Sample A Student field report: Feeding behaviors of gazelle... Major levels: Herbivores Trophic levels: 1 Report score: **85**/ 100	Sample B Student field report: Physical features in beach sand of nesting beaches... Major levels: Predators, herbivores Trophic levels: 2 Report score: **95**/ 100	Sample C Student field report: Habitat preferences of springhare... Major levels: Plants, herbivores, predators Trophic levels: 3 Report score **80**/ 100
Sample D Student field report: Sea turtle nesting... Major levels: Herbivores, Trophic levels: 1 Report score: **90**/ 100	Sample E Student field report: Feeding habits of giraffe... Major levels: Herbivores, plants Trophic levels: 2 Report score: **85**/ 100	Sample F Student field report: Vertebrate enemies of... Major levels: Plants, predators, herbivores Trophic levels: 3 Report score: **85**/ 100
X report score = 87.5	*X* report score = 90	*X* report score = 80
N (A+D) = 3	N (B+E) = 2	N (C+F) = 2

Figure 3.7 A sample of how each student's field report was sorted according to the number of trophic levels that were the main focus of the study. This chart also indicates how the sorted reports could be combined to generate a statistical mean score, represented here with the symbol '*X*.' The symbol 'N' refers to number of student papers in each of the species diversity categories in these fictitious data.

(1) SPECIES GG HC B MATCH NUMBER 1

TIME 4:54 CATENA U GROUP COMP: AM 1 AF 6 SM 2 SF_ CF 1 = 10

FOCAL	SCAN	NN
F(15) WA(16) F	F	AF & SA
F	F	SM
F	F	SM
F	F	SM
F	F	SM

TIME END 4:59 AFC 0 AOM 0 CO 0

****

DATE 27/1/04 LOCATION PC

(2) SPECIES TG HC D/E MATCH NUMBER 1

TIME 3:22 CATENA U GROUP COMP: AM 1 AF_ SM_ SF_ CF_

FOCAL	SCAN	NN
WA(10) V(15) WA(36) V	WA	—
V(55) WA	V	GG - AM
WA(22) V(37) F	WA	GG - AM
F(05) ST(31) F	ST	—
ST(26) WA(56) ST	ST	—

TIME END___ AFC___ AOM___ CO___

****

(3) DATE 27/1/04 LOCATION PC

SPECIES GG HC E MATCH NUMBER 2

TIME 3:34 CATENA M-U GROUP COMP: AM 1 AF 6 SM_ SF_ CF 2 9

ecotone

FOCAL	SCAN	NN
WA(30) ST(39) V(42) WA(46) RU	WA	AF
WA(26) ST out of sight (54) RU	WA	—
RU(04) WA(13) ST(36) WA(39) F(46) WA(51) AOM(58) F	RU	AF
F(13) ST(47) F(49) WA	F	—
WA	WA	—

TIME END 3:39 AFC___ AOM 1 CO___

Figure 3.8 A student's field study data entries of Grant's gazelle (GG) and Thompson's gazelle (TG). In the analysis of these data from a trophic level approach, both species of gazelle represented a single trophic level (both are herbivores).

A student’s incorporation of an ecosystem approach was measurable by observing the following categories that could be obtained by studying a student’s data entries: 1) physical factors, 2) biological factors, and 3) anthropocentric (human) factors. One aspect of an ecosystem was addressed when that aspect comprised at least 10% of the data entered in the entire body of the data gathered during a student's field project. To clarify how I sorted and process the ecosystem data, an example is provided in Figure 3.9 on the following page. The way in which these data could be extracted from students' research papers is presented in Figure 3.10. The students' reports were sorted relatively equitably into three different sets, as had been done previously with species diversity and trophic levels. From this sorting of student papers, I arrived at the following categories based on the extent to which a student examined aspects of ecosystems during his or her fieldwork:

Species-specific:	1 aspect of the ecosystem
Intermediate:	2 aspects of the ecosystem
Ecosystem-focused:	More than 2 aspects of the ecosystem

Confirmation of Topics Addressed

A confirmative step was used to determine whether students actually made appropriate use of data that they had gathered. This was done to address a few of the papers in which students arbitrarily entered data without understanding how to use such data. For example, Figure 3.10 presents a student’s paper that was assessed according to the extent to which the ecosystem was addressed. This figure provides a sample in which humidity and temperature (physical parameters), and ants, (biological parameters) were recorded.

Yet this particular student did not include any written information about the humidity and temperature data that he had collected.

Categories of aspects of ecosystems in students' field reports

Example of 1 aspect	Example of 2 aspects	Example of < 2 aspects
Sample A Student field report: Foraging behaviors of Impala... Factors: Biological Ecosystem aspects: 1 Report score: **90**/100	Sample B Student field report: Thorns and giraffe... Factors: Biological, physical Ecosystem aspects: 2 Report score: **95**/100	Sample C Student field report: Plant selection of springhare... Factors: Biological, physical, anthropocentric Ecosystem aspects: 3 Report score **85**/100
Sample D Student field report: Sea turtle nesting... Factors: Biological Ecosystem aspects: 1 Report score: **90**/100	Sample E Student field report: Feeding habits of giraffe... Factors: Biological, human Ecosystem aspects: 2 Report score: **85**/100	Sample F Student field report: Vertebrate enemies of... Factors: Biological, physical, human Ecosystem aspects: 3 Report score: **85**/100
X report score = 90	*X* report score = 90	*X* report score = 85
N = 2	N = 2	N = 2

Figure 3.9 A sample of how each student's field report was sorted according to the extent to which the ecosystem was addressed in the study. This chart indicates how the sorted reports could be combined to generate a statistical mean score, represented here with the symbol '*X*.' The symbol 'N' refers to number of student papers in each of the species diversity categories in these fictitious data.

Insect Collection Data Sheet

Date: Time: Temp: Humidity:
Tree spp.: Tree height: Base diameter:
Health (1-5): Misc:

Insect Order	Description	Size

Ant Activity

	BASE			MID			TIP		
	B	A	HERB	B	A	HERB	B	A	HERB
1									
2									
3									
4									
VERT									

Figure 3.10 One academic field study data sheet, showing one way in which students made data entries for living organisms (insects) and physical parameters (temperature and humidity) in their field study.

In the previous example, in which a student did not adequately address the physical parameters of the ecosystem, the student's discussion section was examined to confirm this inadequacy. For example, although humidity and temperature were gathered, there was no mention of these parameters in the discussion section of the report (Fig. 3.11). Using the protocol that I had established for this part of my study, this student’s work was placed into a category of one aspect of the ecosystem as the focus of the study. Based on the confirmatory test described here, this student's paper only covered the biological aspects of the ecosystem in which he conducted his field study.

Since this study involved guided, cognitive apprenticeships, I knew the details of each of the students' projects in advance of the student's fieldwork (Table 3.2). Therefore, I was able to sort data on species diversity, trophic levels, and ecosystem aspects smoothly in most situations without having to search closely for the information that each student should be including in their written reports. The confirmative step described here was applied only in cases in which it was apparent after reading a paper that the student had not applied his or her data properly to the integration phase, which was the discussion section of the written field report.

Management Recommendations

The success of game ranches depend upon their ability to utilize the wildlife and resources efficiently (Hopcraft 1990). Ranch managers must keep in mind the carrying capacity of their ranch to achievè this goal. Presently on GRL, there are roughly 75-80 giraffe (Gimpel 1992). Past research has shown that this population is close to, if not at, carrying capacity (9-1994). In order to support healthy giraffe populations, resources must increase or giraffe populations must decrease. Increasing the forage quality of the land will increase the maximum sustainable yield for giraffe, thereby possibly increasing giraffe health.

Possible Solutions:

1. *A. drepanolobium* could be planted in a large distribution to divide and lessen browsing pressure on the population and health of the species.

2. Giraffe crops could be rotated seasonally or yearly to allow heavily browsed *Acacia* to regenerate from browsing damage.

3. Alternative browsed species could be planted to alleviate the stress on *A. drepanolobium*, while providing a constant flux of nutrients available to the giraffe.

4. Giraffe population on the ranch could become limited, reducing the browsing pressure on *A. drepanolobium* and increasing overall productivity of the plant.

Acknowledgements

Many thanks are owed to Derek Madden for assistance, advice, and transportation; to Cath Smith for transportation and assistance in data collection; to Wayne Vos for his continued support; and to the other members of the giraffe research team: Kimberly Richard, Kelli Shonter, Jason Bremner, Nadia Corra, and Deb Kristensen. Additional thanks go out to the Explorer's Club for sponsorship at SFS; Clarissa Marshall for continued scientific support; Debb Robinson for additional support; and my family for guidance, love, and continued support.

Figure 3.11 A sample of a student's field report that was sorted as having addressed only one aspect of the ecosystem. Although his data sheets contained data on humidity and temperature (a second aspect of the ecosystem), no mention was made in his results or discussion section about these physical parameters.

Table 3.2 Topics and data that were intended for students working in cognitive apprenticeships in this study.

Students' field projects topic	Data to be acquired by students
***Kenya academic field studies*:**	
Habitat and forage selection of springhare	Plant species eaten by springhares
Role of ants in inhibiting insect herbivory	Ant response to herbivorous insects
Vegetation census and foraging habits of giraffe	Plant species eaten by giraffe
Habitat and forage selection of gazelle and giraffe	Plants and habitats selected by giraffe and gazelle.
Alert behaviors of wildlife harvested for meat production	Distance that gazelle ran when approached by a vehicle
Differences in giraffe intake of forage	Plants eaten by individual giraffe
Costa Rica academic studies:	
Vertebrate predators of sea turtle eggs	Animals that disturb sea turtle nests
Invertebrate predators of sea turtle eggs	Insects that disturb sea turtle nests
Nest position and turtle egg mortality	Egg mortality and location of nest
Sea turtle nesting behavior	When and where turtles lay eggs
Community harvest of turtle eggs at Ostional	Number of eggs gathered by people

3.9

DATA ANALYSIS

In the sorting of student research papers, I produced tally sheets for each student paper in regards to species diversity, trophic levels, and aspects of the ecosystem. As mentioned earlier in this chapter, I conducted several trials to arrive at categories that would result in fairly homogenous distributions of student reports into organism focused, intermediate, and ecology focused field reports. No single category would be represented by less than 20% of the total number of student papers that had been gathered. Thus, the organism and ecosystem-focused analyses could be statistically conducted with the use of data sets that were each comprised of similar numbers of student papers.

The analyses of data in this study first involved marking the students' reports. As described earlier in this chapter, the students were provided with a tool describing how their end-of-course field reports would be scored. This scoring occurred in a double-blind manner, in which the SFS staff members that scored the students' reports were unaware of the parameters being investigated in this study. The SFS staff was focused upon how well each student performed on their report in regards to the Directed Research Project Description sheet (Fig. 3.4).

Following the scoring of student papers by the SFS staff, I sorted the student papers into categories as described in section 3.5. These student papers were assessed according to the extent to which species diversity, trophic levels, and the ecosystem were addressed in their work. Mathematical statistics were conducted on Microsoft Excel 97-2000. After data were entered on spreadsheets, an appropriate statistical test was selected. I had rendered the raw data into subcategories according to the extent to which the students' work was ecosystem-focused. In responding to the suggestions of a professional reviewer from the University of South Africa, I applied a nonparametric alternative to the one-way independent-samples ANOVA statistical test that I had originally planned. The Kruskal-Wallis test is often used with the type of data that I was going to generate, especially should any one of the following assumptions fail to be met:

1. that the scale on which the dependent variable was to be measured would have the properties of an equal interval scale;
2. that the k samples (number of subgroups that I was testing) was to be independently and randomly drawn from a source population (which it was);
3. that the source populations were going to be reasonably supposed to have a normal distribution (probably not in my study); and
4. that the k samples would have approximately equal variances.

The preliminaries of the Kruskal-Wallis test involved the measures from all k samples (the subgroups in my study) into a single set of size, N. These assembled measures were rank-ordered from lowest (rank #1) to highest (rank #N), with tied ranks included where appropriate. The resulting ranks were then returned to the sample, A, B, or C, to which they belonged and substituted for the raw measures that gave rise to them. In my study, sub-group 'A' represented species-specific field studies, 'C' represented ecosystem-focused studies, and 'B' was an intermediate between these two sub-groups. In this preliminary phase of analysis, the raw student scores were replaced by their respective ranks. Thus in the analysis of the Prep-work subgroup of this study that consisted of a maximum of 15 points (Fig. 3.4), raw scores of 15, 14, 13, 12, 11, 10, 9 were converted into rank-ordered numbers: 7, 6, 5, 4, 3, 2, 1, respectively, with the lowest rank of 1 being substituted for the lowest score of 9 in this sub-category. A sum and mean was calculated for each of these subcategories, the means for each subcategory squared, and the sum of the squared means served as the between-groups sum of squared deviates which were represented in my work by the symbols ^{SS}bg(R).

Further computations required that the means of the sampling distribution be calculated as follows, with 'k' representing the degrees of freedom, and 'N' referring to the number of total ranked numbers: (k-1) x N(N + 1)/12. This formula served as the dividend of the between-groups sum of squared deviates (^{SS}bg(R).), with the end result being 'H', the Kruskal-Wallis Statistic. Each each of the k samples in my study would include more than five observations; the sampling distribution of H is a close approximation of the chi-square distribution for degrees of freedom of k minus 1 (Lowry 2005).

Since the chi-square statistical test was used to determine significance in my study, I am providing a summary of chi-square. This statistical test is symbolized with '*X*' referring to chi-square, 'O' representing observed values, and 'E' representing expected values: $X^2 = \Sigma\ (0\text{-E})^{\ 2}$. The value that results is compared with a table of critical values of chi-square. For degrees of freedom of 2 (which was typical for my analyses), chi-square values smaller than 5.99 were not significant; values greater than 5.99 were significant beyond the 0.5 levels. The Kruskal-Wallis test and the Chi-square statistical test are both inferential procedures that I used to compare student scores with the extent to which the students' work was ecosystem-focused, and in comparing this ecosystem-focused parameter with the students' potential to make contributions to science and site-habitat conservation. Each student's field report either provided results and discussion matter was copied and set aside as having the potential to contribute to a future manuscript or symposium presentation (described in Section 3.8). I separated these student field reports from the reports from students' projects that were considered by the SFS staff to not contain information of a caliber or type that was worthy of publication.

I established ranks to determine the extent to which the students' work contributed to the advancement of science and conservation through the sharing of results to the scientific community. Dr. Harrison Madden of California State University, Fresno, and SFS faculty Antoni Milewski assisted me in setting up these ranks by. The categories, which the students' field reports were sorted into, were as follows. 1. Student field reports that were not selected for publication by SFS staff; 2. field reports selected by SFS staff but not used; 3. field reports selected, written up, submitted, and rejected for publication, and; 4. field reports published or accepted for publication by scientific society journals of national or international distribution or for presentation at international or national science symposia.

In addition to data management on species diversity, trophic levels, and ecosystem aspects, analyses were conducted on student attrition that occurred during each of the field courses in my study. A qualitative analysis of risk management was also conducted, in which I organized my medical notes on student injuries and situations in which injuries nearly occurred (referred to as near-misses). Attrition and risk management were not original topics that were intended for this study, and are not heavily emphasized in the Introduction chapter in this study. However, while conducting the study and organizing the data for analysis, I observed associations in the data in which attrition and risks were factors that may

some students.

month through a sustained yield management strategy aimed at preserving sea turtles by making them economically valuable as a resource.

My students selected a topic to study from a list of projects that the SFS staff and I had field tested before students had arrived at the site in Kenya and Costa Rica. During the research introduction session with the students, I described each project that the students would choose from. Students were provided an opportunity to ask questions about each of the proposed projects before they made their selection. I assigned students to a project when they could not make up their mind which study they wished to undertake. Students worked in groups as they gathered data in the field for a month. Each group had a similar level of supervisory assistance and access to information and the equipment that they would require to complete their study. The field methods used by the various student research teams were based on published literature. The students at both study sites conducted their field research in ways that are described in detail within appendices of this thesis.

Several student field study teams in Kenya focused their efforts in field research on the movement and foraging behavior of giraffe by directly observing the animals. Other student teams examined several species of plants that were known to be important in the diet of giraffe. A deployment of student teams also occurred in Costa Rica. Student teams studied sea turtles by directly observing the nesting activities of the adults and movements of sea turtle hatchlings. Other teams of students studied sea turtles indirectly by examining features of the nesting ecology and the presence and activities of various known predators of sea turtle nest eggs.

At the conclusion of their field research projects, students produced end-of-course written reports, which were scored according to a Directed Research Project Description used by the SFS staff. To decrease the variation in grading standards between instructors, the instructional staff discussed the report assessment tool during a one-week pre-course staff orientation session. After the students' field reports had been graded and duplicated, and the original reports returned to each student, these reports were sorted according to the extent to which the students had incorporated species diversity, trophic levels, and aspects of ecosystems into their fieldwork and end-of-course academic field study report. Sorting student reports according to whether they were ecosystem-focused, species-specific, or an intermediate of these two categories allowed me to examine an association between the emphasis of the fieldwork and student academic performance and the potential for students' work to contribute to science and conservation.

In addition to the ecosystem-focused centered field study emphasis of this study, was an examination of student attrition and injury during the field studies. Attrition was measured as the number of students that enrolled and physically attended a class but chose not to remain for the duration of the course. Risk management was measured subjectively as incidents in which injury or other unforeseen problems were associated with the operation of an academic field study in a remote environment.

Qualitative data on risk management were obtained through organizing and transcribing entries made in my field medical journal. These notes were hand-written in the field, and provided information on the date of the injury, the victim, and the actions that were taken to treat the victim. In some instances, I was required to examine a student's medical forms to see whether a certain treatment would be appropriate, such as when I administered medications with known side affects.

Chapter 4

RESULTS

The first section of this chapter briefly addresses the results of the students' biological field studies. Information about the various organisms that were examined by students in this study is presented in several appendices. This information is relegated to appendices in the back of this thesis because of the science education emphasis of this study, which was focused upon specific parameters regarding how students conducted their studies and how these activities might influence the students' academic performance.

Following the section on biology field data in this chapter are the results of the investigation of ecosystem-focused field studies that students conducted in Kenya and Costa Rica. Also included is a summary of the methods that were used to obtain the results, and a brief rationale for why each method was performed in a specific manner. The students' end-of-course field reports, that had been graded by the research staff, were sorted according to the extent to which the students' fieldwork was based on the study of different species, trophic levels, and features of the ecosystem in which the students worked.

The statistical mean grade that the research staff had awarded for each of the five subcategories (Preparation, Fieldwork, Write-up, Presentation and Completion) of the ecosystem-focused student report set was compared to the mean grade of students' species-specific report set. An intermediate set, comprised of student reports that contained moderate amounts of both organism and ecosystem-focused fieldwork, was included in this analysis.

Sample pages from the students' field notes and reports are included in this chapter to provide examples of what the students were actually doing and how their work was being assessed. Samples of student work are accompanied by graphs that compare the mean score of students' field reports with the extent to which the reports were based on field studies that were ecosystem-focused or species-specific. Results for the investigation of ecosystem-focused field studies ends with a section that describes adjustments that had been made to student projects due to extreme weather conditions and other situations that altered the original design of some of the field studies.

Student attrition and attendance are summarized near the end of this chapter. During twelve months of field studies that were conducted with a total of two hundred and sixty-seven different college students, there were three students that dropped out of their field course due to personal reasons. Risk management is addressed at the end of this chapter, in which the contents of my medical journal from the field study is summarized. These subjective accounts represent situations in which personnel lost time due to an injury or a problem associated with the field study. Results for student attrition, risk management, and ecosystem-focused field studies are addressed further in the Discussion chapter.

4.1

BIOLOGICAL FIELD DATA

Fieldwork was conducted intensively over a total period of three months in Costa Rica and nine months in Kenya. Two hundred and sixty seven students generated much of the field biological information presented in the appendices of this study. Each student spent twenty-eight days at a field campus, with ten to fourteen of these days including activities in which the students conducted field research through cognitive apprenticeships. The School for Field Studies staff members assessed the students' end-of-course field research reports. New staff members rotated in on the various student field projects, and there was no ‘ownership’ of a particular study by any one staff member. Because the focus of this thesis is on science education and not upon the biological aspects of field studies in which the students were involved, information pertaining to the results of the students' biological field studies appears in Appendix L through P.

Highlights of Biological Field Studies in Kenya

In their biology field studies, a majority of the students were able to generate sufficient field data to adequately test their null hypothesis. Many of these students were in a position to make plausible recommendations about how plants and animals on Game Ranching Limited in Kenya might be managed and conserved. Information generated by the fieldwork of five of the student teams contributed to a research paper that was conditionally accepted for publication. This research paper describes how thorn scrub vegetation may be monitored to generate a browsing pressure index for certain Acacia trees.

Acacia populations in many areas of the world are declining due to landscape over-utilization; a situation that is often caused to some extent by the intensive foraging activities of large mammals (Rohner and Ward 1999). One way to measure the extent to which some Acacia species have been overgrazed is to examine some of the features of plants that respond to the foraging activities of herbivores. For example, thorn growth may be a response to large browsers, and may limit the time that such animals spend at individual plants (Cooper and Owen-Smith 1986). Thorns may increase in length with increased loss of leafy matter, such as happens when giraffe feed heavily on individuals plants (Milewski et al. 1991). Much of the success of wildlife ranches in Africa is based on the intricate relationships between the harvested animal populations and the plants they prefer to eat (Kreuter and Workman 1997). Failure to properly monitor how plants respond to foraging can result in major problems on wildlife ranches in Africa (Dekker 1997).

According to some of the students' results from this study, browsing pressure on Acacia can be detected by monitoring thorn growth and the daily movements of large herbivores such as giraffe. A high index of thorniness, measured as the length of thorns on a sampled plant compared to a base-line thorn length for that species, indicates that a plant is being heavily browsed. My students established this base-line index for thorn lengths of *Acacia seyal*, *A. xanthophloea,* and *A. drepanolobium*. Each of these species of Acacia was observed by the students in this study as being crucial forage for herds of giraffe at the study site in Kenya. Some of the students’ data revealed that these three Acacia species comprised eighty to ninety-six percent of a giraffe’s daily intake of forage. Thorn indices that my students calculated for these Acacia species may help the wildlife manager at Game Ranching Limited in Kenya to estimate the number of large browsing mammals the landscape can foster without the vegetation suffering from over utilization. A high index of thorniness may indicate that the vegetation is being heavily browsed, and suggests that the herd size may need to be reduced, or the herds should be moved to new pastures to allow the resident vegetation time to recover.

Highlights of Biological Field Studies in Costa Rica

Many of the students in the Costa Rica field studies acquired sufficient data in their field projects that made it possible for them to support or reject their null hypothesis. I expected such levels of student success because the research staff and I had field-tested the methods that the students would use prior to the students' arrival at the study site. Although the field studies conducted by students in Costa Rica were focused on different aspects of the study site in Ostional, all of the projects were in some way centered on management and conservation of the Olive Ridley Sea Turtle.

Information from the biology field studies that were conducted by four student teams in Costa Rica contributed to a scientific manuscript that is currently being considered for publication by *Copiea*, the Journal of the American Ichthyology and Herpetology Society. This manuscript describes the nesting ecology of Olive Ridley Sea Turtles in regards to this species' egg mortality rate. This mortality of eggs may be influenced by physical features of the nesting environment, and by biological factors such as flies that inhabit the sand in some of the nesting beaches.

In the field study of Olive Ridley Sea Turtles, several teams of students found the hatching success rates for these reptiles to be highly variable. This observation was consistent with the work of other scientists. Embryonic development of turtle eggs at Ostional can exceed 80%, and yet less than 2% may survive to become hatchlings (Cornelius et al. 1991). Sea turtles typically have relatively high hatching success rates unless external factors intervene (Miller 1997). Three of the student teams in Costa Rica investigated this paradox involving a long-lived reptile with high capacity for reproduction and great rate of mortality.

Ghost crabs are frequently blamed for destruction of sea turtle nests. However, several of the student teams in my Costa Rica field studies linked the activities of crabs to the destruction of only a few turtle nests. My students found that crabs initially invaded only 2% of the turtle nests. One source suggests that crabs destroy turtle nests by producing tunnels through which flies and other agents of turtle nest degradation may find entry (Cornelius et al. 1991). Yet, several of my student teams found that flies may contaminate turtle nests without using crab tunnels as entry points.

Fly larvae and other small scavenging invertebrates were found within turtle nests and in the sand surrounding nests. This suggests that many fly larvae were in the sand at the time that the turtle dug her nest and laid her eggs. These larvae were present in the turtle nests without having traveled as egg-laying adults through crab holes that led to a clutch of turtle eggs. Thus, the problem with maggot infestation of turtle nests may be associated with the septic condition of the beach, in which rotting turtle eggs provide nutrients that support scavenging organisms such as fly larvae that are able to exist in beach sand.

Some of the scavenger organisms that subsist on organic nutrients in sand may disrupt the fragile oxygen balance in a turtle nest, causing the clutch of eggs to die of suffocation. My students made a management recommendation that crucial nesting beaches for the Olive Ridley Sea Turtle need to be frequently raked, and the organic materials removed so that populations of flies and other organisms do not proliferate in this reptile's nesting environment. My students also suggested that dead turtle nests be removed from the beach to further reduce nutrients that may support organisms living in beach sand.

4.2

DATA ON SPECIES DIVERSITY

Species diversity was investigated in this study as a parameter that may influence student performance in academic field studies. Will students that focus their time and efforts in the field study of a single species perform better in their end-of-course reports than students that focus on two or more species? The results from this study addressed an alternative (null) hypothesis concerning species diversity, which states that student report scores will not be associated with the degree to which species diversity is addressed in students' field study. This alternative hypothesis was tested by sorting end-of-course student field reports according to the number of species that were examined in the field. The student projects and the major species that the students' fieldwork was focused upon appear in Table 4.1. A student's methods section often stated which species were the focus of a study, and these methods were used to confirm that the student was following the original guidelines of the study (Fig. 4.1).

METHODS

The experimental plot was set up in June 2-3. Twenty-five A. Seyal plants, both small trees & tall shrubs, were randomly selected and marked with an orange ribbon. Two pairs of forked branches were chosen from each plant at heights of 2-3m. At this height, the branches were accessible to giraffes but inaccessible to other browsers such as Impala and Grant's gazelles. The base of each fork was tagged with a white ribbon. The branches selected were located on the outer canopy of the plant so as not to be shielded by other branches (Andrzejewski, 1988). Each fork contained 2 branches of equal size and lengths, and had similar leaf & thorn densities. Thorns longer than 2cm were

Figure 4.1 A sample from the notes of a student's field report, in which the field activities involved the study of several different species.

In the sample shown in Figure 4.1, the student's notes indicate that gazelle, Impala, and giraffe were observed while they fed upon species of Acacia that were flagged with orange ribbon. Four total species were the focus of this field study in which four students comprised the field research team. The sample shown in Figure 4.2 indicates that a single species was the focus of the study. The students in this research team observed the movements, feeding behaviors, and social structure of a population of a single species. Additional information about the student projects in this phase of the study appears in Table 4.1.

METHODS

We classified the groups as being male if adult males equaled or outnumbered adult females and female if adult females outnumbered adult males. In fact, 9 out of 10 "female groups" thus classified had fewer than 3 adult males, whereas all 3 "male groups" had 3 or more adult males. As we identified the group, we noted the direction in which the group moved

Figure 4.2 A sample of a student's notes that reveals the focus of the fieldwork to be of the social structure of a single population (one species).

Table 4.1 A list of the academic field studies and species diversity in this study.

Title of academic field study	Major species studied	Student reports
Habitat and forage selection of springhare	Springhare, Cynodon grass, Themada grass, Pennisetum grass	20
Role of ants in inhibiting insect feeding	Crematogaster ants (2 species), White thorn Acacia, Whistling thorn Acacia, Giraffe	35
Vegetation census and foraging habits of Giraffe	Desert date, Whistling thorn Acacia, and White thorn Acacia, Giraffe	25
Habitat and forage selection of Gazelle and Giraffe	Thompson's gazelle, Grant's gazelle, Giraffe	45
Alert behaviors of wildlife	Thompson's gazelle, Grant's gazelle, Giraffe, Wildebeast, Impala	53
Differences in Giraffe intake of forage	Giraffe, Eland, Impala	40
Vertebrate predators of sea turtle eggs	Humans, Dogs, Olive Ridley Sea Turtles	9
Invertebrate predators of sea turtle eggs	Sarcofagid Flies, Ghost Crabs, Mites, Olive Ridley Sea Turtles	11
Nest position and turtle egg mortality	Olive Ridley Sea Turtles	10
Sea turtle nesting behavior	Olive Ridley Sea Turtles, Red Mangrove	9
Community harvest of turtle eggs at Ostional	Humans, Olive Ridley Sea Turtles	10

In another academic field study, a team of five students used ladders and pole saws to sample the length of thorns at different heights in a single species of tree known as White thorn Acacia (*Acacia seyal*). There were no other species or parameters being considered in this field study. After their study had been completed and graded by the research staff, I found that more than ninety percent of the information in the students' report was centered on White thorn Acacia. According to the species diversity classification that I used in this study, described in Chapter 3, the White thorn Acacia study was identified and sorted into an species-specific data set comprised of other student reports in which one or two species were the emphasis of the students' fieldwork.

Figure 4.4 displays the results of the comparison between students' field study that were species-specific and studies that were ecosystem-focused. No statistically significant difference was revealed in nonparametric, one-way analysis of chi-square through use of the Kruskal-Wallis statistical test.

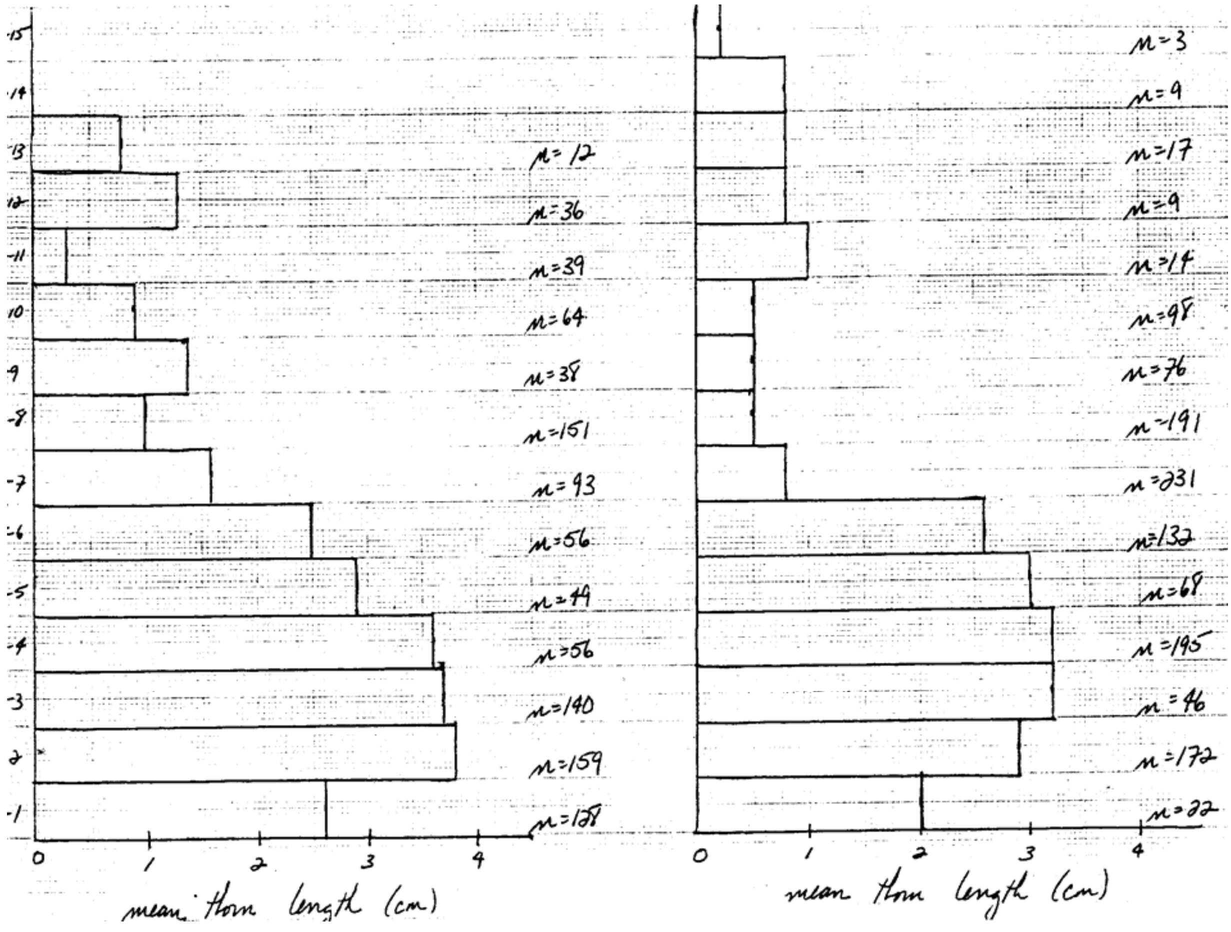


Figure 4.3 A sample from a student's field report in which data from a single species of tree were graphed according to the mean thorn length at each meter interval of the vertical height of the sampled tree.

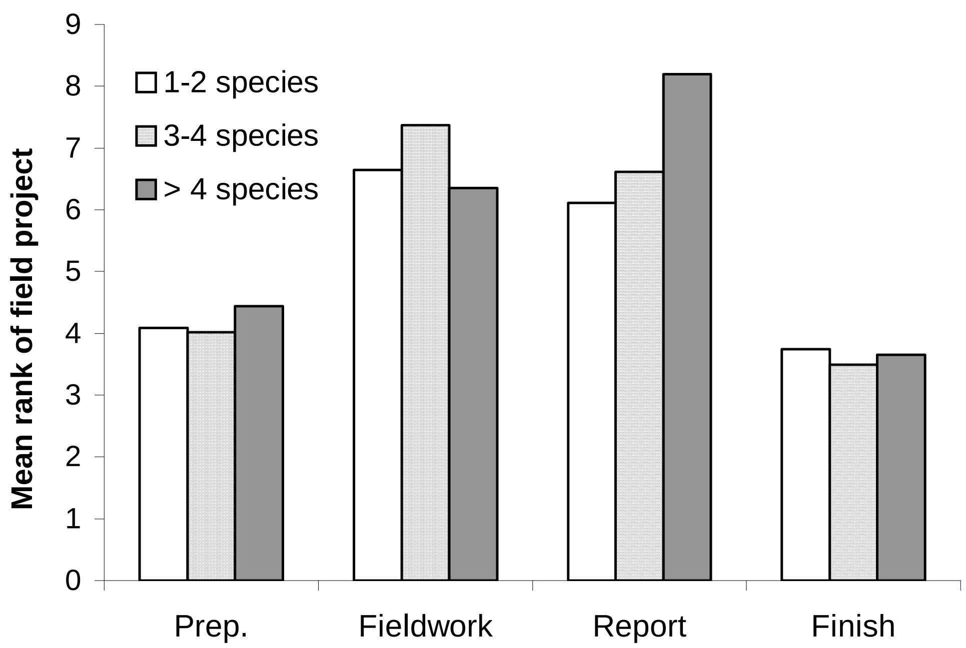


Figure 4.4 Comparison of species-specific studies with broad, ecosystem-focused field studies. Results of Kruskal-Wallis test (*H*) and Chi-square (X^2) are: H=0.003, X^2=99.5, df=2 for Preparation; H=0.015, X^2=99, df=2 for Fieldwork; H=0.064, X^2=95.0, df=2 for Report write-up, and; H=0.001, X^2=99.9, df=2 for Finish and the final presentations of the student reports in Kenya and Costa Rica.

4.3

DATA ON TROPHIC LEVELS

A second parameter examined in the analysis of students' field reports was the extent to which students focused their study on one or more ecological trophic levels. As described in the former chapter, trophic levels represent major tiers of food chains (Letrourneau et al. 2004). The major trophic levels considered in this study were plants, herbivores, and predators. Determination of where a species fit within one of these three ecological trophic levels was determined by a review of Smith and Smith (2002), Primm (1991), and as described in the literature presented in Appendix B through I. The academic field projects that were conducted in Kenya and Costa Rica appear in Table 4.2 on the following page.

The results that are presented in this section address the following question. Will students that focus their time and efforts in the field study of a single trophic level perform better in their end-of-course reports than students that focus on two or more trophic levels? This question was addressed by examining the students' field reports to determine how many trophic levels comprised the main emphasis of their study. Although there was a Directed Research Project Description that was written up as a guideline for students to follow during their study (described in the Methods chapter), I examined the students' field notes and written reports to confirm that they indeed followed the guidelines of the project. The results from this study addressed an alternative (null) hypothesis concerning trophic levels, which states that student report scores will not be associated with the degree to which trophic levels are addressed in the design of their study.

Table 4.2 A list of the academic field studies and trophic levels in this study.

Title of academic field study	Ecological trophic level studied	Student reports
Habitat and forage selection of springhare	Plants, herbivores	20
Role of ants in inhibiting insect herbivory	Plants, herbivores, predators	35
Vegetation census and foraging habits of Giraffe	Plants, herbivores	25
Habitat and forage selection of Gazelle and Giraffe	Plants, herbivores	45
Alert behaviors of wildlife harvested for meat production	Plants, herbivores	53
Differences in Giraffe intake of forage	Plants, herbivores, predators	40
Vertebrate predators of sea turtle eggs	Predators, herbivores	9
Invertebrate predators of sea turtle eggs	Predators (scavengers)	11
Nest position and turtle egg mortality	Predators	10
Sea turtle nesting behavior	Predators	9
Community harvest of turtle eggs at Ostional	Predators	10

As was done for identifying and sorting the reports for species diversity, the students' reports in this phase of the study were separated into groups for analysis according to the extent to which trophic levels were addressed in a study. Samples of students' work on the following pages provide examples in which the students' field reports were identified according to the extent to which trophic levels were addressed in their field project. The results of a field project in which students studied giraffe social structure and behavior appears in Figure 4.5. The students in this team focused upon the movement of giraffe, and the number of calves, subadults, and adults that were observed in each herd. These students' conducted their fieldwork primarily from a vehicle that roamed the ranchlands of GRL in search of giraffe herds to observe. Their study was focused on giraffe, and data collection was entirely of giraffe movement and social structure. After the students' reports were completed and had been scored by the research staff, I identified their reports as being based on a species-specific field study because a single trophic level, that of herbivores, was the emphasis of their fieldwork.

In field study that was similar to the giraffe social structure and movement project, students observed the browsing behavior of giraffe while the students also recorded the types of plants that the giraffe were feeding on. The team of students that conducted this study worked alongside the giraffe social structure team and gathered similar data on giraffe movement and behavior (Fig. 4.6). Reports for this study were identified as addressing a moderate amount of trophic level information, since two trophic levels (herbivores and plants) were examined.

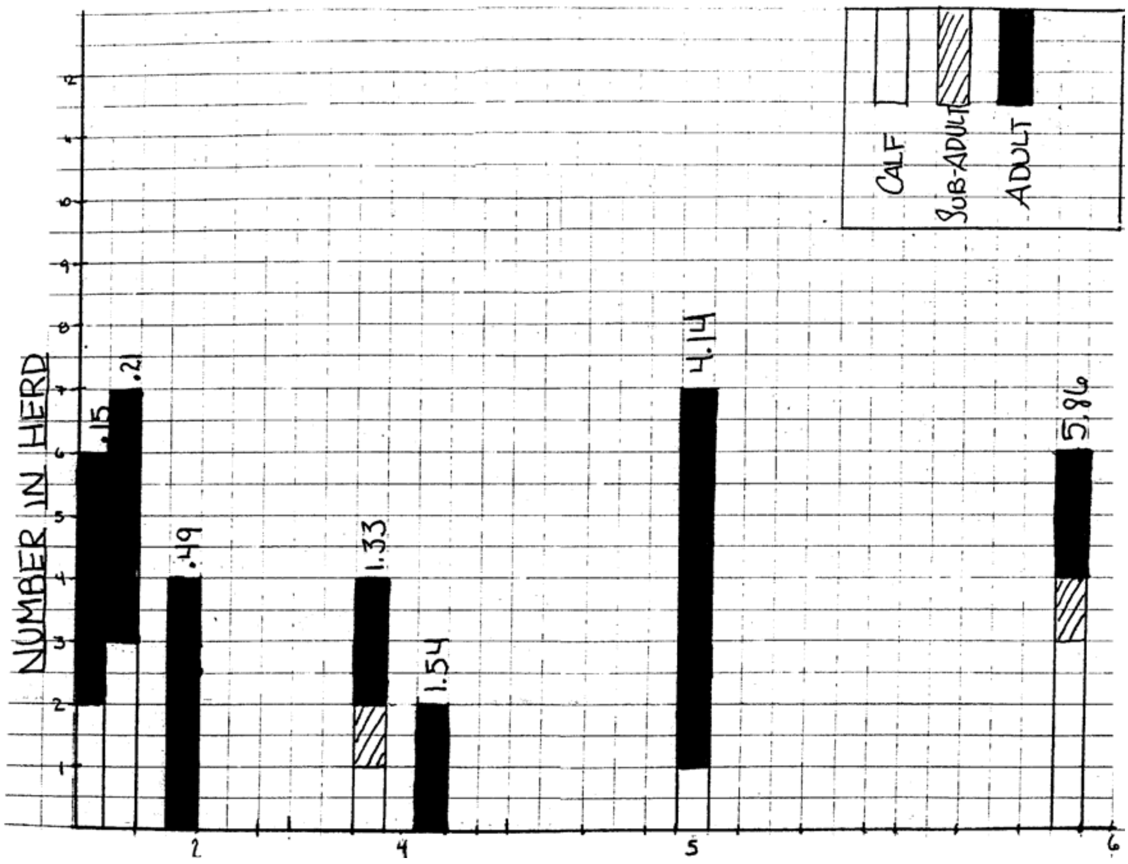


Figure 4.5 An example from a student's field report, showing data on giraffe which represented a single trophic level, that of an herbivore.

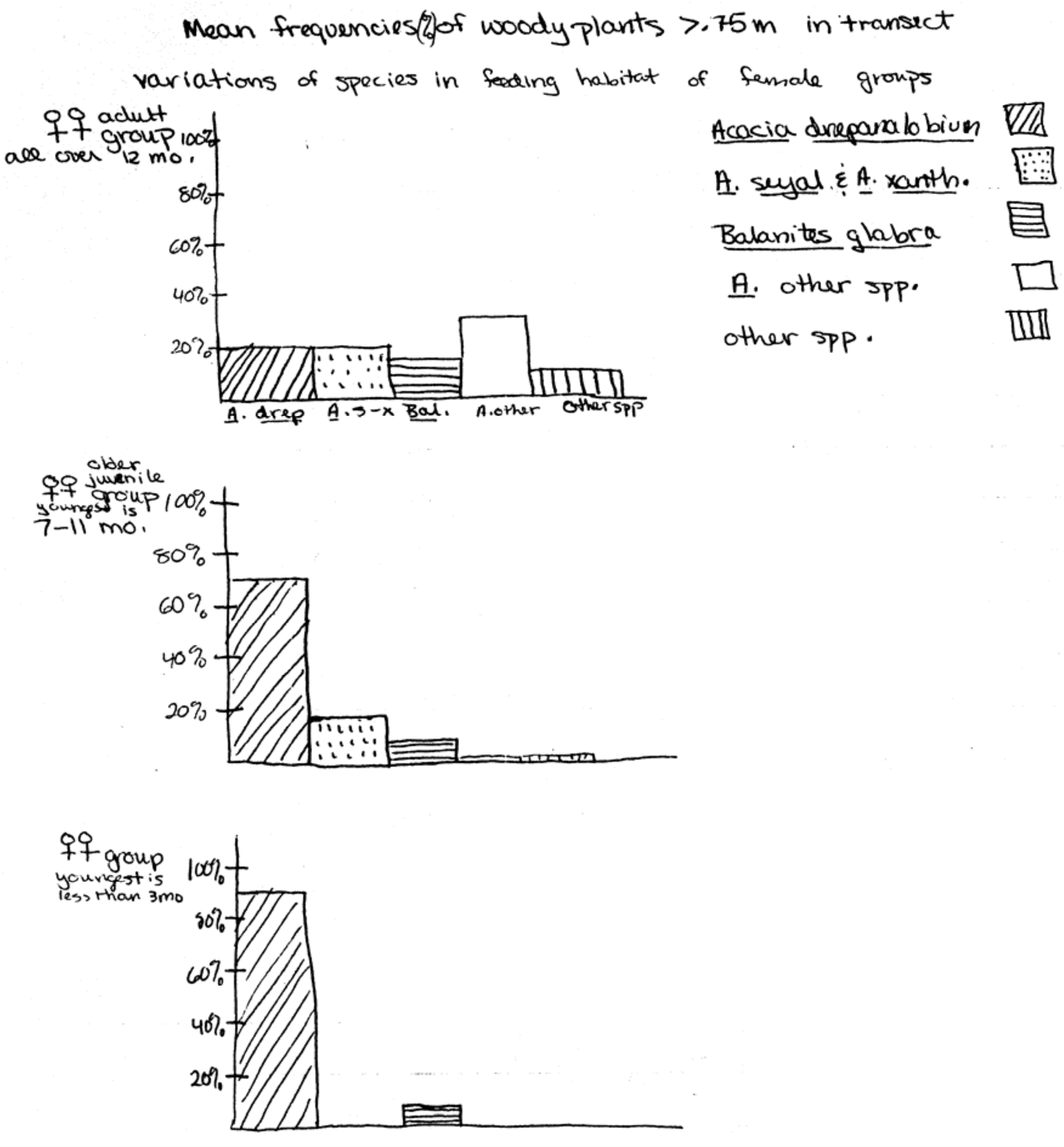


Figure 4.6 An example of a student project in which giraffe social structure and browsed plant species were recorded. This field project was identified as involving the trophic levels of plants and herbivores.

Figure 4.7 displays the results of the comparison between students' field study that were species-specific and studies that were ecosystem-focused. One tropic level represented the far end of the species-specific category of analysis. No statistically significant difference was revealed through nonparametric, one-way analysis of chi-square that was arrived at through use of the Kruskal-Wallis statistical test.

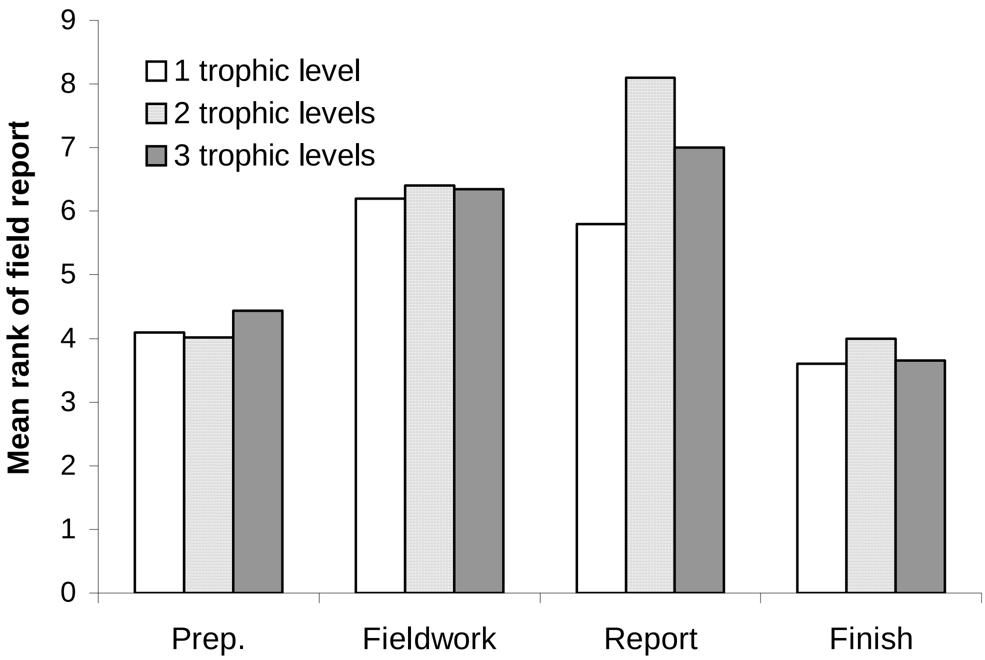


Figure 4.7 Comparison of species-specific studies with broad, ecosystem-focused field studies. Results of Kruskal-Wallis test (*H*) and Chi-square (X^2) are: *H*=0.002, X^2=99.9, *df*=2 for Preparation; *H*=0.013, X^2=99, *df*=2 for Fieldwork; *H*=0.054, X^2=95.0, *df*=2 for Report write-up, and; *H*=0.001, X^2=99.9, *df*=2 for Finish and the final presentations of the student reports in Kenya and Costa Rica.

4.4

DATA ON ECOSYSTEM APPROACH

The third phase of this study explored a possible association between student scores and the extent to which students incorporated various aspects of ecosystems in their end-of-course field research reports. The alternative (null) hypothesis was that there would be no association between student performance on end-of-course reports and the extent to which the students examined the ecosystem in which they conducted their fieldwork. As described in the previous chapter, and as found in the literature of Smith and Smith (2002), and Primm (1991), ecosystems are complex systems that are comprised of all of the living organisms, physical factors (such as geology, weather, and climate), human activities, and all of the cycling of nutrients and energy that occur within a specific area. A list of the academic field studies and the aspects of the ecosystem that were identified for this study appear in Table 4.3.

After the research staff had graded the students' reports, I identified each report as being ecosystem-focused, species-specific, or intermediate between the two, according to the extent to which the report addressed physical factors, biological factors, and anthropocentric (human) factors. One of the springhare studies in Kenya was an example of a project in which there was only a single major feature of the ecosystem examined by students. Although ample data were acquired for the students to test their null hypothesis in this project, the students did not conduct samples on the human or physical aspects of the ecosystem in which they worked. A sample of this team's data appears in figure 4.8.

Table 4.3 A list of academic field studies topics and the major aspects of the ecosystem addressed in each student field project.

Title of academic field study	Aspect of ecosystem studied	Student reports
Habitat and forage selection of springhare	Biological, physical	20
Role of ants in inhibiting insect herbivory	Biological, physical	35
Vegetation census and foraging habits of Giraffe	Biological	25
Habitat and forage selection of Gazelle and Giraffe	Biological	45
Alert behaviors of wildlife harvested for meat production	Biological, physical, human	53
Differences in Giraffe intake of forage	Biological, physical	40
Vertebrate predators of sea turtle eggs	Biological	9
Invertebrate predators of sea turtle eggs	Biological	11
Nest position and turtle egg mortality	Biological, physical, human	10
Sea turtle nesting behavior	Biological, physical	9
Community harvest of turtle eggs at Ostional	Biological, human	10

GROUP IDENTIFICATION	Adult over 12 mos.		Sub-Adult 7-11 mos.		Calf 0-3 mos.		WOODY PLANTS OVER .75 m										OVER 3.0 m			
Group	♀	♂	♀	♂	♀	♂	A. Drepanolobium	A. Senegal	A. Seyal	A. Stuhlmannii	A. Xanthophloea	Balanites	Grewia	Lycium Europaeum	Phyllanthus	Solanum Achal.	A. Fissured Bark	A. Senegal	A. Seyal	Balanites
♀	2	1	0	0	0	0	35	0	30	0	10	10	5	0	10	0	0	0	20	80
♀	6	4	0	0	0	0	5	0	0	65	0	20	0	0	0	10	20	0	0	80
							20	0	15	32.5	5	15	2.5	0	5	5	10	0	10	80
♀ with older juveniles	9	2	2	0	0	0	65	0	30	0	0	5	0	0	0	0	0	0	40	60
♀ with older juveniles	3	1	0	1	0	0	45	5	40	0	0	5	5	0	0	0	0	20	60	20
♀ with older juveniles	4	1	0	1	0	0	100	0	0	0	0	0	0	0	0	0	0	0	20	80
♀ with older juveniles	5	0	1	0	0	0	80	0	10	0	0	10	0	0	0	0	0	0	0	100
♀ with older juveniles	3	2	2	0	0	0	50	0	5	0	0	45	0	0	0	0	0	0	0	100
							68	1	17	0	0	13	1	0	0	0	0	4	24	72
♀ with young juveniles	5	0	1	1	1	1	90	0	0	0	0	10	0	0	0	0	0	0	0	100
♀ with young juveniles	5	1	1	2	1	1	100	0	0	0	0	0	0	0	0	0	0	0	0	100
♀ with young juveniles + 7 others	7	1	1	2	1	0	85	0	0	0	0	15	0	0	0	0	0	0	0	100
							92	0	0	0	0	8	0	0	0	0	0	0	0	100
♂	3	4	0	0	0	0	40	0	20	0	0	25	10	5	0	0	0	0	40	60
♂	8	8	0	0	0	0	50	0	45	0	0	5	0	0	0	0	0	0	40	60
							45	0	32.5	0	0	15	5	2.5	0	0	0	0	40	60

Figure 4.8 A sample data table from a student's field project in which springhares and plants (biological factors of the ecosystem) were the major emphases of the study.

In another field session, I had the students expand the original springhare study to include physical parameters (topography of the landscape). Thus, two major features of the ecosystem (biological and physical) were addressed in this field project (Fig. 4.9). A statistical mean score for such moderate reports, based on grades awarded by the research staff, was compared to the mean score of reports in which one or three features of the ecosystem were the emphasis of the students' study.

Group size

~~Our findings found~~ Springhare ~~to~~ forage individually 49% of the time and 51% in groups of two or more. When comparing only individual and pair clusters, springhare were found to prefer individual foraging over pair formation. (stats)

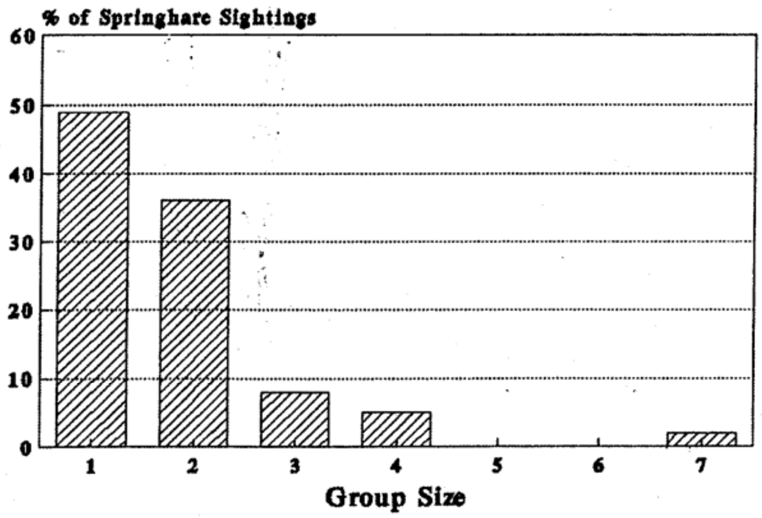


Figure 2. The percentage of springhare observed from June 18-July 3, 1994 that foraged individually or within groups.

Discussion

Habitat preference

In this study, springhare were observed to forage primarily in Zone I. It was shown that springhares prefer habitats with low, yet abundant foliage, and high visibility (Smithers 1971, Kingdon 1979). Possible explanations for this may be resource availability, predator detection, and burrowing convenience. *Cynodon* species was their primary source of dietary intake across five studies conducted on GRL (Augustine 1993, Clarke 1993, Anderson 1994). This conclusion allows for the rejection of the first null hypothesis and acceptance of the alternate hypothesis. This correlates with previous studies indicating that *Cynodon* is a rhizomaceous species with an

Figure 4.9 A sample results and discussion section from a student's field project in which springhares (biological factors) and the landscape (a physical factor of the ecosystem) were the major emphasis of the study.

Figure 4.10 shows the results of the comparison between students' field study that were species-specific and studies that were ecosystem-focused. The species-specific set in this analysis consisted of students' reports that addressed on feature of the ecosystem (e.g. physical, biological, or anthropocentric). No statistically significant difference was revealed in nonparametric, one-way analysis of chi-square that was arrived at through use of the Kruskal-Wallis statistical test.

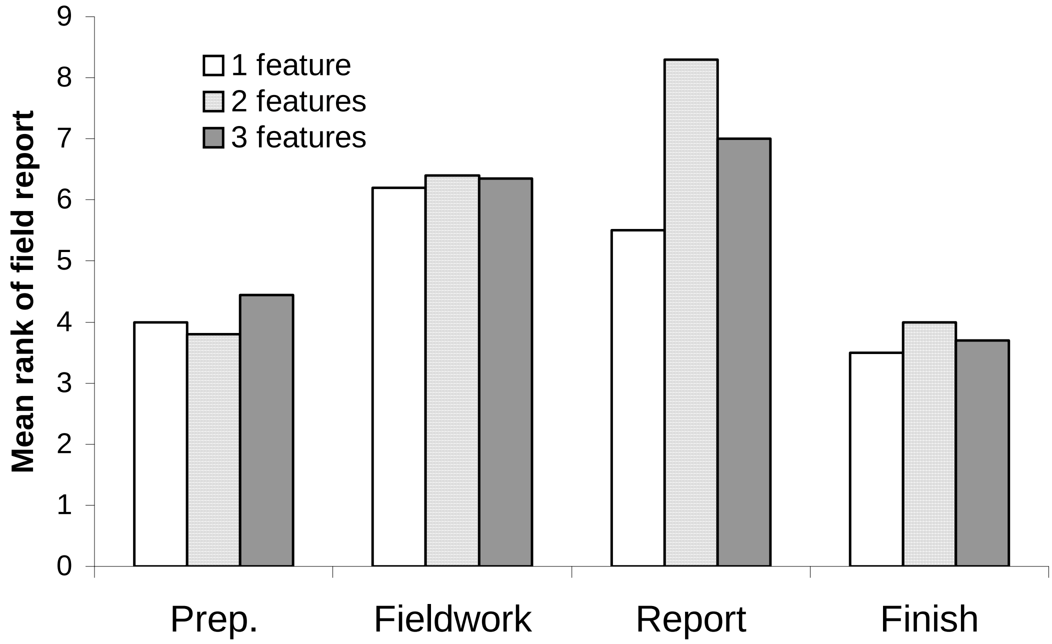


Figure 4.10 Comparison of species-specific studies with broad, ecosystem-focused field studies. Results of Kruskal-Wallis test (*H*) and Chi-square (X^2) are: *H*=0.002, X^2=99.9, *df*=2 for Preparation; *H*=0.017, X^2=99, *df*=2 for Fieldwork; *H*=0.058, X^2=95.0, *df*=2 for Report write-up, and; *H*=0.001, X^2=99.9, *df*=2 for Finish and the final presentations of the student reports in Kenya and Costa Rica.

4.5

CONTRIBUTION TO SCIENCE AND CONSERVATION

This phase of the study was designed to determine whether an ecosystem-focused approach to academic field studies was associated with the potential for students' work to contribute to the advancement of science or the conservation of species or habitats. There is evidence from the work of others that strategies of learning science through an investigation of the actual environment may lead students to make discoveries (Richmond and Kurth 1998). Furthermore, discoveries made by students may be used for improving the way in which we manage and conserve species and our natural resources (Castillo et al. 2002).

The alternative (null) hypothesis tested in this phase of the study states that there is no association between ecosystem-focused field studies and the potential for students to provide meaningful information regarding the conservation of species or habitats. As described in Chapter 3, SFS staff members used an assessment tool for scoring the student's end-of-course field reports. Each staff member had been trained to use this tool during an orientation session prior to the arrival of students to the field camp. Furthermore, no staff member was aware of the parameters being investigated in this study. Student grades on management and research recommendations, which were scored on line item # 16 (Figure 3.4, Chapter 3), ranged from two to five, with five being the maximum possible for this item. An example of a student report that received the full five points possible for the management line item is displayed in Figure 4.11.

In a study of springhare, students examined several species (high species diversity), two trophic levels (herbivores and plants), and two aspects of the ecosystem (biological and physical). The students in this example wrote a section about the potential sources of error, and recommended management approaches for springhare. The students in this project recorded information about rainfall, clouds, and moonlight (physical parameters), about the interspecific and intraspecific interactions of springhare (biological parameters), and they orchestrated these data into a management plan that involved the use of springhare meat.

The last aspect of the study described above was strengthened by the students' diverse data on the various factors that might influence springhare reproduction. The students also used their data to suggest how several factors of the ecosystem might influence the sustainability of springhare as a source of protein for the local populace. Although the example in Figure 4.11 was extracted from a single student's final field report, much of the information in this student's report came as a result of the collaboration of the student's research team. Thus, the individual students in this research team typically worked with similar content as they each went about the task of writing the management section of their end-of-course field report.

Students were not allowed to produce identical reports, even though they worked closely together as a collaborating cohort during much of the fieldwork. Individualized report writing was strongly emphasized, to reduce the likelihood of having students copy off their fellow students rather than conducting their own work. Close communication within each research team; however, resulted in students generating similar data, describing the significance of these data in a similar manner, and resulted in each member of the cohort frequently drawing similar conclusions in the final pages of their report.

This study occurred during a dry, winter season with brief periods of rainfall amounting to approximately 5 cm. Rainfall amounts were found to increase vegetation diversity and abundance which affected springhare distribution. As resources became more abundant with rainfall, springhare were found to be more evenly distributed as in April 1994 at the towers (see ~~Figure~~ 1). As the dry season was prolonged, there was a clustering trend of the springhare because of limited resources. Again, this leads to rejection of the second null hypothesis. Previous studies also suggest that temperature and moonlight affect springhare distribution and should be considered when interpreting activity. Butynski (1984) found that springhare travelled greater distances to forage when clouds obstructed moonlight. This was thought to provide increased shadow area because of trees and shrubs for nocturnal species, especially rodents (Ashby 1972). In the case of rodents, moonlight may in fact inhibit activity as seen with springhare populations. They were found to move closer to trees and shrubs in order to remain within the shadows. Although moonlight was not a focal point of this study, it was a factor affecting springhare activity.

Group size

~~In reference to Figure 2~~, springhare appear to prefer individual foraging over foraging in pairs. When combining all groups of two or more to compare to individual sightings, 51% were in groups and 49% were observed individually. It was postulated that an explanation for formation of groups may be to detect predators. Butynski (1984) found springhare to actively form groups. Although some of the springhare observed were seen in close proximity to one another at night, it is not conclusive that they actively form groups. Results of this study are not significant to support previous research and proposes that springhare are not highly social animals. Therefore, the fourth null hypothesis is not rejected.

Sources of error

Throughout our study we found there to be several sources of error. Due to the positioning of the towers in Zone I, the majority of springhare were sighted in this area. This was dependent on the observer's ability to locate springhare and record it before it moved. If movement occurred, then sighting was regarded as inadmissible due to inaccuracy and

(Continued on the following page)

unnaturalness. Obstruction of the observer's view was also possible due to tall vegetation and coral area that would decrease area of habitat. Difficulty with the equipment may have been a factor in sighting and a source of inaccuracy. Even though a period of twenty-five minutes was allowed for springhares to resume their normal activity, the same springhares may have been observed more than once. Population size could not be established. Limited time reduced sample size and could therefore have affected data analysis. Our final source of error would be the result of human inaccuracy when reading degree of sighting and in other areas of calculation.

All but one of four hypotheses were supported. Springhare consistently exhibited a preference for habitats dominated by *Cynodon* species, low biomass, and high visibility. Each of the study sites have been disturbed, overgrazed areas with relatively flat, open terrain. With regard to individual foraging, even though our hypothesis was rejected, further research may provide more conclusive results.

Management Recommendations

Further study is suggested regarding future utilization of springhare in a game ranch situation. Continued vegetative analysis may be required to find an alternate source of nutrition for the springhare so that they may be able to be sustained. Interaction with other species should be considered because of impact of one on the other. How the springhare affect the cattle in the area and vice versa may have either a positive or negative effects. Culling may be feasible but due to springhare's low reproductive rate, population size would need to be determined to maintain carrying capacity. They may not be able to withstand this type of pressure on their population.

Figure 4.11 A sample of a student's management and research recommendation section.

As another example, in an academic field study that involved the mortality of sea turtle eggs, one student team focused their study on 1) several species (Olive Ridley Sea Turtles and various animals that prey upon the eggs of these reptiles), 2) two trophic levels (herbivores and predators), and 3) two aspects of the ecosystem (biological & anthropocentric). As in the previous example, the study fit the category of ecosystem-focused, according to the guidelines described in chapter 3, Methods. Each member of this student team earned a perfect score of five for the management and research recommendation line item of their project. The student teams that studied Olive Ridley Sea Turtles from an ecosystem-focused approach managed their data in such a way as to produce results that were statistically significant and could be applied to the conservation and management of the Olive Ridley Sea Turtle. A sample of their work appears in Figure 4.12, in which sea turtle egg mortality rate is associated with the number of nests per meter square plot. According to the students' assessment of their results, as sea turtle habitat diminishes, and turtle must crowd together to lay eggs on a few remaining nesting beaches, the survival rates of these crowded clutches of eggs decreases drastically.

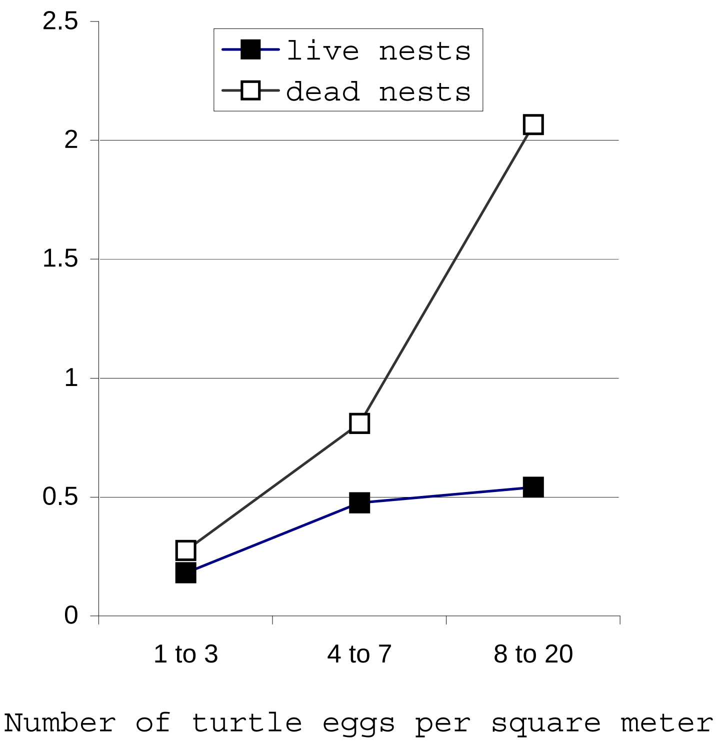


Figure 4.12. A student's results from the study of sea turtle nest mortality as a function of the crowded egg laying conditions on a few of the remaining nesting beaches for Olive Ridley Sea Turtles in Costa Rica.

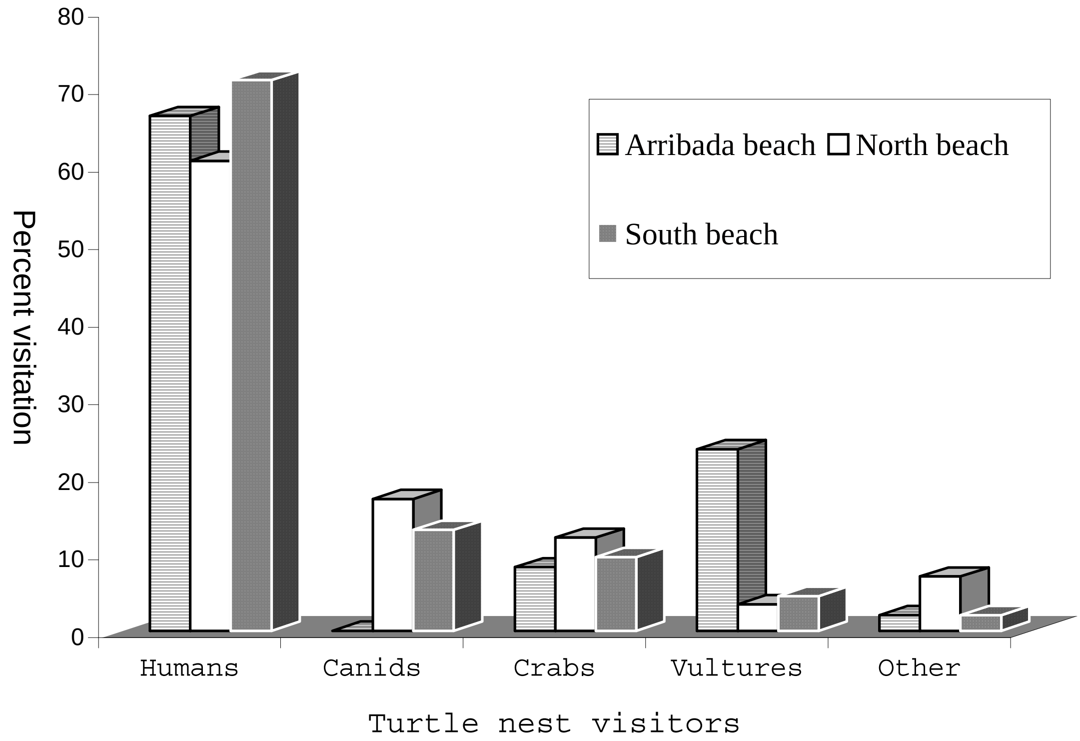


Figure 4.13. A student's results from the study of sea turtle nest invaders, in which humans and vultures were observed to visit and destroy the most turtle nests in a field project in Costa Rica.

A team of students in Costa Rica that examined several different species, in a study that was identified as being an ecosystem-focused study, scored an average of 3.5 out of five points possible on the management and research recommendation section of their report. The written reason that the SFS staff gave for taking points off for this section of the students' work was that no real management plan was generated from the students' data. Thus, while the actual data received high marks by the staff that graded these reports, none of the four students in this research team interpreted the data in a way that satisfied the faculty when he or she graded the management and research recommendation section of the students' field report.

In the analysis of the extent to which students' fieldwork contributed to science and conservation, there were differences observed between the two groups following a calculation of statistical means. Figure 4.14 displays the results of the comparison between the rating given to students' field studies that were species-specific and studies that were ecosystem-focused. Ratings in Figure 4.14 represent: 1) Student field reports that were not selected for publication by the SFS staff; 2) Field reports that were selected by the SFS staff but not used; 3) Field reports selected, written up, submitted, and rejected for publication; and 4) Field reports published or accepted for publication by scientific society journals of national or international distribution or for presentation at international or national science symposia. Analyses were based on the Kruskal-Wallis statistical test, with significance determined by a one-way analysis of chi-square.

In addition to the analysis described above, I generated a list of publications and presentations that were derived from the SFS students during this study (Table 4.4). In the case of a presentation at an international symposium on the conservation and biology of sea turtles, SFS student, Michael April, was the presenter. His presentation was based on the work that he and his SFS team members had conducted at the field site in Costa Rica. The field study was the second phase of a study that had been conducted by a group of SFS students the month before Michael's class began. Thus, a single symposium presentation on sea turtle nest predation did not represent solely the work of Michael April, but the paper was based on the collective work of the 6 students in his research team, and the data from 11 students that conducted the study in the previous session.

A similar situation to the one described above for Costa Rica took place in Kenya. A single paper on plant defenses that was produced by Antoni Milewski was the result of students working during the semester (3-month SFS courses) and the month-long summer SFS courses in Kenya. This single paper on plant defenses involved a sample size of 57 students that were involved with different phases of this project.

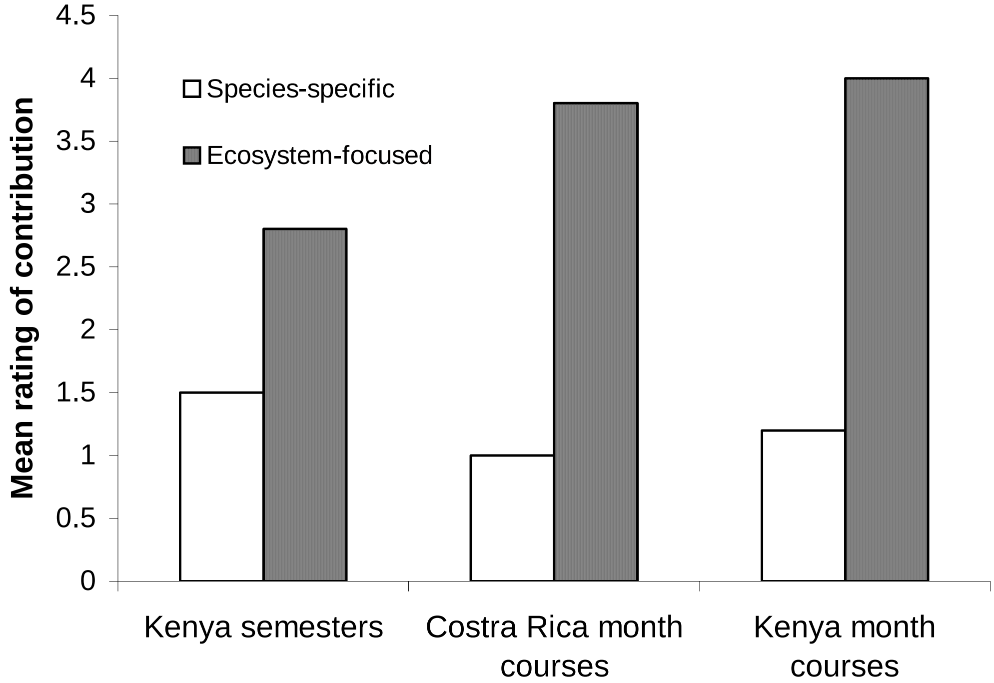


Figure 4.14 Comparison of species-specific studies with broad, ecosystem-focused field studies. Results of Kruskal-Wallis test (H) and Chi-square (X^2) were as follows: H=1.26, $X^2<0.50$, $N_{projects} = 6$, $df=1$ for Kenya semester courses; H=3.35, $X^2<0.10$, $N_{projects}=5$, $df=1$ for Costa Rica month-long courses; H=3.0, $X^2<0.1$, $N_{projects}=6$, $df=1$ for Kenya month-long summer courses.

Table 4.4. A list of contributions to the advancement of science and conservation that resulted from this study on academic field studies in biology.

Presented, submitted or published	**N students**	**Species studied**
Milewski and Madden. (2006). Interactions between large browsers and Acacia on a wildlife ranch in Kenya, *African Journal of Ecology*, 44, 1-9.	57	Giraffe Fever tree White thorn Acacia Desert date Crematogaster ants Whistling gall Acacia
Young and Isbell (2001) Energetics of giraffe feeding ecology, *Ethology*, 8, 79-89.	24	Giraffe White thorn Acacia Desert date Fever tree Crematogaster ants Whistling gall Acacia
April, M. (2003) Predation of Olive Ridley Sea Turtle nests at Ostional, Costa Rica, *19th International Conference on Conservation and Biology of Marine Turtles*, Georgia, US.	17	Olive Ridley Sea Turtles Ghost Crabs Hermit Crabs Black Vultures Raccoons Feral Dogs Humans
Carlson, R. Ballestera, J., and Madden, D. (2006) Nest Ecology of the Olive Ridley Sea Turtle at Ostional, Costa Rica. Submitted to *Copiea*, American Society of Ichthyologists and Herpetologists	32	Olive Ridley Sea Turtles Ghost Crabs Acarine Mites Bacteria (bacillus) Feral Dogs Humans

4.6

ADJUSTMENTS TO THE FIELD PROJECTS

Although the SFS staff and I, in advance of the students' arrival at the field camp, had designed the field projects that were conducted in this study, there were adjustments made to each of the studies. This was necessary due to a variety of unexpected events. In Kenya, a series of intense thunderstorms made it nearly impossible to drive our vehicles down the muddy roads on GRL. This unexpected shift in the climate caused a complete shutdown of the animal behavioral studies for a period of nine days. During this time; however, the students that focused their fieldwork on plants and insects were able to continue gathering data.

A severe bout of gastroenteritis in one of the Kenya courses shutdown the student projects for five days, during which time students could only manage to work in and around the research station. This affected the animal behavioral teams, because students that studied animals such as giraffe and impala could not gather information on their subjects, beyond conducting a review of literature housed in the meager library of the research station. Students that studied plants and insects, as the emphasis of their projects, were able to gather some field data during their recovery time from the bout of gastroenteritis.

Adjustments in the original goals and methods of several student projects in Costa Rica were brought about by extreme weather conditions. A series of cyclonic storms in Costa Rica caused me to change nearly all of the students' projects to some extent due to the flooding of the study site. Such alterations in the field techniques and even the aims of the original study were unavoidable, since the alternative would be for students to continue their fieldwork and possibly drown or suffer from serious accidents brought about by unsafe field conditions. Unlike the situations in Kenya, where extreme weather shutdown only certain student projects, the storms in Costa Rica were of a magnitude that restricted all personnel from conducting their field research.

Additional alterations to the original design of students' field studies, beyond those were caused by storms, were brought about by suggestions from the students as to how the field techniques might be changed for safety or convenience. Such improvements altered the methods in ways that the SFS staff and I had not considered when we first planned the study. The original titles of each research project were maintained throughout each study; however, some of the methods changed in response to student recommendations.

4.7
ATTENDANCE AND ATTRITION

Student attendance was seasonally variable, with field courses offered during the second summer session having the highest average enrollment numbers for both the Kenya and Costa Rica field sites. The average number of students per twenty-eight day field course during the twelve months of this study was twenty-seven, with a minimum and maximum range of eighteen to thirty-six students in any single month during this study. The greatest attendance per course was observed for the Kenya field campus at Game Ranching Limited, where an average number of twenty-eight students completed the courses. Attendance was lower than this figure at the Costa Rica site, where an average number of twenty-four students enrolled and completed the twenty-eight day field studies conducted on sea turtles. Overall attrition during the twelve months of this study was 1.12%, as determined by number of students that had paid their fees, were officially enrolled, physically attended for more than 10% of a course, departed the course before its completion, and earned a failing grade.

Of the two hundred and sixty-seven students that completed field courses during my study, only three of the originally enrolled two hundred and seventy students dropped out of their courses. Each of these incidents was caused by anxieties relating to students' emotional discomfort. According to my field journal notes, the attrition of three students was not caused by medical problems. A summary of the attendance of students during my study appears in Figure 4.15. The drastic drop in number of students in 1993 was due to situations in which I only taught a single field course instead of two courses per summer. These data were based on fieldwork conducted in Kenya in 1990, 1994, and 2003, and on fieldwork conducted in Costa Rica in 1993 and 2002. During the School for Field Studies summer sessions in these years, there were 218 total students in Kenya and 49 in Costa Rica that were involved in academic field studies. The collective attendance of two hundred and sixty-seven students from both field sites was spread out over a total of twelve summer months.

4.8

RISK MANAGEMENT

Field notes about injuries and situations that nearly resulted in injury, which I called a near miss, were transferred from my field medical of this study, and are summarized in Table 4.4. The Costa Rica site had numerous physical hazards (floods, sharp rocks, cliffs, dangerous ocean tides). Field camps in both Kenya and Costa Rica had several types of biological hazards, which came primarily in the form of plant thorns, biting insects, and small acrines (ticks and mites) that burrowed into the skin of some students. In addition to the biological and physical hazards, there were problems brought about by humans that were not officially associated with the academic field studies. One attempted rape of a woman that was living within five kilometers of the SFS field camp occurred during 1990 in Kenya. The incident caused some of my students to express fear and anxiety.

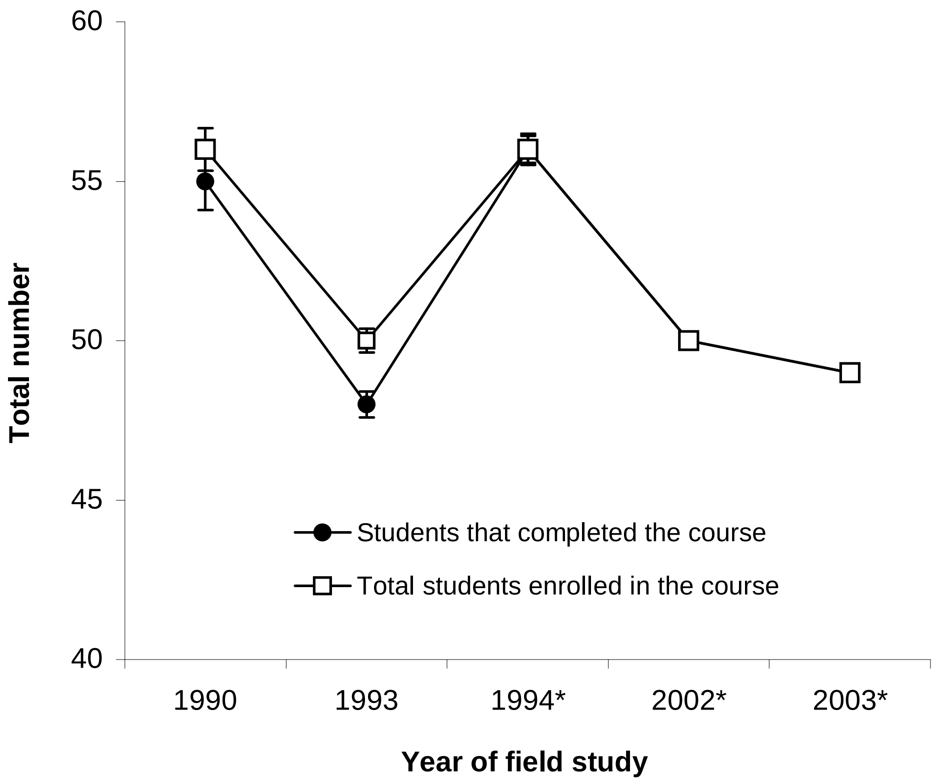


Figure 4.15 The number of students that completed their field courses, and students that attended but did not complete their course. Years marked with an asterisk indicate field courses in which activities during students' free time were scheduled and announced.

Table 4.4 A list of injuries and near misses that were recorded during this study.

Notes on injury or near miss	Diagnosis	Action taken/Notes
Sores near penis, 3 weeks after intercourse with prostitute in Nairobi	Gonorrhea	Dr. Jaffry in Machacos prescribed medication
Severe food poisoning and extreme dehydration due to illness	Food poisoning	Treated with electrolytes
Severe food poisoning and extreme dehydration	Amoebic dysentery	Metranidizole was prescribed
Severe stomach cramps and diarrhea	Giardiasis	Metranidizole prescribed
Severe problem with breathing due to asthma	Asthma attack	Administered bronchi dilating aerosol
Acacia thorn embedded under nail of toe.	Laceration	Used needle-nose tweezers and Betadine
High fever and extreme nausea	Heat exhaustion	Administered electrolytes
Gash on knee from falling near the rocky area	Laceration	Betadine and butterfly bandage administered
Twisted ankle from playing soccer	Stretched tendon	Wrap with athletic tape (not Ace-type bandage)
Fungal infection of groin during travel to Mombassa	Dermatophyte	No effective treatment until weather turned cool
Masaai youths use spears to threaten students in their tent last night	No one injured	Near miss
Tick bites became seriously infected due to scratching skin with fingernails	Cellulites	Antibiotics prescribed; area cleaned 3x per day
Kids threw large rocks at SFS students	No one injured	Near miss

In addition to the near miss caused by humans in Kenya, was an incident that occurred when local adolescents were throwing rocks from dense underbrush in Costa Rica. These adolescents, who I estimated to be from nine to thirteen years of age, ambushed students in the 1993 sea turtle field study. The students were startled from being attacked, and confused until I yelled at them to retreat back to the field station with their arms wrapped over their heads. I retreated last so that I could make certain that my students had all escaped. I approached local law enforcement officers about this attack.

4.9
QUALITATIVE DATA

The emphasis of this thesis was to test several hypotheses regarding how students' field studies might be conducted in ways that foster the generation data that could contribute to the advancement of science. However, there was a qualitative aspect of this study that does not appear in Chapter 3, Methods, for it represents a serendipitous sampling of students' impressions. During my field studies in Kenya and Costa Rica, I encouraged my students to read the entries of former students who had written down their impressions in the field station journal. In this hardback-bound journal with blank pages, I also encouraged my students to write their own impressions. Students were not required to write their full names in the journal; although, most of them wrote initials or first names.

One of the major reasons for the journal was to provide students with an outlet for their frustrations, enlightenment, or other emotional energies that they had while they were so far away from friends and family. This non-premeditated aspect of my study was lacking in controls for extraneous errors. Although I assigned a different student to take the journal with them to their tent each night of the course, this did not guarantee that they would write in the journal. In the analysis of journal entries, I sorted positive student comments from negative comments, and found no statistical association between students' species-specific studies and students' journal entries that were clearly negative. Many of the entries suggest that students experience strong emotions as a result of their involvement in academic field studies in remote and primitive conditions. The following list represents a random sampling of journal entries from Kenya and Costa Rica:

> "There is a major difference between using my mind alone to predict how a project will work out, and using the combined efforts of the mind, body, and soul of the members of my team to actually get the job done... It is as different as night is from day."
> E. M., Costa Rica

> "Every day is like a lifetime, and that is how I feel about this chance to study in Africa. Life is more than a list of tasks to do each day. I have found that life can be a combination of the odors, the crunch of dry grass beneath my feet, a gentle breeze along my skin, a rising moon, and the chance to just exist."
> J. P., Kenya

> "After weeks of field research, data analysis, and write up, we had the chance to share what we had learned with Jorje and some of the locals that will be here long after we leave... What an experience this has been, to do something in school that really matters and affects the lives of others."
> S. J., Costa Rica

> "I was afraid of what I would find, afraid that I could not cope with the Spartan life and being with strangers so suddenly..... Now, I am afraid that I will forget about how I feel right now, at this moment. I am afraid that I

will forget when I return home how important it is to be afraid and to not let fear stop me."
C. C., Costa Rica

"Seeing that Rhino in Amboseli was soooo cool. For a moment, I forgot about the crook in my neck, or about how much pain I had in my rump from sitting on the seats (can we call them seats?) in KSZ. It all came down to this one moment, and it was so cool.
M. S., Kenya

"I hear the hyrax scream, and I feel at peace. I am connected to this world...I am part of the rhythm of this land. The earth is alive with stories of the past. I hear the hyrax scream."
J. M., Kenya

" I now understand that there is a big difference between knowing something and understanding it, and to understand you must experience it firsthand."
K. S., Costa Rica

"The heat is always there, day and night. Why won't the turtles come ashore? I have dreamed of this place, this time, when I would see the turtles come ashore like giant hulks of bone and gristle. I'm hoping they come, but right now, can I just sleep?"
K. K., Costa Rica

Chapter 5

DISCUSSION

In this chapter, I discuss the data from chapter 4, Results. I was primarily looking for two things in the investigation that I conducted. First, I explored the extent to which the student's grades were influenced by the focus of their study. In this phase of the investigation, I sorted the students' graded end-of-course reports and determined statistical mean scores according to the extent to which the reports were based on field studies with an ecological emphasis. This emphasis was determined by the number of different species, number of links of a food chain (trophic levels), and the physical, biological, and anthropocentric features of an ecosystem that the students addressed as major factors in their field reports.

In a second phase of this investigation, I examined the extent to which new knowledge was generated relative to the focus of the students' field study. This was referred to as a contribution to science and conservation. As was done in the first phase of this investigation, I sorted the students' graded end-of-course reports according to the extent to which the reports were based on field studies with an ecological emphasis. From these sorted reports, statistical calculations were made to determine the extent to which students' work contributed to science and conservation.

In addition to investigating students' grades and the focus of their field studies, I examined student attrition and risk management at the field camps in Kenya and Costa Rica where the field projects for this study took place. In this section of the Discussion, data on student attrition, medical situations, and hazardous conditions are interpreted as factors that may be influenced by a leadership.

5.1

FIELD DATA

Students in the Kenya and Costa Rica apprenticeship camps generated sufficient data from their fieldwork that enabled them to write an end-of-course report based on the work that they had conducted in the field. Although academic success varied, measured as the grades received for the end-of-course reports, all of the students in this study were able to acquire data, to analyze and interpret these data, and to propose ways in which this information might be applied. For a detailed discussion of the results for the various students' field projects, from a non-academic perspective, please examine Appendix Q for the Kenya field studies and Appendix R for the field studies in Costa Rica.

The acquisition of good scientific field data was one of the objectives in this study that was met, as evidenced by the students' achievements displayed in Chapter 4, Results, and in Appendices O and P. The primary objective of this study, which involved the examination of several ways in which the instructional design of academic field studies might influences students' field data, is addressed in the remaining sections of this chapter of my thesis.

5.2

ECOSYSTEM-FOCUSED STUDIES AND STUDENTS' REPORT SCORES

This phase of the study examined how the focus of a student's field study may influence the student's grade on an end-of-course field report. The research questions this study investigated arose from pilot studies that were conducted with college students in Panama and California. Results from the current study, conducted in apprenticeship field camps in

Kenya and Costa Rica, suggest that there is no statistically significant difference in grades, whether students conduct narrowly defined (species-specific) or broad, ecosystem-focused field studies. What was different was the rating of the reports in terms of publishability, which, in turn, depends on the creation of new and useful knowledge.

Interpretation of the Results

In the comparison of species-specific and ecosystem-focused field studies, the lack of statistically-significant differences in student scores suggests that academic performance is not dramatically affected by the extent to which students examine one or several aspects of an organism's surrounding environment. This statement was supported by Figure 4.4, 4.7, and 4.10, in which students' performance on each of the subcategories of their field study endeavors was not significantly associated with the extent to which species diversity, trophic levels, and various features of the ecosystem were examined. The results displayed in each of these figures; however, did show trends. Student scores on 1) preparation, 2) fieldwork, and 3) presentation and completion subcategories were randomly distributed. There was no apparent benefit derived from ecosystem-focused field studies except in the report write-up phase of the academic field endeavor. Students that were engaged in ecosystem-focused studies collectively achieved a high mean score on the written field study reports, yet statistical significance was lacking (e.g. H=0.058, X^2=95.0, df=2). Therefore, no conclusive support can be given for the ecosystem-focused approach as an instructional method that influences academic performance in field studies.

The lack of a significant association between what students wrote in the field station journal and what they were investigating in the field, which suggests that students' attitudes and impressions are not strongly influenced by the topic of their field study. Regardless of whether students worked on narrowly defined or broad topics, many of the students' activities in the apprenticeship field studies were not so very different from each other. Each student, regardless of the topic of the study, must learn to operate within a working cohort of peers, must overcome frustrations that accompany most field studies, and must learn to work within time constraints and other limiting factors that require a student to cope and to become resourceful. Based on the qualitative data from the field station journals, students' impressions are strongly influenced by interpersonal relationships and by the dynamics of the physical setting. Based on the students' qualitative entries, the novel setting and unique dynamics of an apprenticeship camp appears to invoke strong emotions and impressions.

Implication of the Results

The results of this phase of the study suggests that there is potential for students to earn high marks on their field study reports, regardless of whether the students are engaged in species-specific or ecosystem-focused academic field studies. Academic scores, as presented in Figures 4.4, 4.7, and 4.10 support the assertion that students generally perform well in field study endeavors, which is a situation that has been observed in several other studies (Cleary and Benson 1998, Burgess et al. 1999, Dresner 2002). There is also evidence from this phase of the study that teachers may benefit from field studies, which in this case came as opportunities for the staff to present their work in science journals and at professional symposia. Mutual enrichment of Students and teachers from field experiences has been observed in other studies as well (Manner 1995, Mittermeyer et al. 1997, Wellnitz et al 2002).

This phase of the investigation presents important negative data in regards to the specific topic of a field study: it isn't the topic that is important per se but rather the focus. Regardless of whether biological field inquiries are species-specific or broad, ecosystem approaches, students have the potential to perform well in all stages of the project if the field studies are a) carefully planned in advance, b) guided through appropriate use of cognitive apprenticeships, c) conducted in situations in which students are exposed to novel situations while they are in a state of relative comfort and safety, and d) when students are provided clear guidelines in regards to expectations and examples of high academic performance.

In many science education studies, comparisons in data often suffer from inherently flawed methodologies in an effort to generate positive data (Clark 1994). The results from this phase of the study on ecosystem-focused field studies were generated through appropriate statistical tests, which yielded negative data. There were no divisive strategies used in an effort to manipulate the information to reveal positive data. The negative data from this phase of the study may be of value to teachers of academic field studies. These data suggest that the topic of a field study may have a minor importance in influencing academic performance, as least as far as grades are concerned. This finding of my study is consistent with the impressions of Mittermeyer et al. (1997) and Burgess et al. (1999), who feel that apprenticeship field studies owe much of their success to extensive and appropriate planning of student activities, and to competent execution through proper leadership of these activities.

5.3

ECOSYSTEM-FOCUSED STUDIES AND CONSERVATION

This phase of the study examined the extent to which new knowledge in science and conservation was generated and shared with the scientific community as a result of the focus of the study. Data were obtained from sorting students' end-of-course field reports according to the extent to which they were ecosystem-focused. The question being addressed in this phase of the study regarded the possible connection between ecosystem-focused field studies and the potential for students' fieldwork to contribute to science and conservation.

Interpretation of the Results

Based on the ratings given to the student's papers (Fig 4.14), there was marginal statistical significance revealed in the investigation of the potential for ecosystem-focused academic field studies to contribute to science and conservation (H=3.35, $X^2<0.10$). At best, there is about a ninety-percent statistical confidence that ecosystem-focused field studies increase the potential for students' fieldwork to contribute to the advancement of science and conservation. The articles and presentations that arose from the students' work further strengthen the argument for ecosystem-focused academic field studies. Data in Table 4.4 reveal that each of the peer-reviewed articles and symposia proceedings were based on ecosystem-focused field studies. Another form of support for the ecosystem-focused approach to students' field study in biology is revealed in the discussions that appear in Appendix Q and R. Typically, it was the more complex field studies, involving the examination of several parameters, that yielded data deemed by the SFS staff of scientists as having the greatest potential for use in journal articles and science symposia.

Implications of the Results

The results of this phase of the study suggest that there is potential for students to contribute to the advancement of science and conservation by engaging in ecosystem-focused academic field studies. A mere ninety-percent statistical significance was obtained in the best-case scenario of the analysis. As mentioned earlier in this chapter, Clark (1994) suggested that strong statistical significance for studies in science education is not always necessary and is sometimes the result of flawed methodologies in an effort to support one's hypothesis. Starr (2005) states that the results of most preliminary studies rarely provide concrete support. Another piece of information, in support of the marginal results of this study, lies with the Kruskal-Wallis statistical test that was applied to my data. In this nonparametric alternative to ANOVA statistical tests, the Kruskal-Wallis examines variances in ranked data. Data in this phase of the study were ranked from one to four, which would reduce the potential for large, statistically significance differences, according to Lowry (1989).

In this study there is the potential for experimental error. Regardless of the convenience sampling, balancing, validity studies, and other efforts to control extraneous variables, several aspects of this study were vulnerable to the subjective responses of the participants. For example, ecosystem-focused field studies tended to provide more complex data than species-specific studies (e.g. the comparisons in Figures 4.3, 4.6, and 4.9). Such complex data may be inherently interesting to the research staff, which might be biased in selecting such work over the some of the species-specific studies. For example, a botanist might favor botanical field studies, and devote his or her energies on such studies while being derelict in proving assistance to a team of students studying animals. Establishing instructional protocols, in which instructors rotated in and out of different student projects, minimized such biases.

Some of the species-specific data might have discouraged the selection of such studies for publication by the SFS staff due to the apparently random nature of behavioral data. For example, in the giraffe behavioral studies, much of the data on what a giraffe did during the day was varied but did not seem connected to anything. A giraffe walked ten steps, defecated, walked three steps, fed on Acacia leaves for 37 seconds, looked northward for seven seconds, etc. Such data created messy data sheets and contributed to confusing charts in the results.

There were other potential sources of extraneous error. Were the ecosystem-focused studies better designed or guided than the species-specific field studies? This would seem unlikely since the field studies were designed collectively by each team of researchers, and were not designed and led by a single research staff member. In examining the relative success of students' field studies, I found that failure was often the result of events that could not have been easily planned for or predicted. For example, a sea turtle hatchling study was based on the successful techniques of Cornelius et al. (1991). However, when we used their methods, crabs that swarmed into our hatchling traps consumed numerous turtle hatchlings. Did Cornelius and others just get lucky not to have crabs when they set their traps? Other chaotic events included hurricane weather, rape of a local tourist, dysentery, a population explosion of Norway Rats, and fire. How could I have predicted that these events would have occurred? How would I know in advance how to alter students' field studies to minimize the influence of chaos? Was the environment or physical setting more conducive to ecosystem-focused studies? Were students expecting to study or better prepared in advance to study the ecosystem rather than one species? I’m not sure those questions can be easily answered at all. They are probably imponderables, and it would be best to focus on sources of error that can be more easily detected.

Before the conservation of a species can be undertaken, there must first be an extensive examination of the environments in which the organism lives in and travels through (Meffe and Carroll 1997, Gibbs 1998, Morrison et al. 2002). Features of the nonliving landscape such as weather and tides, as well as the living factors that an organism interacts with may profoundly affect what an organism is and does (Huston 1994). In addition to aspects of the natural and physical world that impacts an organism that is being managed or conserved, it is prudent to examine the activities of humans as well (Cambell 1998). From these comments, and from the results of my study, I suggest that students’ biology field studies that involve the examination of an organism’s environment may lead students to make plausible suggestions regarding how an organism may be managed. Such suggestions are likely to include a consideration of habitat, which is of paramount importance when the management of a species in the wild is being considered (Barnes 1998).

Students that work in contextual situations, such as cognitive apprenticeships, may generate new knowledge. As suggested by Castillo et al. (2002) and Burgess et al. (1999), students have the potential to produce new information upon which future conservation efforts may be based. Students that actively learn about the environment through direct interaction with it are often in a position to suggest how improvements to the environment might be made (Dresner 2002). It is unlikely that many of students in this study would have made contributions to research and conservation through passive learning. Also, it is unlikely that students would have felt such dramatic openness to learning, as suggested by student comments that appear in Qualitative Data, Section 4.9, had they conducted these studies without direct involvement in the field (Chapter 4, Results).

It required hours of sifting buckets of sand in the search for fly larvae, and long hours of observing giraffe and plants in order for the students' discoveries to happen.
We must look beyond the organism if we wish to understand it, for the organism's niche has incredible breadth. As many naturalists have observed, when we uproot one creature in the environment, we find it attached in some way to nearly everything else on the planet (Orr 1999). In a similar sense, when our students uproot one creature as the focus of a field study, they need to look beyond, to the intricate web of life on planet Earth that surrounds the creature.

5.4
ATTENDENCE AND ATTRITION

This phase of the study is primarily based upon Figure 4.15 and Table 4.4 in chapter 4, Results. Of the two hundred and sixty-seven students that completed field studies in either in Kenya or Costa Rica, there was little disruption brought about by the loss of three students that left their courses for emotional reasons. In each case of student attrition, I made adjustments to the student teams that had become short-handed as a result of losing one of the members of their research team. There was a lack of student attrition in field courses that had social and physical events available for students. These extracurricular activities may have fostered the development of a learning community from what was originally a group of individual students independently dealing with their personal anxieties. Evidence for this perspective of student attrition is thin, as my interpretation is based upon qualitative entries in my field notebook, and upon trends observed in the data.

Implications of Student Attrition

There are often nonacademic reasons for students to fail in field studies. Emotional stability may influence the decisions that students make regarding whether to complete a field course or to drop out of the course. In their work with college students, Bell and Bromnick (1998) suggest that while most university students cope well with a change in location, it is common for most to experience homesickness. Daily challenges involving lack of privacy, discomfort, sleep deprivation, and irregular meals may lead some individuals to become depressed. Such individuals may seek unhealthy outlets as a means of escape from their state of emotional instability (Nolan 1986). This was the case for many of the American soldiers serving during the Vietnam War. Depression, drug abuse, and alcoholism became some of the outlets for the soldiers' frustrations (Nolan 1991).

Although the living and working conditions of my students in the Kenya and Costa Rica field camps were different than the war camps in Vietnam, there were some similarities between the two situations. In my field camps, the students' lives were often disrupted. Crawling and buzzing nocturnal insects, high humidity during the monsoon season, anxiety, and other disruptions often resulted in sleep deprivation. The students' meals were often irregular or bland. Periodically, the students were required to subsist on coarse vegetables, boiled eggs, porridge and other local foods that were available. Phone calls and other forms of communication were often not possible in my field camps. This left students unconnected to their family and friends back home.

Nolan (1991) observed that morale drastically improved when American soldiers in Vietnam were involved with various physical and social activities that provided an escape from their emotional state of isolation and frustration. Although my data on attrition is more anecdotal than empirical, there is some indication from my study that some of the students in remote field camps may benefit from involvement in various social and physical activities.

5.5
RISK MANAGEMENT
Hazardous and Medical Situations

The discussion in this section refers primarily to Table 4.4 in the previous chapter, in which I transcribed injuries and hazardous situations from my field medical journal. In many of the situations described in this table, rapid and wise decisions were required. The invasion of Masai into our field camp in Kenya caused me to sound an alarm that wakened my driver and support crew, and brought these individuals to my aid. My immediate response to the ambush in Costa Rica resulted in the students' quick and organized retreat from the barrage of rocks. The electrolyte solutions that I administered to students suffering from gastroenteritis and dehydration may have prevented serious illness. The trauma to the body caused by severe gastroenteritis may lead to death if not properly treated (Larson 1990). These and many other situations that I faced as a leader of academic field studies required immediate assessment and the formation of a rapid and effective plan of action to avoid further injury and complications.

In many situations in the field camp, it was necessary for me to observe when things went wrong, and to make adjustments so that such events were not repeated. This was the case for many simple scratches that students experienced. The students frequently attached adhesive bandages tightly against their skin. Such bandages caused the injured skin to become warm and damp, which resulted in septic conditions. Following this observation, I required students to have me check their bandages daily to curb infection. Observation and a change in regimen probably prevented some skin infections and many other situations from becoming a medical crisis.

Risk management, which refers to reducing the potential for injury to occur, was often required of me as a leader of academic field studies in California, Kenya, and Costa Rica. One example of this preventative activity was the three-person buddy system. I required students to be accompanied by two other people when they were away from the research station. If one member of the trio was injured, one person was to remain with the victim, while the third member went for help. One student disregarded this protocol, and his action resulted in one of the most complicated medical conditions that I dealt with during this study. According to this student's account, he became lost when shopping alone in the city of Nairobi. A woman offered to help him find his way, but instead she brought him to her flat where the two of them had intercourse. The student acquired Gonorrhea. This situation could have been avoided if the student had been operating within the buddy system. A trio of students would probably have found a better way to navigate the streets of Nairobi than this lone student had done.

In summary, a leader of student field studies in remote settings may be expected to make rapid and wise decisions in crisis situations that cannot be fully predicted, such as occurred in the ambush in Costa Rica and the invasion in Kenya. Leaders need also to be attentive to small problems, and to make adjustments to camp protocols to prevent such problems from increasing in magnitude, such as was done in the case of student bandages. Leaders may also need to conduct an assessment of potential risks and to establish protocols that reduce the likelihood of injury, such as was done with the 3-person buddy system. Leadership in a remote field camp amounts to more than the mere instruction of students and assessment of grades. Remote settings require that a leader be alert, decisive, and experienced if students are to avoid injury.

Chapter 6

CONCLUSION

This chapter begins with a summary of my study, in which an educational approach referred to as cognitive apprenticeship was used to test whether ecosystem-focused field studies influenced student grades on their end-of-course field reports. Also addressed is the potential for ecosystem-focused field studies to contribute to the advancement of science and education. Student attrition and risk management are discussed in the next section. Some hazards may be managed through appropriate leadership to create relatively safe and predictable settings in which students conduct their fieldwork. The next section addresses some of the limitations of this study. Suggestions are made for future research in academic field studies. This chapter concludes with a framework for academic field studies. In this section is briefly described my suggested instructional scaffolding of biology field studies in remote settings.

6.1
SUMMARY

This study is based on the fieldwork of two hundred and sixty-seven college students that conducted biological studies in either Kenya or Costa Rica. The research questions in this study originated from academic field studies I had previously conducted in California and Panama. In this study, I examine the extent to which students' grades on field reports and their acquisition of new knowledge was influenced by the focus of their study. I sorted the reports according to the extent to which the students examined ecological parameters of the niche of an organism that was the focus of their fieldwork. The results of this study provide evidence that students' grades and acquisition of new information are not significantly influenced by the extent to which students used an ecosystem-focused approach to their academic field studies. This study also indicates the importance of appropriate leadership in dealing with and preventing problems in field camps in remote situations.

The field studies in Kenya and Costa Rica address some of the new thinking in science education that has helped teachers change their practices, and has helped students to experience success in learning new information. With this approach, everyone shares some of the responsibility for students' learning (Hirsch 1996). The consensus for many educators of field studies is that students prefer to be involved in learning situations in which they are busy and feel that they are contributing something meaningful (Wellnitz et al. 2002).

Cognitive apprenticeships may provide students with the feedback and collaboration that help students to work toward meaningful goals (Collins et al. 1991, Bentley et al. 2000, Barab and Hay 2000). Such apprenticeships also create communication between students and teachers as they work together. There are numerous reports in the published literature, in which field explorations with students resulted in scientific discoveries that addressed environmental problems. Sometimes novice researchers may help in various ways to make these discoveries happen (Greengrove and Secord 2003, Madden and Grayson 2003).

6.2
LIMITATIONS OF THE STUDY

Many of the potential systematic errors in this study, described in the Methods chapter, were addressed through the use of convenience sampling, balancing, and double-blind techniques for assigning student projects and assessing their work. Regardless of the use of these techniques, there were limitations to this study. For example, there was no true experimental control group. Instead there were groups of students randomly assigned to study different degrees of the experimental variable (ecosystem-focused field study).

In the design of my study, there was not an adequate way in which an individual’s performance was measured as a function of different experimental variables. Each student worked at a single level of the experimental variable. The students' individual improvement or decline in performance was not tracked in relation to a specific level of the experimental variable. This deficiency might be avoided by having each student work on several different types of field projects. In this way, an individual's performance in field studies could be more adequately measured. This change in the design of the study might compromise the biological field data if students fail to master the techniques and thought processes needed to conduct one project with a high degree of accuracy and precision. Extending the duration of study by adding days or weeks to the students' field course might allow students to effectively conduct more than one field project.

6.3
A FRAMEWORK FOR ACADEMIC FIELD STUDIES

In the midst of the chaos that is inherent in many research stations in primitive and remote settings, the wide-eyed students arrive expecting a '*National Geographic'* experience led by gifted and patient researchers. In reality, such situations are rarely possible to achieve. However, I have developed a framework that may influence student performance and reduce many of the problems that are encountered in biology field studies. Each segment of my recommended framework for biology field studies is underlined in this section.

Ecosystem-focused field studies refer to fieldwork in which students examine the ecological niche of an organism in an attempt to learn about that organism. There is evidence from my study that students may have a greater potential to contribute to the advancement of science and conservation by examining the environment of an organism rather than by focusing their fieldwork on a single species or single factor in the environment (Madden and Grayson 2004). No organism can be fully understood without a consideration of the environment in which that organism lives or moves through (Huston 1994, Smith and Smith 2002). While a species-specific approach to biology field studies may provide students with a convenient and simple design in which to learn about an organism, such studies are unlikely to probe the realities about what an organism is and does.

A Learning community refers to a group of people that are interconnected in various ways as they learn. A learning community may be strengthened by group activities. College-age students sometimes require such extra-curricular involvement to offset feelings of depression as a result of being physically isolated from home (Nolan 1991, Bell and Brommick 1998). Students may benefit from activities that provide an escape from emotional duress that is brought about by irregular meals, lack of privacy, physical discomfort and other unsettling conditions that may arise during their stay at a research station in a remote environment. Through my fieldwork at remote camps in the African bush and a rainforest in Costa Rica, I acquired anecdotal information and limited empirical data suggesting that in remote settings, student attrition may be reduced by social and physical events that are made available to students during their free time.

Authentic exploration, as the term is used in this paper, refers to activities in which students are involved in the search for solutions to real problems, or in the search for answers to questions**.** Students and instructors may both benefit from authentic explorations. It is also important for the development of future science curricula that teachers conduct authentic studies (Shepardson et al. 2003). Exploration is the central theme of science (Starr 2005). My study did not measure the level of satisfaction that students and staff experienced as a result of their authentic explorations, yet I did measure the achievements that these people experienced in the form of reports and scientific manuscripts. There is often a link between achievement and satisfaction. Many students are motivated when they are investigating real problems that they may be instrumental in solving (Hirsch 1996, Greengrove and Secord 2003). Instructors may also benefit from the professional and personal satisfaction that comes from solving real problems (Manner 1995).

Cognitive apprenticeship refers to situations in which students learn by observing a model in action (Choi and Hannafin 1995). This instructional strategy often provides direct experiences in which students may learn content. Cognitive apprenticeships can provide ongoing feedback and instructional assessment that is embedded in the activity rather than being separate from it. The communication that can develop from contextual learning experiences helps connect teachers with their students and the real world (Wellnitz et al. 2002). A contextual approach to learning, such as conducted through cognitive apprenticeships, may provide opportunities for students and teachers to go far beyond the content that the experience was intended to address (Collins et al. 1991). My students did more than to merely learn about conservation. Through cognitive apprenticeships, these students made discoveries that may change the way scientists manage and conserve Olive Ridley Sea Turtles in Costa Rica as well as several species of Acacia in Africa.

Contribution, as I use the term, refers to the potential for the results of students' work to have meaningful applications to the real world. Service to the community or the environment currently receives relatively little attention in many public schools (Cleary and Benson 1998). However, this situation is rapidly changing, as we are facing increasing numbers of problems that students and teachers can help to solve (Walls 1996). It is likely that the research conducted by students will contribute important scientific information upon which many future environmental management decisions will be made (Castillo et al. 2002). Students can be the source of new information that may benefit the planet (Madden and Grayson 2003). Through fieldwork in Africa and Costa Rica, my students demonstrated that, given the proper guidance and research design, they could solve complex environmental problems.

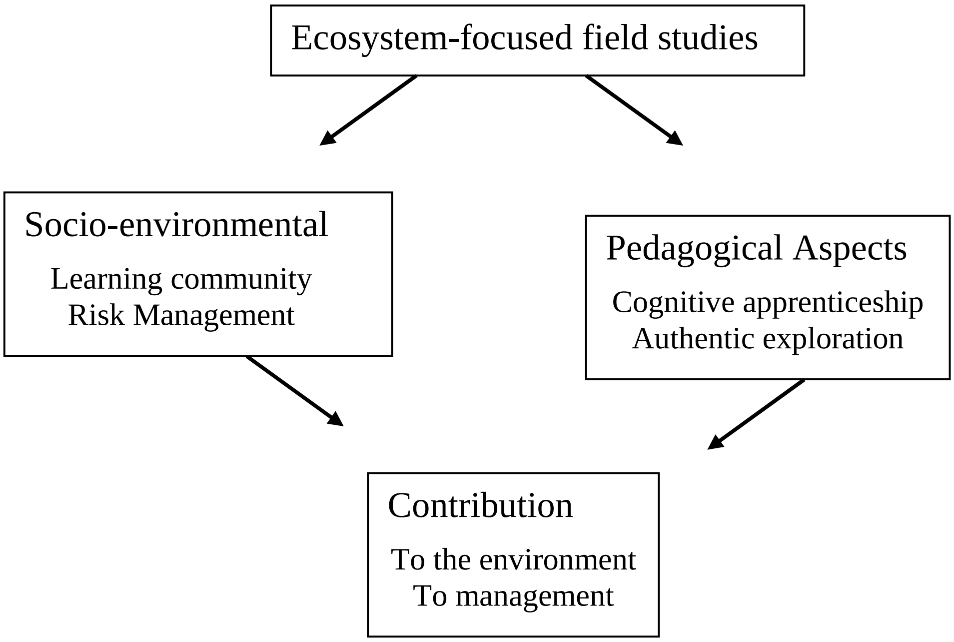
Risk management refers to preventative measures that may reduce the likelihood of injury or other complications in an academic field study. Research that is conducted in remote conditions may require a different set of considerations than field research conducted where the local infrastructure allows for rapid mobilization in the case of injury or severe environmental conditions (Gibbs 1998). Leaders of academic field studies in remote environments may be faced with various, unpredictable situations requiring fast and wise guidance.

Effective leaders do not neglect small problems, which may gradually become major dilemmas if left unattended. And, successful leaders of field studies in remote settings establish protocols that reduce the likelihood of injuries and complications from reoccurring. The risk management phase of my investigation resulted in qualitative and anecdotal data; therefore, this phase did not undergo rigorous scientific testing, as did the main focus of my investigation. However, from a practical perspective and from the observations that I made in this exploration of field studies, if students are sick or injured, then their fieldwork is likely to suffer. A leader that conducts effective risk management may minimize some of the trauma that students typically experience when they work in a remote field camp.

Final Comments

There is mounting evidence from the field of environmental studies that judicious management of our natural environments will require the working hands of future students and teachers. Many students have proven that they can be sources of inspiration and ideas that improve our planet. These contributions often came as a result of students learning through cognitive apprenticeships while working under the guidance of a master. Such students often felt motivated because they believed that their schoolwork was connected to the real world.

While context provides one platform upon which students may learn and contribute, mere provision of appropriate settings may not be adequate unless matched with a fitting instructional design. For example, students may learn something about a giraffe by watching these animals during a field trip. Students might learn more about giraffe by observing how various factors of the landscape influence giraffe. This ecosystem-focused approach may lead students to perceive some of the physical and biological interactions that help define what a giraffe is and does. Such an instructional strategy may contribute to scaffolding that eventually leads to contribution. One such example of this scaffolding appears in a flow chart on the following page. With proper context, content, and instructional design, students may acquire knowledge as they work together with teachers to improve many of the conditions on planet Earth.



Ecosystem-focused field studies
Socio-environmental
Learning community
Risk Management
Pedagogical Aspects
Cognitive apprenticeship
Authentic exploration
Contribution
To the environment
To management

APPENDICES

Appendix A

Description of Panama study site, and author's illustration of a Panamanian tamarin

Situated on the southern border of the Canal Zone near Gatun Bay in Panama lies Barro Colorado Island and a small mainland area that is preserved for the study of tropical ecology. The Organization for Tropical Studies (OTS), along with the Wildlife branch of the Government of Panama, manages Barro Colorado and the mainland site where one of my early experiences in academic field study took place. Both of the study sites have primary and secondary rainforest vegetation that is fostered by over 500 mm of annual rainfall in an inter-tropical convergence climatic zone. I was a teaching assistant that led small teams of students in field studies of the Panamanian tamarin, illustrated below.

Appendix B

Description of field studies in Modesto, and author's illustration of a riparian ecosystem that was studied

Modesto Junior College (MJC), a public, two-year college accredited by the Western Association of Colleges and Schools, supported apprenticeship field studies in California. Caswell State Park, situated on the lower reaches of the Stanislaus River in California's Central Valley, hosted the apprenticeship camp in its partnership with MJC. Ecologically, the parkland near Modesto is classified as a Valley Riparian ecosystem, and contains one of the few remaining pristine stands of primary Valley Oak woodlands of great magnitude in California (Madden et al. 2005).

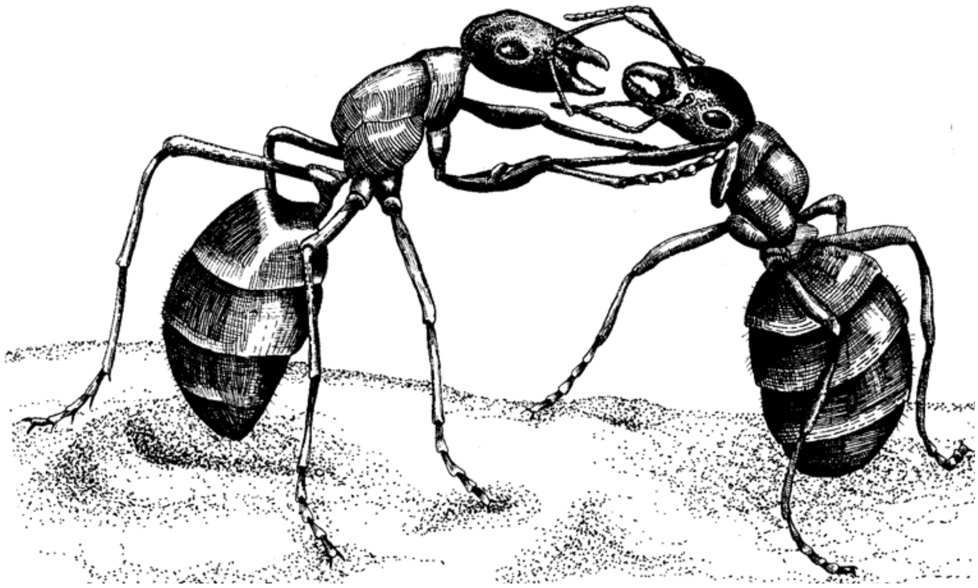
Students conducted biological field studies during 3-month semesters, in which 24-32 students actively work in the field collecting data. Native tree biology and conservation were the broach thematic topic assigned to all students during this apprenticeship.

Appendix C

Trophic cascade academic field study site, and author's illustration of ants

The author's first study in Costa Rica was organized and supported by the University Research Expedition Program, which is a tax-exempt organization under Section 501 (C-3) in the US Internal Revenue System Code. This study took place at La Selva Biological Research Preserve, situated in the Caribbean lowlands near the town of Puerto Viejo de Sarapiqul, in the Heredia Province. Annual rainfall here is over 400 mm per year, and the site contains stands of both primary and secondary rainforest.

The forest preserve at La Selva occupied about 1,750 hectares, centering on the confluence of the Rio Sarapiqul and Rio Puerto Viejo Rivers. The number of plant species at the reserve is estimated to exceed 2,000 species of vascular plants, and La Selva is home to many rare invertebrate organisms, some of which have yet to be discovered by scientists. The symbiotic role of ants was examined as I worked as a teaching assistant and led teams in investigating these ants at La Selva.



Appendix D
Description of an academic field study site in Ecuador

One of the author’s early academic field studies upon which the central theme of the thesis was designed took place at Jatun Sacha Biological Station in the upper Rio Napo province at about 450 m elevation. Annual rainfall at this site is approximately 4100 mm. Rainfall is evenly distributed throughout the year. The life zone of Jatun Sacha is Tropical Wet Forest. This region is an ecological transition zone between the lower slopes of the Andes and the Amazon lowlands. The Government of Ecuador gave Jatun Sacha official status as a biological reserve in 1989. The biological station and surrounding property is managed by a private, non-profit organization called the Fundacion Jatun Sacha.

Rainforests are the most species rich ecosystems on earth, providing sanctuary to many organisms, which are found nowhere else outside of this system. Scientists do not understand many tropical species, and there are many other species that have never been identified or even catalogued by science. Rainforests of the Amazon Basin are an enormous pharmacopea; a source of new medicines that have yet to be discovered (Shultes 1979). Many of the plants here produce complex chemicals that may be rendered useful in treating human disease.

The Ecuador study followed basic protocols of the National Cancer Institute for the collection of voucher plant specimens, with emphasis upon discovery of plants with metabolites having the potential for treating some forms of human cancer (Madden and Bennet 1991). Research teams comprised of college students were established, and field research began on a number of different topics. The author’s team examined a relationship between a plant’s natural biochemical makeup and the survival of that plant. These plant chemicals that relate to the survival of a plant may also have applications in medical treatment for human beings.

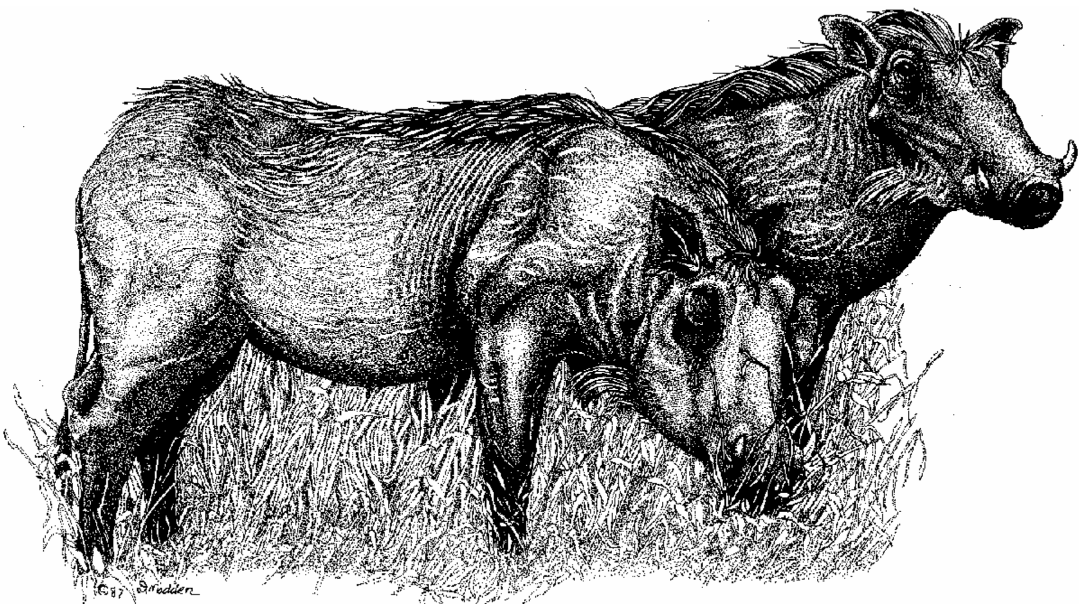
The project in Ecuador provided me with a basic plan for how to structure academic field studies with college students, and also provided me with a variety of experiences that made it possible to foresee some of the problems that I would encounter in the thesis study that came later.

Appendix E

Description of the Kenya academic field site, and illustration of warthogs

Vegetation of the study site at Game Ranching Limited in Kenya is composed of wooded grasslands, consisting primarily of scattered trees occupying less than 20% of the landscape. The landscape is creased with numerous ephemeral streams, and there are several areas occupied by the houses of residents and a large compound where meat-processing activities occur. The ranchland is situated in a biologically productive *Themeda-Acacia* rangeland zone. Soils are primarily fertile vertisols, which contain high concentrations of clay and organic matter. The arid climate and unpredictable droughts in this region are not conducive for crop cultivation; however, the conditions are appropriate for economic wildlife ranching (Hopcraft 1990).

Through a long coevolutionary history of interactions, various species of hoofed animals have developed specialized anatomy and behaviors relating to optimum foraging (Rohner and Ward 1999). To avoid competing with other species, a term referred to as interspecific competition, each species feeds in ways that reduce overlap in the utilization of food resources. In such partitioning, zebra are the first to feed on coarse grasses, and are followed by animals such as gazelle and warthogs that feed on small herbs.



Appendix F
Wildlife ranching and vegetation considerations

One example of optimum foraging is the feeding successions in the Serengeti of Africa where zebra forage first on the coarse grasses, and wildebeest, warthogs, and other animals forage next on herbs growing in the same plot. Such grazing lawns are maintained through specialized features of the zebra’s gut that allows these mammals to process coarse grasses, and through the feeding anatomy of other herbivores, which relegate these animals to a diet of non-grass species that are low in lignin and silica (Seagle and McNaughton 1992).

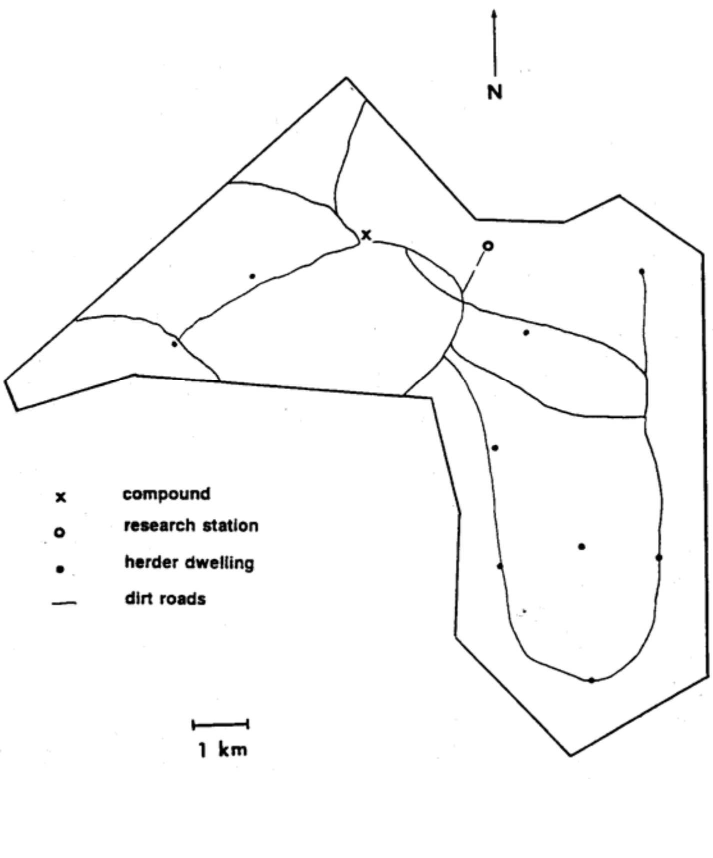
Native herds partition plant resources in ways that reduce interspecific competition; however, variations in the physical environment make such a competitive equilibrium among resident herds somewhat unpredictable (Kock 1995). Mixed species ranching using both indigenous and domestic stock can be more cost effective and environmentally sound than strictly raising domestic grazers in some of the dry savannas of southern Africa (Milton 1987). Through their foraging activities, browsers may ultimately benefit the plants that they feed on. For example, nitrogen-rich droppings, excreted by large mammals as they feed, impart the soil in a plant’s root zone with various trace nutrients that are often in poor supply in a savanna ecosystem (Seagle and McNaughton 1992).

To succeed as a sustainable and economical endeavor, wildlife ranching utilizes the natural hardiness and ecological suitability of indigenous animals of the rangelands where they naturally occur. As logical as it first appears, wildlife ranching is plagued with problems relating to the effective conversion of plant matter into body mass of the harvested animal populations (Kreuter and Workman 1997). Land degradation and economic loss occurs in wildlife ranching just as it does with domestic live stocking when basic concepts of savanna ecology are not well understood (Dekker 1997).

Browsers may benefit the plants that they consume, and yet intensive browsing may also cause a drastic decline in resident populations of Acacia (Rohner and Ward 1999). This decline in Acacia, one of the most crucial plant species found in many dry landscapes, is apparent in parts of sub-Saharan Africa. Overbrowsing has completely altered the vegetation throughout much of this region, and has resulted in landscapes with low fertility and drastically decreased biodiversity (number of different species in an area). There is evidence that the loss of native vegetation in much of arid Africa is one of the factors contributing to the conversion of once productive landscapes into infertile deserts (Rohner and Ward 1999).

Seeds that are consumed by large browsers often pass entirely through an herbivore’s gut without being destroyed. Such seeds have a relatively high likelihood of germinating after the animal excretes them. Laying in a fertile clump of dung, and protected from the destructive activity of seed-eating bruchid beetles, the defecated seeds may sprout at a greater rate than unconsumed seeds from the same plant (Rohner and Ward 1999). The feeding activities of native browsers may also benefit the trees they feed upon through increased dispersion of seeds

Palatability of Acacia is seasonal, with some species being more acceptable to herbivores in dry or wet seasons or in other conditions relating to subtle changes in plant growth and development (Caister et al. 2003). Palatability is also a function of the age, sexual differences, and social structure within the resident herd on a wildlife ranch, further complicating the study of plant palatability in the field (Young and Isbell 1991). A map of the rangelands of GRL appears below.



Appendix G
Sea turtle nesting ecology

Even after extensive scientific research over the past thirty years, much of the Olive ridley sea turtle's natural history remains poorly understood. Much of a sea turtle's life is spent in water, where the large reptile migrates in search of food and mates. A prolonged time to reach sexual maturity, and the numerous hazards that turtle hatchlings face during their development were probably offset historically by prolific egg production. A single sea turtle may come ashore to lay 102 to 118 eggs several times during a nesting season (Fowler 1979).

The mass nesting behavior of many sea turtles probably resulted in high egg mortality in the distant past, and is a process that continues today. For example, of the thousands of Olive ridley eggs deposited annually on beaches, less than 5% of the eggs typically produce hatchlings (Cornelius 1991). What was an acceptable mortality rate in the distant past for sea turtle eggs may no longer be a negligible amount when considering the global reduction of pristine sea turtle nesting sites.

Sea turtle nest ecology

Olive ridley nesting ecology is open to some interpretation. Although reproductive success is typically low, the amount of fertile eggs produced by females arriving on the beach to nest is often ninety percent (Fowler 1979). Hatching success rates for these turtles is highly variable, and the cause for fluctuations is unclear. Various factors reduce the survival of sea turtle eggs after they have been laid. Many turtle eggs may fail to hatch simply by being deposited in poor locations in regards to sand-moisture conditions (Hendrickson 1995). Turtle nests also fail due to the foraging activities of dogs, flies, crabs, humans, and a variety of other organisms that feed on turtle eggs (Erk'akan 1993).

Research conducted on Olive ridley turtles during the 1970's and 1980's on the Pacific Coast of Costa Rica concluded that sea turtle hatchling rates were nearly eighty percent higher in sections of the beach where nests were widely spaced apart. There was only a zero to two percent survival rate observed for eggs laid in crowded conditions (Cornelius et al. 1991). From these data it appeared that too many turtle eggs in the beach might have contributed to egg mortality.

It was suggested by several scientists that removal of some eggs from crowded conditions might improve the hatchling rates of Olive ridley turtles. By 1986, an experimental sustained yield program was in place to provide economic incentives for preserving the Olive ridley sea turtle. Placing an economic value on the Olive ridley at Ostional, in the form of turtle egg sales, induced a potentially beneficial situation for turtles and humans (Cambell 1998). The conservation through utilization scheme being employed at Ostional is an experimental project that undergoes frequent evaluation to determine ways in which the egg harvest can continue to generate revenue while also ensuring that turtle egg production is not impaired. The consumptive egg harvest, as conducted by the local Ostional community, may reduce the number of poachers, dogs, and other predators of sea turtle eggs. The egg harvest and management activities that are conducted by members of the local community; however, may not control crab population that some scientists believe indirectly destroy many turtle nests.

Appendix H
A sample of field methods used in Kenya

Thorns, leaves, and flowers

Students that participated in field studies on Game Ranching Ltd., Kenya, located individual trees that giraffe were reported in the literature to frequently browse. Trees were selected randomly by using a wandering quarter vegetation sampling technique originating at random points along pathways (Milewski et al. 1991). Trees were measured for flower and fruit production. Ladders and pole clippers were used to reach one branch from each 1 m vertical interval within the canopy of living trees. After removing 80 cm of shoot tip from a random branch, a total count of flowers and seedpods was conducted from 0-40 cm and 40-80 cm from the branch tip. Sampling continued upward in the canopy in this manner to 6 m, at which point it became too hazardous for students to gather data.

One student team measured thorns and spines as plant features associated with the foraging activities of large mammals on GRL. Students selected random plants through a wandering quarter vegetation sampling technique, and used metal calipers to measure the maximum length (cm) of one mature thorn and leaf growing nearest points 0, 20, and 40 cm from the sample branch tip. Thorns and leaves at these points were clipped off at the base. Total thorn, flower and leaf counts then were made 0-20 cm from the sample branch. The shortest distance (cm) between a thorn at 20 cm on the sampled branch and a thorn tip on the nearest neighbor branch was measured. Students clipped thorns and leaves from sampled branches, and these were air-dried in trays for 2 weeks in order to calculate dry mass.

Thorns, spines and herbivore use

Student teams measured thorns and spines as plant features associated with the foraging activities of large mammals on GRL. Students selected random plants through a wandering quarter vegetation sampling technique, and used metal calipers to measure the maximum length (cm) of one mature thorn and leaf growing nearest points 0, 20, and 40 cm from the sample branch tip. Thorns and leaves at these points were clipped off at the base. In the same way described in the previous paragraph, students gathered data on the total thorn, flower and leaf counts 0-20 cm from the sample branch tip. The shortest distance (cm) between a thorn at 20 cm on the sampled branch and a thorn tip on the nearest neighbor branch was measured. Students clipped random thorns and leaves from sampled branches, and these were air-dried in trays for 2 weeks in order to calculate dry mass.

Student teams assessed herbivore use intensity (HUI) of randomly sampled plants encountered throughout the wandering quadrate sampling activities on GRL. Herbivore use was determined by counting large mammal dung within 5 m around the periphery of the living canopy. Bleached-appearing dung was not recorded, as it was typically old dung that had been trampled, was flaking apart, or otherwise difficult to accurately count. In the data analysis, students determined the HUI for each sampled plant with the following formula: X_1/X_m x 100, where X_1 = dung counts for the individual plant, and X_m = the maximum dung count recorded for that species in this study. Dung counts were used to estimate a collective HUI for each plant species, and used for comparing plants with high to those with low HUI (Gadd et al. 2001).

To further examine the relationship between large browsers and the plants they eat, students clipped off the thorns from 30 cm of a random branch tip on the tree being sampled for HUI. This experimental branch, and a similar length of branch, without thorns removed (Control group) was flagged and observed 9 months later. The student research teams studying *Acacia drepanolobium*, *A. seyal*, and *Balanites glabra* were provided with scientific literature relating these trees to the foraging habits of giraffe. Each team examined features of these plants, such as thorns, spines, flowers, and other aspects of growth as they related to giraffe. The focus of these studies was to acquire information about the foraging habits of giraffe by conducting field study on the plants these large browsers utilize as a major source of food on GRL

Giraffe

Several teams of students assessed the foraging behaviors of giraffe by locating; tracking, and watching these large mammals feed on GRL. Observation of free-ranging herds involved minute-timed focals taken from a distance of 15 to 30 m through field glasses.

Herds were located by vehicle, and data were gathered after the giraffe had ceased its vigilant response and had returned to foraging or wandering. Population densities of the various large browsers on GRL during this study were: 1.19/ km^2 Impala (*Aepyceros melampus* Lichtenstein), 0.93/km^2 giraffe (*Giraffa camelopardalis tippelskirchi* L.), and 0.25/ km^2 Cape Eland (*Taurotragus oryx* Pallas). Giraffe herds numbered between 53-67 individuals, and included adult males (18.1%), adult females (53.9%), juvenile and subadults (4.1%). Impala herds numbered between 72-79 individuals, with adult males (8.5%), adult females (64.0%), and subadults (27.5%). Eland numbered 9 individuals, with 3 being subadults.

Focal observations

During observational focals, each team of student recorded the following information on data sheets: 1) plant species being eaten, 2) height above the ground where feeding bouts took place, 3) browse handling technique (described below), 4) number of bites per bout (browsing pressure), and 5) duration of each feeding bout. For feeding heights, adult male and female giraffe were estimated to be 1.0 m at the knee, 2.0–2.5 m at the point of the shoulder, and 4.5-5.5 m at the head, respectfully. A spotter researcher relayed verbal focal accounts to a scribe who timed each feeding bout. A feeding bout was considered to be terminated when either 1) the animal began feeding on another plant species, 2) the animal walked for more than 3 steps from its previous feeding station, or 3) more than 60 seconds had elapsed without feeding being resumed.

Student teams examined the ways in which giraffe feed on plants, which was referred to as browse-handling methods. These students used the same established focal-observation protocol conducted by the other focal student teams. In this study; however, the spotter used a monocular field scope to acquire a close image of the giraffe being observed so that precise movements of the mouth could be reported. The student that conducted the observational focal, watched for precise movements that a giraffe made while feeding on a branch. Data were gathered on whether the giraffe 1) used the tongue to strip leaves off a branch, 2) nibbled on the branch, or 3) used its front incisors to clip a shoot completely from a branch. Written notes accompanied the recording of the three categories, and included notes on any other behaviors that the giraffe was displaying as it foraged on various plants.

Browsing behavior

Browse handling measurements that were used by the students were based on experimental work done with kudu (*Tragelaphus strepscieros*) and giraffe (Cooper and Owen-Smith 1986). Browse handling techniques of free ranging browsers were recorded as either 1) strip, when tongue, lips, or inside of mouth was used to rip leaves off a section of branch, 2) pull, when a branch was pinioned, between palate and lower teeth, and tugged entirely free from a plant, or 3) nibble, when the lips cropped leaves from branches without the distinctive head movements associated with pulls or strips.

One team of students assessed habitat utilization by using the previously described methods to locate and observe giraffe. In this study, students used GRL maps to determine where the giraffe were foraging. A spotter relayed the exact number of animals in the giraffe herd, while a student timed the session. A student recorded this information on a GRL map, using roads, structures, and various topographic features to determine location. The spotter also conducted a random count of living trees within 10 m of the giraffe herds, and these data were recorded for that sample plot. All members of the student research team rotated their positions throughout each two-hour field study session. Student teams made their initial focal contact with giraffe from various dirt roads throughout the ranch. From here, students followed the focal animal on foot in order to gather data on foraging strategies. Data were not gathered after heavy rains due to the near impossibility of safely navigating the muddy roads.

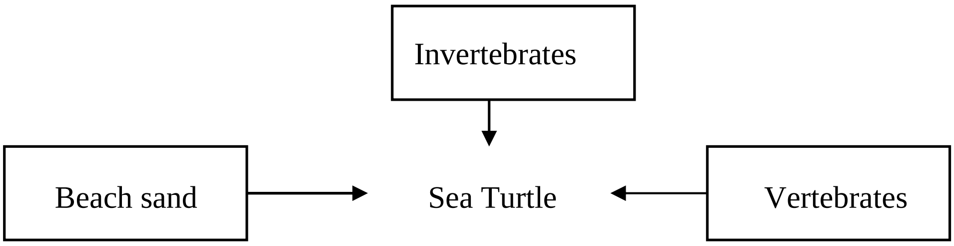
Appendix I
Academic field methods in Costa Rica

In an effort to understand how to conserve sea turtles in Costa Rica, two student teams investigated the organisms that attacked turtle nests. Ecology-focused teams concentrated their efforts on the invertebrate organisms (crabs, flies, etc.) and vertebrates (dogs, humans, opossums, etc.) that were associated with turtle nest disturbance. Ecology-focused teams also examined the situation of the nest in regards to its distance from the water and upper vegetation. Also examined was the depth within the beach in which the nest had been laid. These student teams worked closely together due to constraints of sea turtle nest disturbance as outlined by the Ostional Regulations on Sea Turtles. Methods used by the ecology-focused student teams are described below.

Turtle beach studies

Student teams worked on the beaches of Ostional, where sea turtles came ashore to nest in great frequency in summer between June and August. Sample plots (m^2) were roped off on the beach, and sand excavated to a depth of 1 m. Data recorded were 1) depth (cm) to top of nest, 2) nest location according to a previously mapped beach grid, 3) distance (m) to high tide line and to zone of >80% vegetation, 4) number of dead and developing turtle eggs, and 5) terminus of crab holes in the plot. Methods for egg examination followed Fowler (1979), which reduced the need to destroy each egg. A 255 ml container was filled with sand from around turtle nests. A control sample was scooped at 0.5 m away from the center of the nest. Samples were sifted; the living contents examined, and representative invertebrate specimens found in the nest were preserved in ethanol. Students kept written records on the invertebrates found in excavated turtle nests.

Students based their research techniques on the work of a team of scientists that provided evidence that sea turtles mortality may be linked to features of the nesting beach (Cornelius et al. 1991). Crabs, flies, bacteria, fungi and other organisms in the nesting beach of sea turtles may influence hatching success rates. The ecological field study for my students was aimed at various organisms that had been reported to have some association with sea turtle egg mortality.



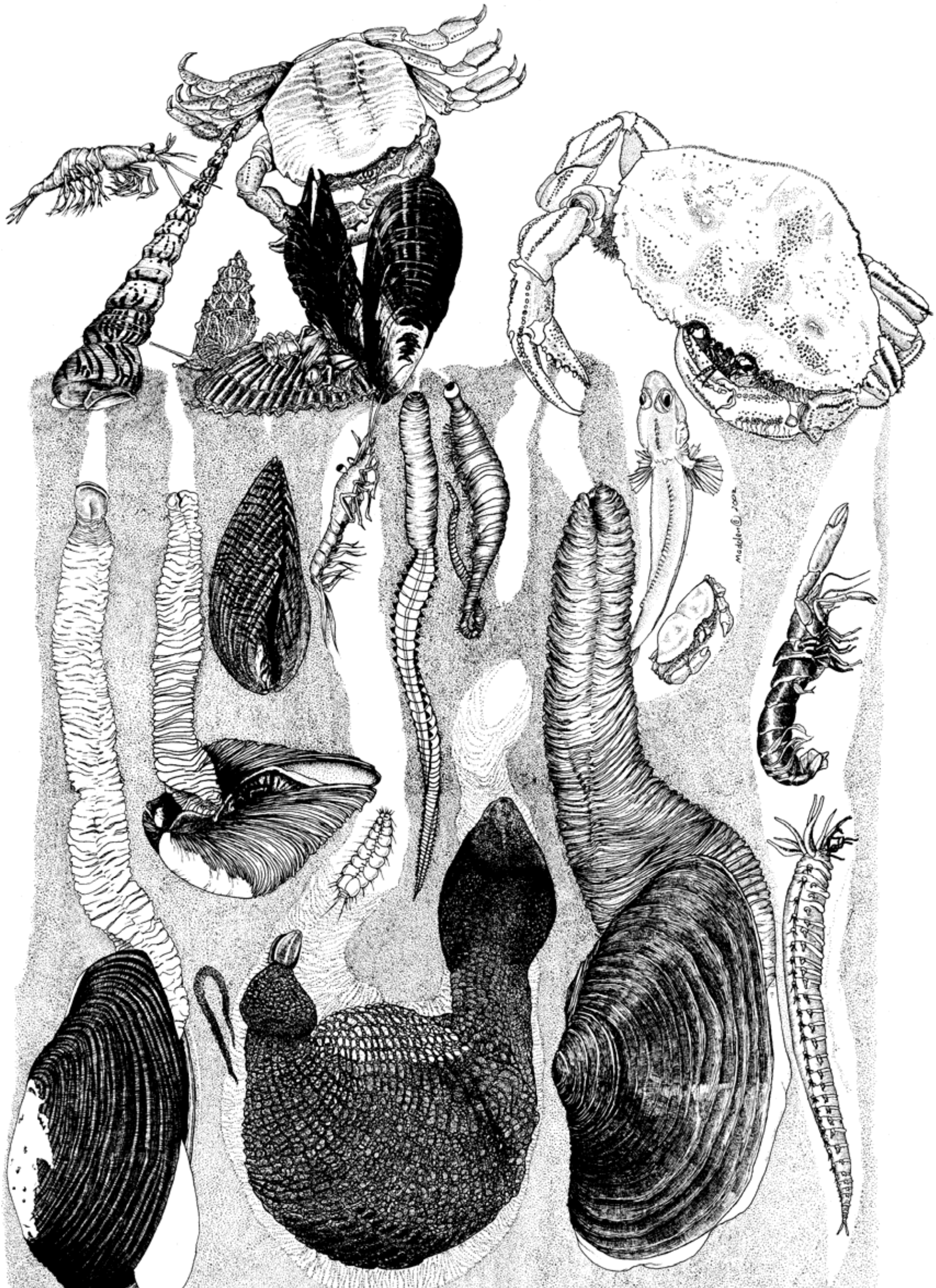
Students' field study of turtles

In an effort to understand how to conserve sea turtles in Costa Rica, student teams observed turtle nesting activities as they related to the mortality of sea turtles. As was the case for students studying the habitat of sea turtles, students that directly studied the movements and activities of sea turtles based their field techniques on previously established research (Cornelius et al. 1991). Students conducted two-hour beach patrols during which time they walked the 880 m beach strand at Ostional, and visually searched for sea turtles. These beach patrols were conducted in two-hour shifts, twenty-four hours a day.

When a sea turtle was spotted, the research team moved slowly toward the posterior end of the turtle, and avoided any sudden actions or loud speech that might disturb the nesting turtle. If it was dark, flashlights were covered with red lenses. Lights were only used when necessary to record data or to find a safe path to the nesting turtle. A student recorded the number of eggs that were laid, time (24-hour clock), and the species of sea turtle. A spotter relayed this information in a quiet voice. Duration of the nesting event and number of eggs laid was recorded at the end of the egg-laying session. The nest site was marked with a flexible stake. On the following day, hardware cloth, known more commonly as chicken wire, was placed around the turtle nest so that the emerging hatchlings could be trapped and observed after having emerged from the nest. These hatchling traps were checked by student beach patrols as part of their duty in each two-hour shift on the Ostional beach.

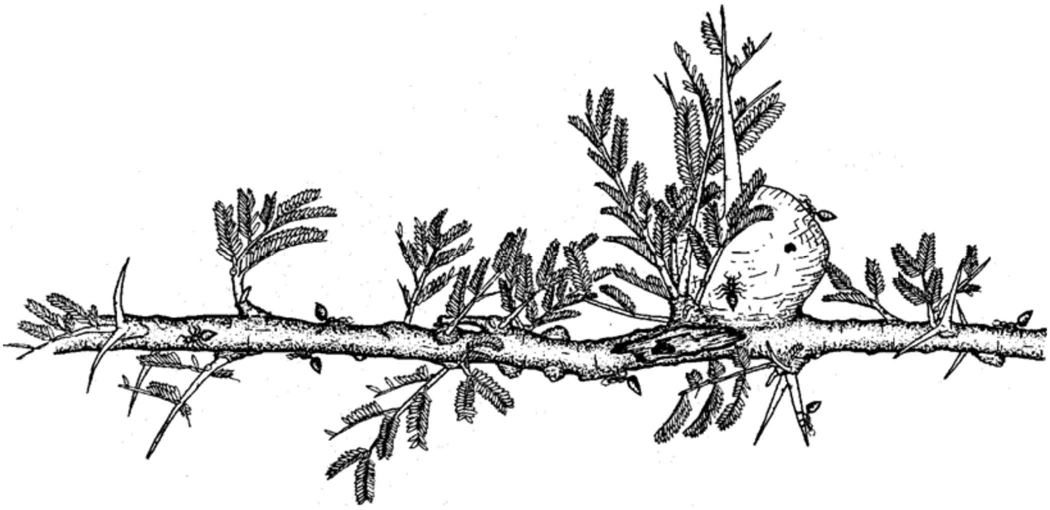
Appendix J

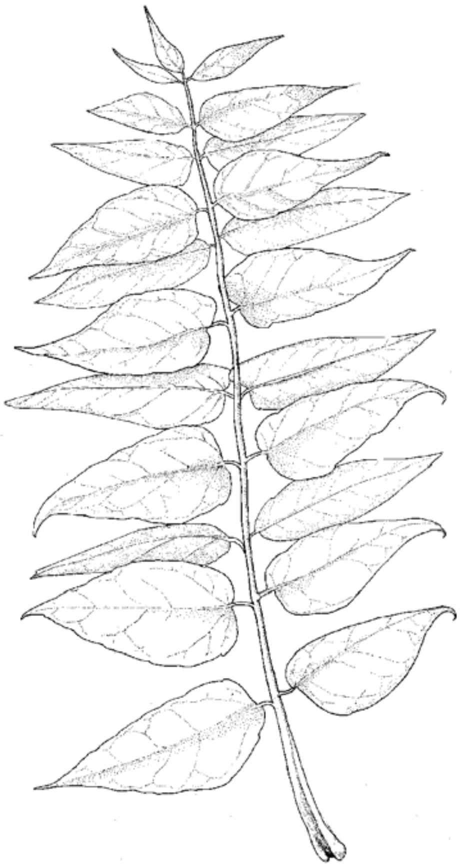
Author's illustration of organisms found in turtle nesting areas



Appendix K

Physical defenses (top illustration) and an example of a plant with chemical defenses that deter giraffe



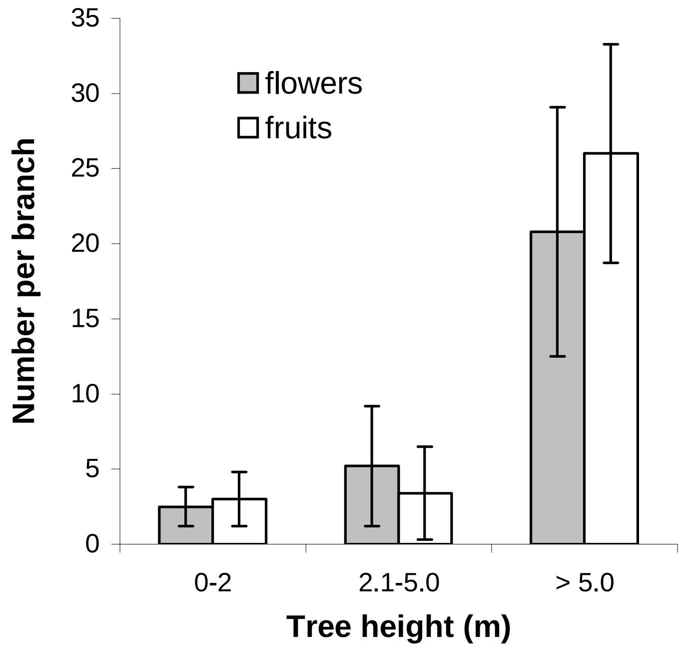


Appendix L

Students' field study of giraffe habitat

In the study of giraffe habitat, where students located individual trees that giraffe browsed, the students observed a relationship between giraffe browsing heights and the occurrence of flower and fruit production. Students conducted parametric analyses of their data prior to moving on to write up a discussion section. These student teams discovered significant differences ($p <. 05$) in the data for the abundance of flowers and fruits in tree canopies above 5 m and those below this height.

The chart below shows mean and ± standard error of flowers and fruits in relation to tree height of *Acacia seyal* observed by 3 student field teams (n=13 students) on Game Ranching Ltd. Fruit and flower counts were >70% at 0-40 cm from the shoot tip on *A. seyal*, compared with >65% reproductive structures being found on branch sections from 40-80 cm from the shoot tip on *A. drepanolobium*.



Students that collected field data for *Acacia seyal*, *A. drepanolobium*, and *Balanites glabra*, as the thorns on these trees were associated with giraffe, observed a close association between large browsers and their woody forage. Students observed that

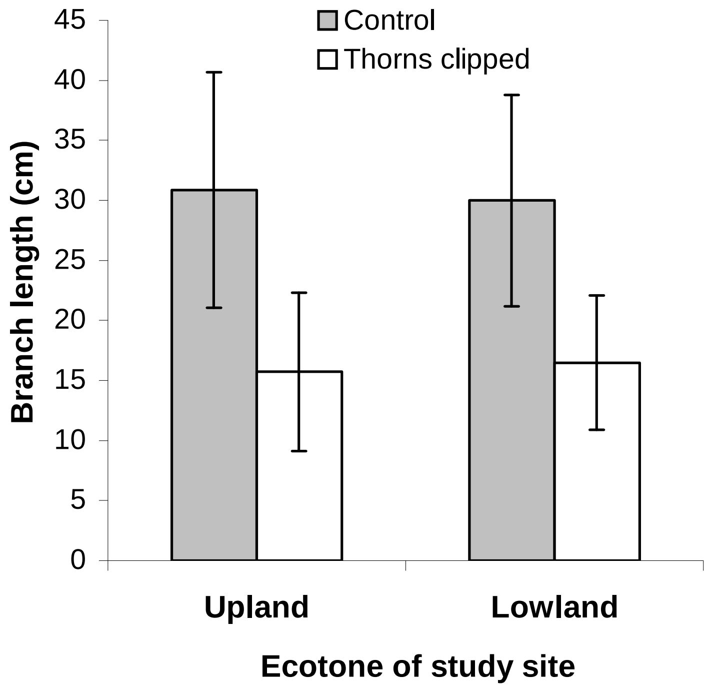
Acacia seyal had 18.5 (±6.5) thorns along 20 cm of branch length. *Acacia drepanolobium* was the thorniest sampled species, with a mean number of 29.6 (±8.85) thorns per 20 cm of branch tip. Students observed that thorn abundance was associated with thorn mass on the trees they examined. *Acacia drepanolobium* had a mean of 14.57 grams greater thorn mass than *Acacia seyal*. Other data appear below, and show the mean ± standard error tree descriptions and browser utilization on Game Ranching Ltd. as observed by 4 student teams (n=15 students).

Foraged plant species:	*A. drepanolobium*	*A. seyal*	*B. glabra*
α Shoot protein/lignin/ash %:	28 / 12 / 13	15 / 3.5 / 14.5	29 / 10 / 15
Tree height (m)	1.3 ±0.63	3.7 ±1.9	3.7 ±1.5
Coverage/hectare (m^2)	387.0 ±71.0	189.5 ±34.3	99 ±52.8
Herbivore use (%HUI)	63.8	12.6	23.9
Thorn mass (g) †	15.67 ±2.41	1.10 ±0.17	--
Leaf mass (g) †	1.9 ±0.84	1.69 ±1.02	--

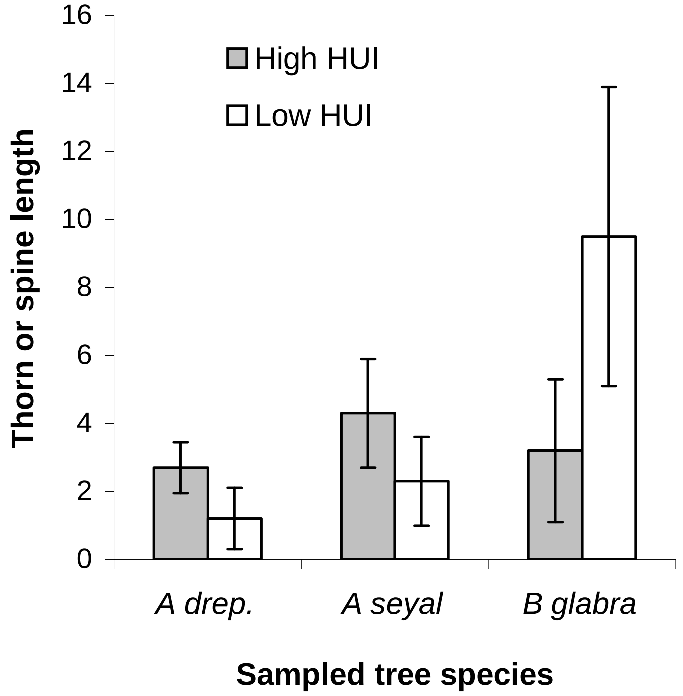
α (from Altmann et al. 1987)

† Dry weight of that plant material removed from along 20 cm of shoot tip.

Students observed the greatest herbivore utilization intensity (HUI), based on dung counts, for *Acacia drepanolobuim*. This shrubby Acacia had ant galls and paired straight thorns associated with leaves. *Balanites glabra,* a species with photosynthetic solitary spines, was the least abundant of the sampled plants; however, its HUI exceeded that of *Acacia seyal*. Herbivore utilization was observed to be lowest for trees growing in and around ranch compounds where intense human activity, fencing, equipment and other factors associated with humans were barriers to large browsing mammals. In areas with high herbivore use, experimentally clipped branches of *Acacia seyal* lost substantial amounts of shoot tip one year following the treatment. These data appear below as mean and ± standard error of branches with thorns removed. Results were gathered 9 months after students had removed thorns from random branches on 30 plants in areas frequently utilized by giraffe herds on Game Ranching Ltd.



In field studies in which students were examining dung as a measurement of herbivore use intensity (HUI) for various tree species, four student teams observed that thorn lengths for *Acacia seyal* and *A. drepanolobium* were greatest for trees with >70% HUI. This value was significantly different than what the students observed for *Balanites* trees. This spiny tree had an inverse relationship to the sampled Acacia, with spines on *Balanites* being significantly shorter (p <. 05) on heavily browsed individuals than on plants with a low HUI. These results appear on the following page, in which the mean and ± standard error thorn and spine lengths are displayed in relation to herbivore use intensity (HUI), determined through dung counts around sampled trees, observed by four student teams (n=16) on Game Ranching Ltd.



Students’ field study of giraffe

Student reports that described the behavior of giraffe on GRL were grouped for analysis as organism-focused data. Many of the students that studied animal behavior experienced difficulty in acquiring data. To assist students in generating sufficient data entries, the study of giraffe was expanded by the research staff to include two other large browsing mammals with an ecological foraging niche similar to that of giraffe. In the foraging study, Cape Eland and Impala were included in the focal observation sessions. With the addition of these large browsing mammals in their data, students continued to gather information on foraging behavior, movement, and interspecific behavior of large browsing mammals. The latter category involved observing the interactions that the focal browsers had with other species, including humans, which were encountered on the rangelands of GRL.

The collective browsing heights of Masai Giraffe, Cape Eland, and Impala feeding on two species of thorny Acacia and one species of spiny *Balanites*, was observed by students to be from near-ground surfaces to a maximum of 5.5 m. Only 4 adult males of the 42 individual giraffe observed by students fed above 5 m. These male giraffe were observed to stretch upwards and temporarily have both forelegs leave the ground surfaces when browsing above the height of 5.5 m. Such behavior was observed in less than 0.03% of the total focal observations conducted on all browsers.

Student teams that conducted field studies on the giraffe's utilization of different habitats, where GRL maps and vegetation maps of the region were consulted during the study, found giraffe to prefer mixed woodlands (< 87%). These habitats supported woodlands, dominated by *Balanites glabra* and various species of Acacia. These data revealed trends; however, mathematical means were not statistically significant. Of the three browsers that four different student teams observed, giraffe spent the greatest time feeding on *Acacia drepanolobium*, *A. seyal*, and *Balanites glabra.* The latter species is not related to Acacia, and produced photosynthetic spines that were green and pliable or gray and short.

When students pooled their data on browsing behavior, the data revealed a significant difference between the way giraffe forage on Acacia and *Balanites.* Giraffe typically employed a pull type of feeding strategy when foraging upon Acacia shoot tips in the canopy of these trees. However, when feeding on spiny *Balanites* trees, giraffe most often nibbled, without the distinctive head movements associated with pulls or strips. Other foraging strategies observed by students were grouped into one of the major three categories (pulls, strips, and nibbles). For example tongue strips (use of the tongue to strip leaves) and lip strips (use of the lips to strip leaves) were pooled together as strip foraging data.

Appendix M

Observation data gathered by students in Kenya

The table below shows results of the field observations conducted by 4 student teams on free-ranging, large browsers of Game Ranching Ltd. Mean numbers and ranges are based on one-minute focals from distances of 15-30 m conducted in two-hour daily sessions June-August, 2001. The total number of observation focals was 1,961. The total number of individual animals observed by the students was 67 Masai Giraffe, 56 Impala, and 9 Cape Eland.

Prickly plant species:	*A. drepanolobium*	*A. seyal*	*B. glabra*
Feeding height (m):			
Giraffe (*x* / range)	1.07 / 0.2–3.0	1.02 / 0.5-5.7	2.0 / 0.5-5.7
Eland (*x* / range)	1.05 / 0.2-2.3	1.02 / 0.4-1.7	0.85 / 0.2-1.9
Impala (*x* / range)	0.91 / 0.2-1.7	0.70 / 0.2-1.8	0.85 / 0.2-1.9
Relative browsing (%):			
Giraffe/Eland/Impala	47 / 1 / 2	2 / 1 / 2.5	19 / 0.05 / 0.0
Browsing strategy (%):			
Strip/Nibble/Pull	4.4/ 29.9/ 65.7	6.5/ 34.4/ 59.1	3.1/ 59.8/ 37.1

Appendix N
Students' field study of sea turtle habitat

The first of my student teams conducted field studies at Ostional beach in Costa Rica for a total of 4 months during the summer months May through August 1993. One set of student teams focused on the habitat of sea turtles; specifically, the nesting beach where female turtles came ashore to lay eggs. These students did not record data on the behavior of sea turtles unless the reptiles' activities were involved with some aspect of the habitat being studied. The focus of their study was on factors in the environment that were associated with the mortality of sea turtle eggs.

Invertebrates and turtle nests

Students that studied invertebrates, as these organisms might be associated with sea turtle mortality, found several statistically significant associations. Eight teams of students that focused on sea turtle habitat found the hatching success rates for the Olive ridley to be highly variable. The cause for these fluctuations is still unclear, even with variable analysis of the field data. However there were several significant data sets generated and trends that were observed by the students studying sea turtle habitat.

Beach-dwelling crabs are frequently blamed for the destruction of sea turtle nests; however, the student teams that studied crabs found that only 2.0% of the crab tunnels led to developing turtle nests. Most crab holes led to turtle nests that were already in a state of decay. An infested turtle nest can foster many organisms. One of the sampled nests contained 29 fly larvae, and several other invertebrates. Such organisms may infect neighboring turtle nests. Fly larvae were found alive and wriggling in control samples of sand collected away from infected turtle nests. These flies were identified as being primarily in the family muscidae and sacrophagidae, based on the adults that were observed to lay eggs in exposed turtle nests. Crabs were identified as various species of Ghost crabs, which were most active between sunset and sunrise.

Various other organisms were observed and reported in the students field notes, and included beetles (family tenebrionidae), mites (order Acarina), crane fly larvae (family tupulidae), and several immature invertebrates which were either damaged beyond recognition or could not otherwise be properly identified in the field. In the analysis of data on these various invertebrates, no significant association was found between their occurrence in turtle nests and sea turtle egg hatching or mortality rates.

Vertebrates and turtle nests

Student teams that examined vertebrates on Ostional beach observed that several animals were linked to the destruction or initial degradation of sea turtle nests. The rate of nest disturbance was associated with the beach location. The students sorted their data so that information about vertebrates disturbing turtle nests could be examined, as it was associated with the nest location.

Black vultures were included in the students' data. These large birds are reported in the literature to be scavengers that typically consume turtle eggs from nests that are doomed to die. However, Black vultures were observed by students to disturb turtle nests that may have otherwise survived. These birds swished their beaks back and forth across the surface of turtle nests, gradually excavating the nest until the eggs could be consumed. In several instances, the students reported that Black vultures would prey upon turtle eggs while the female turtle was in the process of laying eggs. Such egg predation while turtles were ovipositing (laying eggs) was observed only for turtles that nested during the day. Relatively few turtles (less than 2%) came ashore to nest during the day, but the incident of egg predation by vultures on day-nesting turtles was observed to be 96 %. In this manner, vultures were direct predators of sea turtle nests.

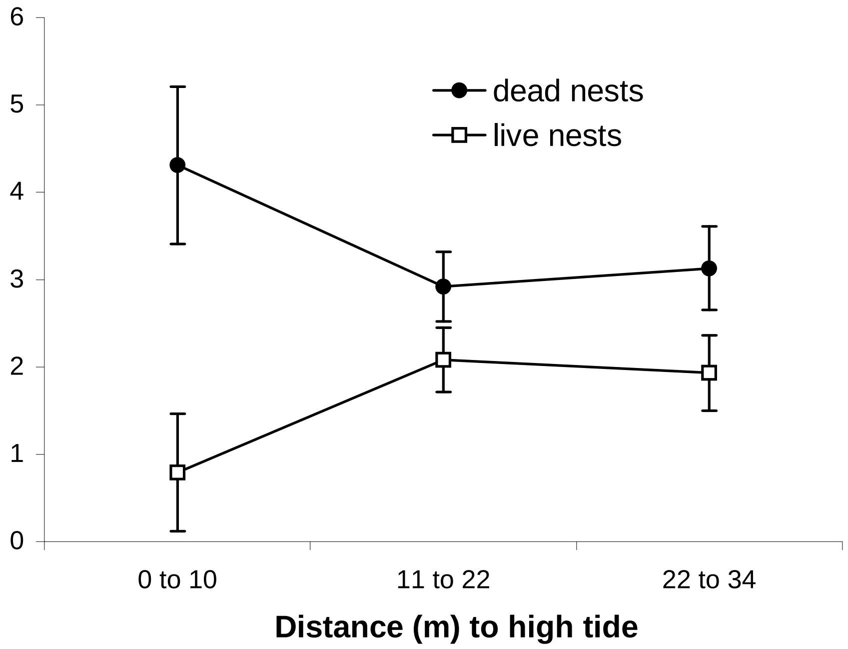
Student teams found that some potential turtle egg predators, such as opossum and raccoons, were not associated with the disturbance of sea turtle nests at Ostional beach. Humans, dogs, and vultures were observed to be responsible for much of the initial sea turtle nest invasion in this study. Dogs destroyed the most turtle nests on beaches that were not patrolled by members of the Ostional community.

Poaching activities conducted by humans disturbed the least number of turtle nests on the patrolled beach. Yet, humans accounted for the majority of the sea turtle nest disturbance on all beaches as observed by these student field studies. The various student groups presented their results from the vertebrate and invertebrate studies on sea turtle habitat separately; however, for the sake of keeping this information organized, the data is combined in the table below. This table shows Olive ridley nesting beach data gathered by students at Playa Ostional. Legal egg gathering is allowed for the first 36 hours after a nesting event on the Main beach. The other beaches do not permit a legal turtle egg harvest.

	Main beach	rural beach	Remote beach
Mean live nests /m^2 ±SE	1.17 ±0.95	0.5 ±0.41	0.3 ±2.7
Mean dead nests /m^2 ±SE	6.3 ±4.5	2.5 ±1.3	1.3 ±0.93
Nest mortality rate (%)	85.1	83.3	81.3
Mean nest depth /m^2 ±SE	33 ±6.2	37.1 ±5.9	6.25 ±4.25
Average fly larvae per nest site ±SE	4.3 ±0.32	2.9 ±0.71	3.3 ±0.86
Nest disturbance frequency (percents based on n=2,640)			
Dogs	4.0	16.4	19.6
Humans (poaching)	67.5	73.0	62.3
Black vultures	25.0	6.5	4.0
Other animals	3.5	4.1	14.1

Sea turtle nests and beach situation

Another team of students that investigated sea turtle habitat examined how the condition of tides may be associated with the mortality of sea turtle eggs. The data was sorted by distance from the center of the sea turtle nest to the high tide line on all three beaches being examined at Ostional. Several of the student teams observed sea turtle egg mortality to be greatest ($p < .05$) for turtle nests situated more than 11 meters below the high tide line.

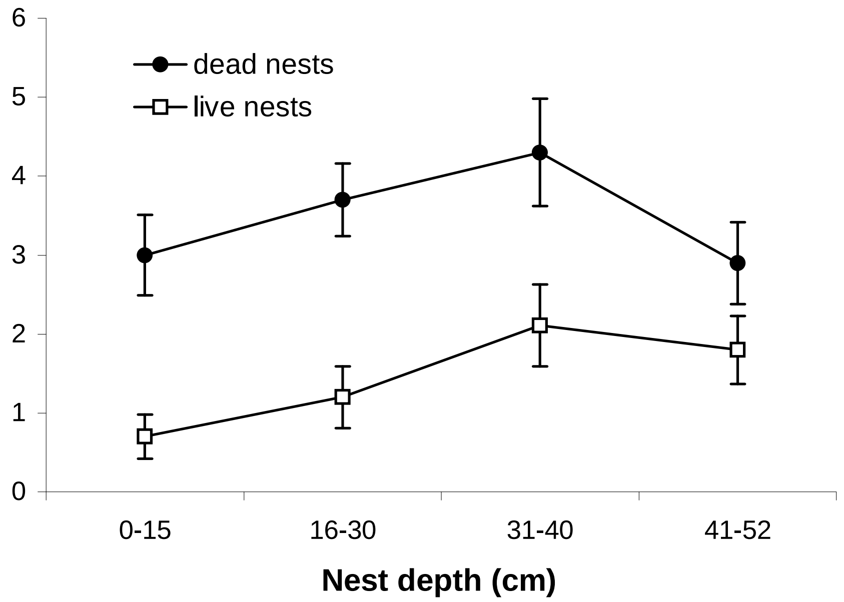


The graph above shows the mean ± standard error turtle egg mortality associated with distance to high tide, observed by students. The students examined 303 turtle nests (3,484 turtle eggs). Student teams investigated the association between the depth of a sea turtle nest and the mortality of turtle eggs. There was a closed association between where the nest was laid on the beach and the depth of the turtle nest. A majority (>90%) of the shallow nests were situated in the area below the high tide zone. Students observed Olive ridleys to lay most of their nests at depths of 31-40 cm.

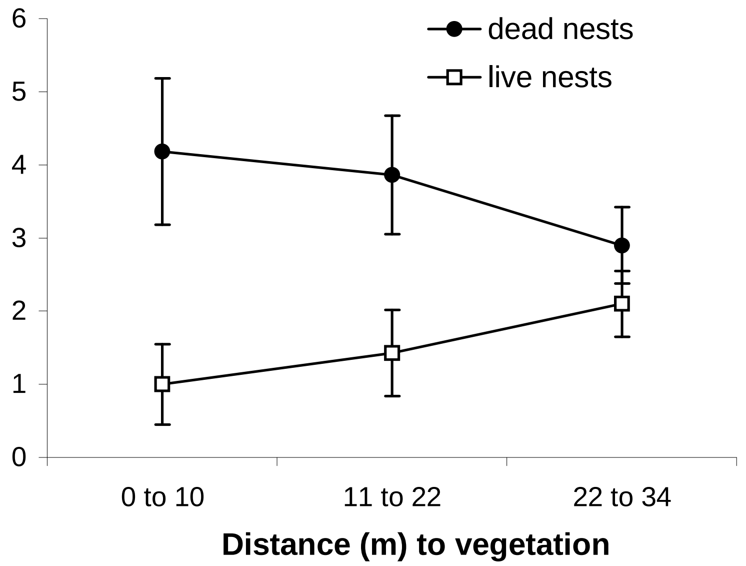
Location of the nest on the beach platform was related to the depth of the nest, with mortality being associated with location low on the beach where tidal action was strong. Many of the students observed wave action on the beach to wash sand away from sea turtle nests so that many turtle nests became exposed. Vultures often consumed these exposed eggs. Shallow nests experienced great mortality rates. Sea turtle nest mortality was also associated with the distance a turtle nest was from the upper beach where vegetation was >80% continuous.

Appendix O

Turtle egg mortality results in the beach at Ostional



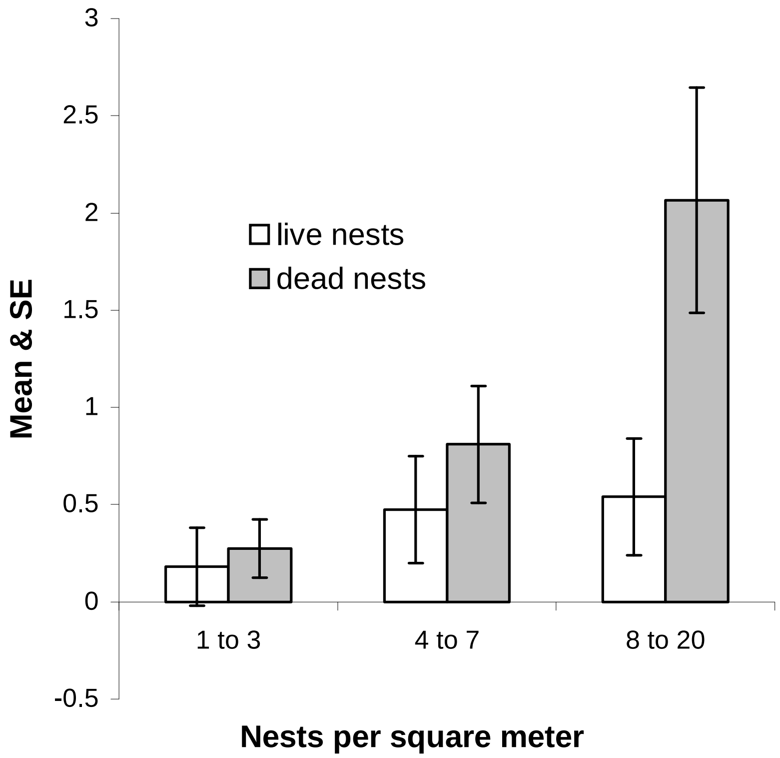
Mean ± standard error turtle egg mortality associated with depth of nest, as observed by students. N=303 nests (3,484 turtle eggs).



Mean ± standard error turtle egg mortality associated with location in relation to the upper beach, as observed by students. N=303 nests (3,484 turtle eggs).

Appendix P
Students' results of sea turtle nest crowding

Student teams that examined how the crowding of sea turtle nests may be associated with egg mortality found strong associations between these two factors. These data were sorted according to the number of sea turtle nests that the students excavated in a meter square plot. The maximum number of turtle nests presented in the graph displayed below was 20. Through analysis of the sorted data, students found a significant increase ($p < .05$) in egg death where sampled plots contained over 7 turtle nests (or 749 eggs). Field study students observed egg mortality to decrease with decreased number of eggs per plot. The graph below shows mean ± standard error (SE) of turtle egg mortality associated with number of nests per meter observed by students conducting field studies at Ostional Beach (N=3,484 turtle eggs).



Several student teams focused their activities on locating, observing, and tracking the movements of sea turtles as they came ashore to nest at Ostional beach (organism-focused studies). Students sampled 286 Olive ridleys nesting during this phase of the study, with nests containing an average of 107 (± 4.0) eggs per clutch. Turtle nesting activity that disturbed other nests was common on heavily used nesting sites on the main beach. Here, 11% of the nesting turtles disturbed another turtle's nest. This typically happened during the nesting activities when female turtles came ashore to lay their eggs. After selecting a nesting site, a female began digging with her hind flippers. If a previously laid nest was in the sand that she was excavating, then its contents of eggs was disturbed as this turtle produced her nest within the pre-existing turtle nest site.

Students observed that nesting turtles on all three beaches (Main, Rural, and Remote sites) frequently excavated old egg debris, along with beach sand. The pile of excavated sand that resulted from their digging activity contained at least one old turtle egg in 93% of the observed cases (n=179). This differed from the remote nesting beach, which had 0.7% nests (n=33) with excavated material including old egg debris. The rural nesting beach was observed by students to have 65% of the nests (n=74) containing old egg debris. My students calculated the average number of turtle eggs per clutch to be 109.5 (n= 303 nests, 33,179 eggs).

Appendix Q
Discussion of results from the field study of giraffe

Through the field studies described in this paper, several student teams arrived at new information and they suggested several plausible ideas regarding the relationship between plants and large, potentially destructive browsers such as giraffe. Acacia populations in many regions of the world are gradually declining due to landscape over-utilization relating to intensive foraging activities of large mammals (Rohner and Ward 1999). Might this same process be gradually happening on the rangelands of GRL?

Much of the success of a wildlife ranch is based on the intricate relationships between the harvested animal populations and the plants they prefer to eat (Kreuter and Workman, 1997). This relationship is based on a historical co-evolution between herbivores and plants. Failure to properly monitor how plants respond to foraging animals can result in a collapsed wildlife ranching endeavor. Examples of such failed wildlife ranches can be found in various places where wise use of the landscape was not a strong aspect of the endeavor (Dekker 1997).

One way to measure the palatability of some species of African plants is to examine external features that interfere with the foraging activities of the herbivore. Structural defenses that may reduce the palatability of plants include features such as thorns and spines that can snag the lips, nostrils, and ears, restrict the bite size, and cause damage to the esophagus of large mammals.

Thorns increase the overall food handling time of large browsers, and may limit the time they spend at individual plants (Cooper and Owen-Smith 1986). Besides the sharp jab that a thorn imparts to browsers that visit spinescent plants, thorns may also interfere with the physical processing of leaves (Milewski et al. 1991). Ants that protect the plants may further protect some of the Acacia that were examined by my students. Such ants may function like nettles to repel herbivores (Madden and Young 1992).

Flowers and giraffe

Students observed that the occurrence of flowers and fruits on the two Acacia in this study were probably associated with relative browsing pressure. The abrupt flush of flowers and fruits growing along 40 cm of *Acacia seyal* branch tips was closely associated with the upper foraging height for most of GRL's large browsers. Upward stem growth and the development of an umbrella-like canopy beyond the reach of browsing mammals may be one adaptive phenology pattern of *A. seyal*.

In contrast, *Acacia seyal* canopies situated within the foraging height of GRL's browsers had few fruiting structures, suggesting that short individuals of this species may not be a rich source of pollen and seeds. Such an understanding of the value of tall Acacia relates to the intense demand for firewood from the burgeoning human population growth in this area. *Acacia drepanolobium* revealed a different pattern than *A. seyal*, with flowers and fruits situated on living branches away from the shoot tips. These shrubby plants were not observed to grow beyond the feeding height of giraffe. Low numbers of flowers and fruits along shoot tips of *A. drepanolobium* probably relates to browsing mammals which remove these reproductive structures when foraging for leaves.

The relative abundance of flowers and fruits away from shoot tips on *A. drepanolobium* probably relates to the reduced browser activity deep within the canopy of this thorny shrub. These protected reproductive structures may play a role in Acacia survival, such as when intense browsing strips all flowers from the outer canopy prior to pollination and seed production. Intense browsing can result when overstocking occurs, and in some situations has drastically reduced Acacia germination rates and seedling recruitment (Rohner and Ward 1999).

Herbivore use and spines

A long co-evolutionary relationship between giraffe and thorny Acacia probably accounts for the propensity for giraffe to select plants that can be optimally foraged. In the case of giraffe, my students observed that the close proximity of bites suggests there is little search time independent of forage handling time. Thus, favorable nutrient concentrations may be a major foraging selective force since the handling of thorns requires similar feeding strategies in the Acacia examined here.

My students observed that *Balanites glabra* grows increasingly prickly in response to browsers, and it is probably this species' favorable protein to lignin ratio that is at least partially responsible the giraffe's propensity to forage this spiny plant. Unlike Acacia thorns that lengthen when browsed, heavily browsed *Balanites* produced stout spines that were gray rather than being the long, green elastic spines found on individuals with a low HUI. Reduced green structures of heavily browsed branches of *Balanites glabra* suggests that there is a reduction in chlorophyll at the expense of fortifying plant defenses. Such energy required for plant defenses often comes at a cost, and may limit the resources a plant devotes toward growth, maintenance, and reproduction.

Plant palatability is influenced by structures such as thorns that may physically impede foraging efforts and chemically interfere with digestion. Even browsers such as giraffe with a specialized anatomy to deal with structural defenses must physiologically contend with a thorn's concentrated deposits of indigestible lignin and cellulose. The reproductive fitness of an herbivore is influenced by the efficiency of its foraging, which relates in various ways to the palatability of the food the herbivore selects.

Plants, herbivores, and wildlife ranching

Acacia populations in many regions of the world are gradually declining due to landscape over-utilization associated to intensive live stocking (Rohner and Ward 1999). In addition to Acacia mortality caused by local physical and anthropocentric factors, large browsing mammals can also accelerate Acacia mortality rates and alter species composition over time in a savanna landscape.

One crucial aspect of wildlife ranching is to develop an understanding of the relationship between resident herds and the their natural forage. Variability of both the food resource and the feeding strategies of resident herbivores make it difficult to accurately understanding this herbivore-vegetation association. The students found this situation to be challenging; however, data on this association was gathered successfully when students examined the herbivore's environment.

Many African Acacia species have adaptive responses to browsers and can tolerate extensive tissue loss. However, some species do not necessarily thrive under chronic and intensive herbivory without a reprieve. The three plant species that students examined in this study all appear to have elevated defenses in response to browsing pressure. Students observed that *Acacia seyal* and *A. drepanolobium* appear also to have reduced flower and fruit production during the dry season in response to browsing pressure.

The phenology of thorns, spines, and flowers may be measurable indicators, reflective of the browsing activities of large mammals, and as such may be features to consider in the study of African mammals and their prickly forage. Through monitoring the resident forage, wise decisions can be made by the ranch manager regarding whether to move large herbivores to new pastures or toe reduce the numbers of large ungulates in order to give the over utilized plants an opportunity to recover from intense herbivory.

Appendix R
Discussion of results from sea turtle field study

Although students found the hatching success rates for Olive ridley sea turtles to be highly variable, and the cause for these fluctuations unclear, some of my ecology-based field teams made several discoveries about the nesting ecology of this endangered species. Embryonic development of turtle eggs at Ostional can exceed 80%, and yet less than 2% may survive to become hatchlings (Cornelius et al. 1991). Sea turtles typically have relatively high hatching success rates unless external factors intervene (Miller 1997). All of this suggests that Olive ridley turtles have a high capacity for reproduction; however, drastic losses occur during the relatively brief period of time that turtle eggs incubate within the beach.

Crabs, flies and sea turtles

Beach-dwelling crabs are frequently blamed for destruction of sea turtle nests; however, my student teams did not find crabs to be linked to the destruction of many turtle nests. Students observed crabs to invade only 2% of the turtle nests in the current study. One source suggests that crabs destroy turtle nests by producing tunnels through which flies and other agents of turtle nest degradation may find entry (Cornelius et al. 1991). Yet, several of the student teams that studied this concept found that it was probably the crowded nesting conditions that provided flies with avenues for turtle nest invasion.

Fly larvae and other small scavenging invertebrates were found in variable abundance both within turtle nests and in the sand surrounding nests. This suggests that many apparently undisturbed turtle nests were probably contaminated with fly larvae and other scavenger organisms that infested the beach sand. Rotting turtle eggs, which were abundant within the beach, probably sustain populations of flies that spread as wriggling maggots into healthy sea turtle nests

Flies and other such organisms found in sea turtle nests may degrade the nest environment and attract various secondary scavengers to the nesting site. Flies also have the capacity to vector other organisms, including species of mites that attach to the cuticle of flies and disperse their young from this perch (Madden and Harmon 1998). The

Ostional Development Institution’s beach cleanup protocol, which included raking organic material from the beach, may be partially responsible for the reduced number of fly larvae observed in the main beach where such human activities regularly occur. These beach cleanup activities probably have a major impact on reducing fly invasion of sea turtle nests. Based on the great number of flies found in turtle nests, the reproductive success of these ancient reptiles might improve from a protocol for turtle nesting beach cleanup activities that would further reduce fly populations.

Sea turtle nest sites

Porosity of sea turtle eggs allows gas exchange to occur when free oxygen is somewhat limited in the nesting pit. However, there is a point at which turtle eggs will not survive extreme conditions relating to oxygen. My students suggested that such conditions might account for a high number of dead turtle nests situated low on the beach platform where sand was frequently saturated with water. These eggs were also at risk of being exposed by wave wash.

Vultures that flocked on the beach ate many of these exposed eggs. The role of the Black vulture as an egg predator is unclear at Ostional because many of the drowned turtle eggs these birds consumed were unlikely to hatch. Students suggested that drowned turtle nests, along with nests situated in the estuary or vegetation zone, probably represent a valuable resource to be harvested by the local human community since eggs in these settings were likely to die before hatching.

Sea turtle future at Ostional

My students found evidence that the community-operated beach patrols may restrict the predatory activities of dogs that excavate turtle nests. Illegal poaching remains a major source of sea turtle nest disturbance at Ostional; therefore, the regulatory institution at this site may need to evaluate its beach security protocol. This could be done through the production of random beach patrol schedules so that poachers would not know when it would be safe to illegally gather eggs on turtle nesting beaches.

Through inherent egg-laying strategies, sea turtles have responded successfully to natural enemies and physical obstacles over the millennia. However, the destruction of former nesting beaches has contributed to a drastic global reduction of many sea turtle populations. Sea turtles influence the nesting beach ecology by transferring nutrients between land and sea during their lifetime (Bouchard and Bjorndal 2000). The intricate links between turtles and a beach suggest that not only do sea turtles require a nesting beach, but that the beach ecosystem also benefits from visitation by these reptiles. The students who conducted field studies at Ostional made several observations that may advance our understanding of how to conserve sea turtles. My students in the last field study session presented their findings to the Leadership Committee of the Ostional Community.

Appendix S

Selected student comments

"There is a major difference between using my mind alone to predict how a project will work out, and using the combined efforts of the mind, body, and soul of the members of my team to actually get the job done. It is as different as night is from day."
E. MacMillian, Costa Rica

"Every day is like a lifetime, and that is how I feel about this chance to study in Africa. Life is more than a list of tasks to do each day. I have found that life can be a combination of the odors, the crunch of dry grass beneath my feet, a gentle breeze along my skin, a rising moon, and the chance to just exist."
J. Pickens, Kenya

"I feel that all my previous education has prepared me for the real world, and today I finally experienced that. After weeks of field research, data analysis, and write up, we had the chance to share what we had learned with those whose lives it affected."
S. Jenkins, Kenya

"I was afraid of what I would find, afraid that I could not cope with the Spartan life and being with strangers so suddenly..... Now, I am afraid that I will forget about how I feel right now, at this moment. I am afraid that I will forget when I return home how important it is to be afraid and to not let fear stop me."
C. Cox, Costa Rica

"One of my life's dreams was to study in Africa...the SFS program allowed us to study and observe animals... it also immersed us in Kenyan culture. Personally, my experience can be described by one word - amazing!"
M. Simmons, Kenya

"So, imagine a country where every change in landscape presents a view fit for lifelong revelations. What we had not learned in our classes has been taught through the hands-on experience of interacting with the social and biological ecosystems around us."
N. Savransky, Kenya

"More than classes and schoolwork, stepping out of my comfort zone has taught me the most about who I am."
J. Zangmeister, Kenya

"From my Costa Rica experience... I learned there is a grand difference between knowing something and understanding something, and to understand you must experience firsthand."
K. Surfus, Costa Rica

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