INCORPORATING EXPERIMENTAL DESIGN IN EDUCATION ON MANAGING HUMAN-WILDLIFE CONFLICTS AT COLORADO STATE UNIVERSITY

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Abstract: Knowledge about how to design research experiments is important when evaluating the extent of damage caused by wildlife, the effectiveness of damage management interventions, as well as evaluating if the design, conclusions, and inferences of research conducted by others is appropriate. I emphasize experimental design in FW565: Managing Human-Wildlife Conflicts, a 3 credit senior/graduate level class that I teach at Colorado State University. I provide a 1-hour lecture on the basics of experimental design. I then provide an example of an elk *(Cervus elaphus*) repellent experiment and request students to indicate what were the treatments, dependent variables, etc. The students then independently write a 1-page manuscript on designing an experiment that evaluates the effectiveness of 1 of 2 wildlife damage management techniques. We follow with an on-site field trip to discuss and critique the students' experimental designs. Then, students are requested to write a 3-page manuscript and give a 6 to 8 minute presentation on designing an experiment that evaluates a new and unique method for reducing conflicts with wildlife in Colorado. Although we emphasize quantitative skills in our undergraduate program, a fair amount of repetition is required for students to grasp experimental design.

Key words: education, experimental design, research, wildlife damage management

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INTRODUCTION

I teach a senior/graduate level, 3-credit-hour course, FW565: Managing Human-Wildlife Conflicts in the Department of Fishery and Wildlife Biology at Colorado State University. The course is designed to cover a large array of topics that I feel are important for students with interests ranging from a professional career in this field to assisting with conflicts in their own back yards. Topics covered in the course include identifying causes of damage; assessing the extent of damage; experimental design; various methods of resolving conflicts including habitat management, repellents, relocation, compensation programs, and various lethal control techniques; predation and competition; economic analyses; population dynamics; animal behavior; public attitudes; conflict resolution; and wildlife damage control philosophy (Conover 2002). The course includes two 1-hour lectures and a 2-hour lab each week. Here, I focus on the aspects of experimental design in the course.

IMPORTANCE OF EXPERIMENTAL DESIGN IN MANAGING CONFLICTS WITH WILDLIFE

Knowledge about experimental design is important for researchers, Colorado State University students, as well as others, such as pest control operators who work in the area of managing conflicts with wildlife. The knowledge can greatly assist when attempting to evaluate the extent of damage caused by wildlife, and the effectiveness of various techniques for managing conflicts (Conover 2002). The knowledge can also assist biologists when they are requested to review research proposals and results of studies, or when practitioners evaluate if the design, conclusions, and inferences of research conducted by others are appropriate.

IMPORTANT ASPECTS OF EXPERIMENTAL DESIGN

Experimental design consists of several important components. Most are nicely reviewed by Ostle (1963). The components include experimental unit, experimental error, treatment, control, independent variable, dependent variable, randomization, replication, sampling, and confounding. I will define these below.

Experimental design. A design that provides the maximum amount of information about a problem at minimum cost. It is the spatial and temporal arrangement of factors (such as pest abundance, crop variety, and distance from roosting sites; a factor really is the independent variable which is composed of 2 or more treatments {also levels}).

Experimental unit. A unit to which a single treatment is applied.

Experimental error. Describes the failure of identically treated experimental units to yield identical results.

Treatment. A particular set of experimental conditions that will be imposed on an experimental unit.

Control. An experimental unit to which no treatment is applied.

Independent variable. The variables used to explain results of the experiment.

Dependent variable. The response variable (the variable that we measure).

Local controls. Refers to the amount of balancing, blocking, and grouping of the experimental units that is employed in the statistical design. The purpose is to make the experiment more efficient.

Randomization. The process of randomly assigning treatments and controls to experimental units. Randomization is used to avoid inherent confounding effects.

Replication. The use of several experimental units (e.g. plots) to which we apply treatments or controls. We need to use adequate sample sizes so differences (if present) between treatments and controls can be detected. Replication is used to provide an estimate of experimental error. We should not confuse replication with repeated measures on the same experimental unit.

Sampling. The spatial and temporal arrangement of sampled units (e.g. days in a year).

Confounding. A mixing together of effects. We need to avoid differences between treatment and control sites (i.e. inherent confounding effects) except for the treatment which is applied to the treatment site.

Inferences. Inferences or conclusions from the data only can be extended to the animals, area, etc. that was sampled in the research.

To further clarify the meaning of the above components, I review an experiment (Andelt et al. 1992) that we conducted to evaluate the effectiveness of various repellents for reducing consumption by elk. We placed each of 10 captive-reared cow elk in individual isolation pens at the Colorado Division of Wildlife's Foothills Research Facility in Fort Collins, Colorado. We sprayed alfalfa cubes with 7 different repellents and water such that a given quantity of alfalfa cubes had only 1 repellent or water on it. We allowed the cubes to dry for 24 hours. We placed 1,000 grams of alfalfa cubes treated with 1 repellent in several plastic buckets. We placed 8 plastic buckets that each contained alfalfa cubes treated with a separate repellent or water in each of the 10 isolation pens. The location of buckets was chosen at random in each pen each day. We measured the amount of alfalfa cubes that remained in the buckets 24 hours later. We repeated the experiment for 5 days.

In the above experiment, the experimental unit was a cow elk. Experimental error was the differences among elk in their consumption of a specific repellent treatment. The primary treatment was the type of repellent or water that was placed on the alfalfa cubes. Our control was alfalfa cubes treated with water. The independent variables were treatment, elk, and day. The dependent variable was the amount of cubes with each repellent treatment that was eaten each day. Our local control was the use of only female (cow) elk in the experiment. We randomized the location of buckets in each pen each day. We had replication in the experiment by using 10 different elk. The factors that were replicated were cow elk. We did not use sampling in this experiment other than using all 10 elk that were available and consumed alfalfa cubes during a pretreatment period. We did not have confounding effects in the experiment, but could have confounded the experiment by placing buckets containing a given repellent at greater heights than buckets containing the other treatments in the pens. Our results and conclusions can be applied to captive cow elk that are in pens under conditions similar to ours; our scope of inference should not be applied to bull elk or elk in the wild, because they may have different responses to the various repellents. Our null hypothesis was the amount of alfalfa cubes that were consumed did not vary by the type of repellent that was applied to them. Ultimately, we desire to ascertain if 1 repellent deters elk more than another repellent and if each repellent is more effective than the use of plain water.

APPROACHES USED FOR TEACHING EXPERIMENTAL DESIGN IN FW565: MANAGING HUMAN-WILDLIFE CONFLICTS

One-hour lecture. I provide a 1-hour lecture on the basics of experimental design that includes definition and discussion of the above components. We also discuss various experimental designs including systematic, completely random, randomized complete block, incomplete block, and Latin square. After the lecture, I provide a summary of our experiment that evaluated the effectiveness of repellents for deterring consumption of alfalfa cubes by cow elk (Andelt et al. 1992). After the summary, I request students to identify the major components of the experimental design.

One page manuscript on designing an experiment. The students then independently write a 1-page manuscript on designing an experiment that evaluates the effectiveness of 1 of 2 wildlife damage management techniques. The students are assigned to 2 similar sized groups. Students in the first group work independently to design a research project that evaluates the effectiveness of nylon lines for deterring pigeons *(Columba livia)* from landing on ledges. Students in the second group also independently design a research project that evaluates the effectiveness of 2 sonic devices for deterring elk from browsing on apples. A caveat is that both experiments should be designed so that our class could evaluate the devices in a 4-hour lab and later obtain results from statistically analyzing the data. Below is additional information on both research areas that should be incorporated in the student's design.

Pigeons and nylon lines: Pigeons land on about 5-m-long ledges at the

Colorado State University Hughes football stadium. The pigeons crawl through small openings behind the ledges and roost and rear young under the bleachers. Pigeons are currently using 3 of the ledges. Defecation from the pigeons usually is removed before football games. The objective is to design a class project to evaluate the effectiveness of 1 and 3 nylon lines stretched across the flight paths of pigeons to deter them from landing on the ledges.

Elk and sonic devices: The Colorado Division of Wildlife maintains at least 12 elk at the Foothills Wildlife Research Facility that is in northwest Fort Collins. Students are asked to envision that the elk are maintained in a 5-ha holding pen and 1 or more elk can be moved into three 0.5-ha test pens. The 0.5-ha test pens are far enough apart and far enough from the holding pen that elk cannot hear treatments placed in other pens. The students are asked to design a research project to evaluate the effectiveness of 2 types of sonic devices (one that is ultrasonic [above 20,000 cycles and inaudible to humans] and the other is audible to humans [around 10,000 cycles]) for deterring elk from feeding on apples placed in the test pens. The sonic devices contain motion detectors that detect when elk are nearby and then activate the devices.

We visit the 2 research sites where I lead a discussion asking students how they designed various aspects of their experiments. The students are asked to comment and critique each others designs.

Data analyses. Students also participate in a 2-hour computer lab where they statistically analyze data, collected in a previous lab, on the effectiveness of nylon lines for deterring pigeons from landing on ledges. The data, a SAS program for analyzing the data, and a detailed explanation of all the code in the program are provided to the students. The students are given directions on how to perform the statistical analyses. After the analyses are conducted, we review output from the analyses in class. Then, the students are given a take-home quiz where they compare results of the lab analyses to the results of a similar but larger experiment (Andelt and Burnham 1993) that colleagues and I conducted previously. The quiz also contains data from a deer (*Cervus hemionus*) repellent trial which students are instructed to place in the SAS program, modify the program, and then answer various questions about the analyses.

Manuscript and oral presentation. Students are also requested to write a 3-page manuscript and give a 6- to 8-minute presentation on designing an experiment that evaluates a new and unique method for reducing conflicts with wildlife in Colorado. The manuscript should include the scope of the problem, past research on solutions to the problem, the technique that the student proposes to test, past research on the proposed technique, its success and who did the research, why the technique might be successful, hypothesis, independent variable(s), treatments, dependent variable(s) and what specifically will be measured, type and number of replications, efforts to minimize confounding effects, methods for conducting the study, and proposed statistical analyses. Literature cited should consist primarily of manuscripts that have been published in peer review journals. The oral presentation is 6 minutes long with 2 additional minutes for questions and answers. The students are requested to use Microsoft PowerPoint to emphasize their major points.

My midterm and final exams also encompass experimental design. Although we emphasize quantitative skills in our undergraduate program, a fair amount of repetition appears to be necessary for students to grasp experimental design.

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