INQUIRY &
INVESTIGATION

A Case-Study Approach to Teaching Population Management & Conservation

JOEL CARLIN

Abstract

Conservation employers have long valued the in-depth, highly technical training provided by graduate and undergraduate environmental science curricula. However, employers also highly value communication and critical-thinking skills beyond research science, especially the ability to make management decisions within sociopolitical, financial, and ecological contexts. I developed and implemented a budgeted management plan assignment in lower- and upper-level courses in biology and environmental studies programs at an undergraduate liberal arts college. Students must develop specific, assessable conservation objectives to manage a population within a budget that limits available money, time, and sociopolitical will. Students must conduct extensive scientific literature reviews, then decide which of 89 actions will be most cost-effective. Instructors and students responded positively to the assignment, particularly noting difficulty, realism, and interdisciplinarity as defining features, especially in comparison to more traditional field lab reports. The resulting writing assignment involves little class time and instructor supervision, can be customized for both advanced undergraduate and secondary education curricula, and involves high critical-thinking skills in all four cognitive dimensions of learning as described by Anderson and Krathwohl (2001).

Key Words: *Interdisciplinary; environmental; conservation; management plan; budgeting.*

○ Introduction

Improving undergraduate environmental education is a long-standing and current concern, as evidenced by recent publications that address perceived gaps between employers seeking new natural resource biologists and those who educate them. Typically, graduate schools supply students with both specialized information and rigorous training in critical thinking around highly focused scientific issues. Graduate education's reliance on technical knowledge is vital for initial employment, but Edge (2016) suggests that much of the learning is made obsolete or irrelevant by changes in both our scientific knowledge and a person's lifetime career changes. In addition to technical knowledge, then, European and North American employers greatly desire graduates who can apply scientific information within the contexts of social science, policy, and administration – and employers rate graduate schools as poorly to moderately proficient at preparing future employees in these skills (Pita et al., 2015; McMullin et al., 2016). Mastering technical science within appropriate social contexts takes practice, and thus the most desired traits in new employees are critical thinking and effective written and oral communication, which also are perceived as skills most predictive of professional success (Kranz et al., 2004; Kroli, 2007; Bullard, 2015; Pita et al., 2015; Essig, 2016; McMullin et al., 2016; Terre, 2016).

The solutions to this disparity are easy to imagine but difficult to achieve. One practice suggested by employers is, unsurprisingly, actual work experience via internships or applied undergraduate research (Edge, 2016; McMullin et al., 2016), but this does little to effect positive change in the undergraduate classroom. The next-most-desired solution is revision of undergraduate curricula to include more case studies that better reflect the practical and interdisciplinary concerns of natural resource management (Pita et al., 2015; McMullin et al., 2016). For example, students need practice creating multiple, competing alternatives from different stakeholder objectives and then resolving them into a single plan created within financial constraints (Colvin & Peterson, 2016). Edge (2016) echoes these concerns and emphasizes the increasing importance of social diversity and a global perspective. Gaining practice with interdisciplinary conservation management is especially important in providing confidence for environmental leadership, where early exposure to concerns outside ecology is both formative and necessary for the student's future success (Terre, 2016). Curricula that feature interdisciplinary decision making for a conservation case study are uncommon but impressive in their scope. For instance, a Texas A&M course had teams of students work with private landowners and agencies to create management plans useful to tax valuation (Lopez et al., 2006). In another approach, Lynch (1994) describes a week-long practicum for indigenous high school students in which they create a management plan for the hosting tribe. However, given the budgetary and time constraints already faced by wildlife and

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fisheries education programs (Kroli, 2007; Edge, 2016), the creation of internships, special partnerships, and dedicated seminars are likely impractical for most educational institutions. A potential, more easily implemented solution is to reduce reliance on traditional lab reports through intensive writing assignments that provide depth of learning, realism, and interdisciplinarity within existing undergraduate ecology courses.

I sought to address employers' concerns without seriously impacting existing course resources. Therefore, I developed a case-study approach to technical writing that requires interdisciplinary, realistic decision making and implemented it within three courses (Table 1) at a small, private, undergraduate liberal arts college in rural Minnesota. All three courses require at least one semester of biology or geochemistry and typically feature a large majority of students identifying an interest in environmental careers.

Here, I present an alternative to the traditional lab report assignment: a budgeted management plan (BMP) project. Overall, the project asks students to research, create, write, and (in some classes) orally present an original management plan. The plan must meet a well-defined set of 10-year goals for a single population, and the goals should be attained while staying within budget. Compared to a traditional lab report, the BMP project provides greater rigor in critical thinking (Anderson & Krathwohl, 2001), greater realism, and the transferable skills desired by employers.

○ Project Description

The BMP project is a series of short assignments (Figure 1), culminating in a larger, peer-reviewed writing assignment. Depending on the instructor and course, students either could choose their own population and goal or choose from a list of deceptively short goals supplied by the instructor (Table 2). The final written paper consists of a persuasive argument, a literature review of the organism and the target geographic area, a main goal, several short- and long-term deliverable objectives, a plan of work with a budget, and an assessment plan.

In order to identify meaningful management goals within a budget, the student completes a series of worksheets on which they compile information on the species, including its demography, life history, and habitat (Figure 1). Additional worksheets require the student to describe potential stakeholders, economic activity, and regional governance. A list of 86 conservation and management options is provided (for examples, see Table 3). The options are presented as a restaurant-style menu, complete with prices. Each management option's price involves up to three kinds of cost: money, time, and political points. The latter is a novel unit that tries to represent the sociopolitical support required to accomplish

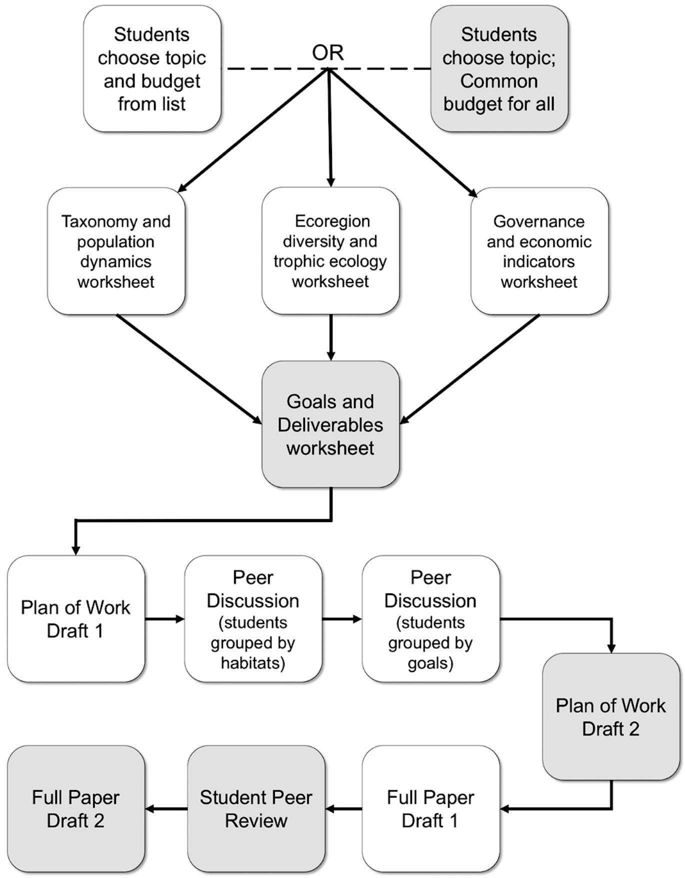

Figure 1. Work flow for the budgeted management plan project, showing ungraded steps (open boxes) and graded steps (shaded boxes). The project begins with a prepared list of management goals (see Table 2) and ends with a management plan that includes both a primary literature review and a budgeted plan of work. One instructor used a common budget for all students but then conducted one-on-one interviews regarding topic choice to ensure student understanding of resource limitations and options.

Table 1. Classroom settings and student populations that tested the budgeted management plan project at Gustavus Adolphus College. The project should be applicable to other undergraduate and secondary education courses that expect students to critically apply ecological principles and their social implications.

Course	BIO205 Case Studies in Marine Conservation	BIO245 Conservation Biology	BIO383 Aquatic Biology
Prerequisites	1 semester of biology	1 semester of biology or geochemistry	3–4 semesters of biology, 1–2 semesters of chemistry
Duration	32h lecture, 0h lab	41 h lecture, 33 h lab	41 h lecture, 33 h lab
Biomes	Marine	Mostly terrestrial	Freshwater

Table 2. Examples of pre-assigned budgeted management plan projects assigned in an upper-level undergraduate limnology course (the full list is available from the author).

Target Population & Management Goal[a]	Budget[b]		
Bluegill (*Lepomis macrochirus*), Lake Biwa, Japan; drive to extinction	8T	6P	7$
Brown trout (*Salmo trutta*), New Zealand; expand revenue for Maoris	6T	6P	7$
Colorado pikeminnow (*Ptychocheilus lucius*), Glen Canyon NRA, Utah, and Arizona; increase abundance	7T	7P	10$
European eel (*Anguilla anguilla*) (O), Andalusia, Spain; increase population size	7T	8P	11$
Common carp (*Cyprinus carpio*) (leather strain) (O), Champagne-Ardenne region, France; sustainably expand trophy fishery	6T	7P	10$
Philippine duck (*Anas luzonica*), Mindanao, Philippines; increase population size	7T	5P	9$
Walleye (*Sander vitreus*), Lake Oahe, Cheyenne River Reservation, South Dakota; increase fishing tourism	9T	7P	7$
Weed shiner (*Notropis texanus*), between Iowa City and Davenport Iowa; increase population size	8T	5P	8$

[a]O = ostentation penalty, indicating those species whose economic value is inflated due to cultural values, which makes some management procedures more costly; in these cases, an additional one unit of T, $, and P has been added to the cost shown.
[b]Budgetary abbreviations: T = units of time; P = units of political support; $ = units of money.

Table 3. Twenty example options provided to students in a budgeted management plan project. The full list, which includes 86 options organized among six categories (scientific research, regulation, policy enforcement, socioeconomic change, income generation, and intensive manipulation) is available from the author.

Management Option[a]	Cost[b]
Abundance/migration estimates by mark and recapture, using inexpensive plastic tags	3T 1$
Abundance/migration estimates by mark and recapture, using radiotags or satellite tags	1T 3$
Analysis of legal harvest data for population modeling	1T 1$
Breeding sterile stock (e.g., triploids); protocols are previously known	2T 1$
Bulk removal of invasive plant species by mechanical means	2T 3$
Chemical and genetic analysis of wildlife products to detect illegal harvest/trade	1T 2$
Closure of resource to foreigners/“outsiders” (O)	1T 5P 2$
Country-of-origin labeling for imported wildlife or agricultural products (O)	1T 2P 2$
Corporate sponsorship (O)	Creates 2$, Costs 1P
Create one moderately sized or two small no-take reserves (O)	2T 4P 3$
Different harvest limits for personal vs. commercial, or indigenous vs. non-indigenous, harvest (O)	1T 2P 1$
Economic analysis of harvest (can get estimates with or without management scheme) (O)	1T 1P 2$
Ecotourism (fishing, scuba, sailing)	Creates 2$ 2P
Education of harvesters (foresters, fishers, hunters) (O)	2T 1P 2$
Export/import restrictions on wildlife products (O)	2T 2P 2$
Fines and restrictions on urban development	4T 5P 5$
Fishing/hunting tournaments	Creates 2$
Habitat improvement, single local event (e.g., one controlled burn with volunteer labor)	1T 1P 1$
Purchase of land; no mineral/development interest (O)	2T 2P 4$
Total moratorium on harvest of previously commercial species (O)	4T 9P 5$

[a]O = ostentation penalty, indicating those species whose economic value is inflated due to cultural values, which makes some management procedures more costly; in these cases, an additional one unit of T, $, and P has been added to the cost shown.
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a task. For example, administering pesticides is inexpensive in time and money, but costly in political points due to both liability concerns and the potential for the public to misunderstand (and oppose) the pesticides. An additional novel feature of the BMP project's goals and restaurant menu is an ostentation penalty for some conservation targets. Students are unsurprised that there are additional sociopolitical conservation challenges for some species and that an ostentation penalty is attached to charismatic megafauna and flagship species (e.g., rhinoceros and elephants; Lawson & Vines, 2014). However, the ostentation penalty also applies to non-charismatic species such as Gaboon ebony (Jianbang et al., 2016) or high-value coral reef fishes (Sadovy et al., 2003). These species' commercial demand is driven by high symbolic social value even in the face of increasing rarity and price ("anthropogenic Allee effect"; Courchamp et al., 2006). For a rare wood in high demand, then, students must pay more political points to limit harvest. However, students can generate additional money for their BMP project by seeking corporate sponsorships and celebrity-led fund-raising, options not open to those working with less famous organisms. In total, the goals, options, and budget are all unique approaches for undergraduates and thus require the instructor to implement careful time management.

An investment of class time for the BMP project, though relatively light, is necessitated by its attempt at realism. The list of management options and their costs is daunting and unfamiliar, so students are sorted by the instructor into small teams grouped by common goals or habitats. For instance, students in one team may be seeking to control invasive species, while those in another team may have a variety of goals but all be working in tropical developing nations. Students are informed that the teams are models for professional collaborations, in which revising goals, comparing procedures, and sharing scientific literature are essential parts of effective management. A concise plan of work with a budget is graded, followed by a first draft of their paper written for their peers to review (using a checklist provided by the instructor). In total, the instructor grades four assignments: worksheets (checked for completeness rather than technical accuracy), a one-page plan of work, the review of a peer's first draft, and the post-peer-review final draft (Figure 1). After grading the Goals and Deliverables worksheet, one instructor required an additional one-on-one interview with each student to discuss their plan of work, resulting in clear writing earlier in the process, but at a cost of time. The other instructor did not require individual consultations, but nearly a third of the class, both high- and low-performing students, sought help anyway. The only formal in-class time investment was for team discussion, which occurred in the last one or two laboratory sessions of the semester, when December weather in Minnesota makes fieldwork difficult. The marine conservation case-study course (Table 1) added a 15-minute presentation, asking students to convince ecologically literate policy managers (as played by the instructor and fellow students) to approve their proposal. This option was too time-intensive for the other two courses but serves as an example of the assignment's versatility and could be utilized in wildlife biology, population biology, fisheries, aquaculture, verterbrate zoology, and other undergraduate courses.

Additionally, the BMP assignment can be adapted to fulfill learning goals in secondary education. For example, the BMP project is highly relevant to 2019 state science standards in Minnesota. The project's concepts and their integration involve almost all the Minnesota Department of Education's Science and Engineering Practices, and its content addresses 9 of 25 life science benchmarks for grades 9–12 (Minnesota Department of Education, 2018), which are adapted from the recommendations of the National Research Council (2012). For a successful adaptation, instructors could provide only four to eight choices of project with prepared background information. The choices might range in geographic diversity (i.e., teaching about global biomes) or provide greater classroom relevance by featuring local invasive or endangered species. Similarly, the large menu of management options (Table 3) could be reduced to reflect only relevant content, emphasizing the management implications of food webs, basic population models, and biogeochemical cycles. Even in a reduced form, the assignment could enable a variety of student learning objectives in ecology, population biology, and their application to solve complex real-world problems.

The BMP project's goals of realism, interdisciplinarity, and depth of learning were assessed by anonymous semester-end surveys. When a student took more than one class with a BMP project, only responses from their first survey were considered. Students were provided an alphabetized list of 16 approaches to managing natural resources, asked to identify up to four choices that were the most effective, and then asked to identify the least effective. Finally, students were asked to write a few sentences to specifically evaluate the BMP project. Assignment prompts, written student responses, and instructor interview responses were classified by comparison with the transferable skills desired by employers (briefly reviewed above). Depth of learning was approximated by further comparisons with Bloom's taxonomy of learning, as revised by Anderson and Krathwohl (2001).

○ Discussion

The BMP project demands high levels of critical thinking, providing the class with an engaging, interdisciplinary capstone that emphasizes feasibility. The assignment necessitates synthesizing information from chapters found in deceptively distinct textbook locations. The exhaustive literature searches involve not only primary literature in ecology but also social science publications. Unifying and creating a plan from such sources involves a variety of critical-thinking skills, all done with considerable depth. For example, in Anderson and Krathwohl's (2001) revision of Bloom's taxonomy of learning, the project requires a student to manipulate information at the second-most advanced skill level (at the very least) across all four cognitive dimensions. Students must classify social and ecological information to diagnose a problem ("factual application"; Anderson & Krathwohl, 2001), create a plan of work ("conceptual creation"), differentiate and choose among procedures ("procedural evaluation"), and combine all of these to construct a synthetic argument ("metacognitive application"). It is not surprising, therefore, that students describe the BMP project as difficult, useful, and a realistic synthesis of the entire course.

The requirement of naming deliverable goals and the unfamiliar management options create an unusually high level of student engagement – unlike with other assignments, both high-performing students and those with moderate to poor performance came to instructors for advice. In one case, an undergraduate student contacted the agency manager for her target population, resulting in two weeks of e-mail and telephone exchanges that culminated in her designing an alternative fish passage device specific to an actual dam. Thus, the greatest strength of the BMP project appears to lie in its application of knowledge from disparate chapters and disciplines as a cohesive whole, and both instructors feel justified in adding this assignment to existing curricula.

Overall, students responded positively to the project (76% postive, 14% negative), primarily because of its realism (32% of the 59 written responses). Many students in all classes indicated that the BMP project is difficult (32% of responses), mostly due to the ambiguity involved. For example, students must grapple with the realization that fecundity estimates may simply not exist for their species, or that there is no perfect type of fish passage around major dams. Ambiguity is present in the management options as well, where costs can differ between undefined categories such as small versus large habitats. The lack of scientific data was possibly the most surprising to the students, perhaps due to a history of exposure only to well-outlined textbook examples. Those students who cannot find illegal harvest rates must create their best estimate based on known numbers in related ecosystems and species, and then admit this lack of precision in their management plan. Instructors warned their classes that frustration with these difficulties is both natural and yet counterproductive – students, like actual managers, must use peer-reviewed literature to argue decisions that are in the best interests of the wild populations and their human stakeholders.

In addition to information gaps, students realized that their most preferred options are often simply impossible to implement or enforce, or that increasing one population may affect another species of interest to different stakeholders. In such cases, students relied on worksheets containing information from outside biology (e.g., the worksheets in which they discover local industry, literacy, governance, and so on). Students had to grapple with seemingly insurmountable difficulties, such as extremely high prices for some illegal wildlife products, a complete lack of governmental enforcement, or no jurisdiction over half of their organism's life cycle. A lack of biological data required additional searches for comparative literature, but it was the interdisciplinary, sociopolitical issues that inspired the refining of goals into implementable, assessable objectives. The most common student evaluation comments described the assignment as interesting and useful (57% of respondents), as a synthesis of the entire course (38%), and as preferable to a lab report assignment (27%). A third of student comments suggested that the BMP project could serve as a capstone experience, an opinion shared by both instructors.

Although the BMP project is interdisciplinary and realistic, it is intended to augment, not replace, field-based experiential learning of practical conservation skills, which also is highly valued by employers and academia alike (Smith, 2004; Bullard, 2015; Pita et al., 2015; McMullin et al., 2016). Traditional pedagogy in these courses involved lectures steeped in theoretical ecology, complemented weekly by field-intensive laboratory sessions. To teach quantitative and scientific literacy, students traditionally convert their lab observations into a final report in the style of ecological primary literature. The conservation and limnology courses had required a more traditional ecological lab report with literature review. The lab reports have students engage with their own data, but overall, student observations often suffer from inaccuracy and a lack of replication. Such lab reports feature student-generated data that are often unreliable and without replicates, which certainly does not reflect best practices. Also, the lab reports are written in research journal format, a writing style taught by multiple upper-level biology courses. By contrast, the management plan's audience is biologically trained policy officials, requiring students to justify their choices clearly without an overreliance on jargon. This not only emulates a style of writing used in actual conservation management careers, but also means that student mastery of course material is easier to assess. Both instructors judged the clarity of writing, the degree of information literacy, and the judicious use of class content to be of much higher quality in the BMP paper than in the traditional lab report.

While considering this project an effective addition to their courses, instructors noted areas for improving and customizing it. Instructors used two alternate approaches to assigning BMP project goals. For the conservation biology class, students were allowed to choose their target population and location, invariably resulting in choices that were far too ambitious in scope but of presumably high personal interest to the student. Narrowing the focus is an essential step in scientific writing but requires some additional time investment. These students had a common budget (24 units, which the student could distribute among time, politics, and money). In the limnology and marine policy classes, some ambiguity was removed by providing a list of specific case studies, each with a custom budgetary limit (Table 2). The latter approach accelerated the writing process but restricted student choice and, conceivably, could impact student motivation.

The list of management options and budget was designed to help engage students in decision making. Budgeting in a case study is prominently mentioned by natural resource employers as a major issue that is poorly taught by higher education (Kroli, 2007; Edge, 2016). However, the prices for various options used in the BMP project are admittedly quite unrealistic. In the interest of simplicity, prices are in whole units and are relative to similar options within a single category. Thus, commissioning a static life table costs two units of time less than the cohort life table, which is consistent with students' classroom learning about how these tools are constructed. Yet the cohort life table is nearly the same price as creating an education program for foresters, fishers, and hunters – an admittedly highly unrealistic comparison. In addition, the political points and ostentation penalties are at once novel and realistic but are perhaps the most arbitrary features of this assignment. Therefore, I invite guidance from natural resource social scientists in revising how these issues could be better budgeted. These shortcomings should be adjusted by individual instructors, but the main point – that students must have and stay within a budget – remains a valuable lesson that needs to be better addressed in natural resource curricula.

The BMP project is one approach to teaching a personalized case study with a budget. Service-learning partnerships (e.g., Lopez et al., 2006) are valuable and realistic learning opportunities but are not always possible. The BMP project involves no extra budget and little increased time investment in relation to the high gains in student critical thinking. Successful completion of the project necessitates applying biological issues within the constraints of the social norms and political realities of the target area. Students must also justify their management decisions within financial limitations, as well as budget for the costs of sociopolitical will and the added costs for ostentatious species. Although a literature-based case study is hypothetical in nature, a project written for a policy audience that requires decision making within a budget is both an easily approached and a highly impactful capstone writing experience for undergraduate natural resource courses.

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JOEL CARLIN is formerly Associate Professor of Biology and Environmental Studies at Gustavus Adolphus College, 800 W. College Ave., Saint Peter, MN 56082. He is currently a Science Teacher at American Pacific International School, Banpong, Chiang Mai, 50230 Thailand; e-mail: joel.carlin@apis.ac.th.