**Preliminary Exam Questions: Dr. Dinsmore**

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1. **One general perception in our profession is the notion that research without management implications (e.g., theoretical ecology) is of diminished value. I would like you to contrast theoretical and applied ecology, citing specific examples of each from your own areas of research. Should our profession continue to emphasize applied ecological questions, or is some other approach more worthwhile? Your response should demonstrate the breadth of your knowledge in these areas. [~5 Pages]**

In ecological scientific research, natural resource management, sustainability, and climate change, applied ecological research is quite useful for making use of observational data and predicting outcomes of management action, but broader theoretical ecology plays a significant role in generating applied management hypotheses. Together, applied ecology and theoretical ecology can provide ubiquitous and robust explanations of natural phenomena. Fields such as fish and wildlife management, forestry, and agronomy use applied ecology to quantify effects of management actions and define how the structure and function of certain ecosystems operate. Theoretical ecology includes behavioral ecology, evolutionary biology, and many other interdisciplinary fields that rely on the conceptual realm of data analysis where existing theories are tested, and novel theories are explored. There are costs and benefits associated with both approaches to ecology, and both contribute to the foundations of human knowledge in different ways.

Theoretical ecology is a function of the inherent quest for knowledge about ecological phenomena, and many fields of research contribute to a vast base of knowledge and information. Hypotheses in theoretical ecology rely on parsimony and simplification, often with broad, relaxed assumptions to encompass more taxa, more environments, or more time. Modeling simulations are cheap experiments, and computer power is continually growing. We’re entering the age of “Big Data” and I believe that Bayesian statistics will develop innovative ways to predict unobservable environmental variables. The widespread applicability of population ecology study design among animals and plants (e.g., occupancy modeling) is a great example of how theoretical ecology can contribute to the portfolio of knowledge about a certain taxa or ecosystem. Integrated population models (IPMs) are becoming an essential component of ecology, and I plan to use IPMs to explore the connections between common carp and bigmouth buffalo responses to harvest (i.e., mechanisms that may compensate for harvest mortality, and what covariates affect those mechanisms).

Defining the boundaries of an ecosystem is a critical part of experimental design. Ecosystems are nested units, too broad of an analysis can miss fine-scale variation while a narrow study with many replicates may detect a “significant” result while missing larger environmental covariates like climate are not accounted for. Theoretical ecology tends toward simplifications of the larger world, perhaps dredging parameters to use in model simulation. While meta-analyses are valuable and informative, these wide-scope studies may be biased from subjective searching and the “file-drawer” problem of data being left unpublished due to discouraging results. The boundaries of ecosystem closure in space and time often come with significant assumptions that should be accounted for in analysis and are subjective. Challenging existing components of theoretical ecology through a failure to reject a null hypothesis is difficult. However, it is for exactly this reason that novel approaches to explain natural phenomena are developed.

Applied ecology is usually specific to a problem or need regarding management of the natural world. Research in applied ecology has local impacts and often attempts to quantify effects of management actions, and data collection can be limited to narrow boundaries. However, the application of robust study design toward a specific question can yield fundamental information toward managing a resource. Indices of biodiversity, length-weight relationships in fish, and most direct measurements of organisms in the field are examples of data that can appropriately answer several specific ecological questions. In addition, applied ecology is particularly suited for adaptive management framework because of the small scale and modular nature of applied research; the same data can answer a variety of ecological questions.

As stated before, the narrow scope of applied research can sometimes be a drawback. Once research leaves the realm of controlled experiments, constrictions on the quantity data collection in the field limit the number of covariates that can be accounted for. Not only are lakes, wetlands, and watersheds nested and transitional ecosystem, but the openness of environmental data leads to inherent variation and “noisy” data; however, practical and thoughtful study design with appropriate replication leads to unbiased estimators which improve knowledge of how management actions will impact environments. The restrictions and assumptions of closure in my research lakes have certainly been challenged during the study (e.g., severe flooding and escapement, recreational and subsistence harvest). Still, careful model selection and sensitivity analyses can compensate for broad variation caused from external factors.

While both theoretical and applied ecology are based on similar hypotheses, applied ecology focuses more on observation of the natural world whereas theoretical ecology relies more on mesocosms, models, and simulation to extrapolate trends through space and time. Environmental stochasticity is a drawback to both methods, but for opposite reasons. Theoretical approaches incorporate broad stochasticity and may neglect fine-scale variation, but applied approaches are adept and handling local variation at the expense of regional to global heterogeneity in the processes, functions, and interactions that drive ecosystem composition. Both approaches are subject to the “file drawer” problem, but again hurdles like those can force us to think about analyses in novel ways and build the base of knowledge around functional ecology.

Both approaches have drawbacks that lead to potential pitfalls of analysis. In particular, overfitting of models leads to spurious results that are a function of how well the data are described, not how natural processes are described. Both approaches are subject to selection bias and measurement error, and to a degree these can be controlled for. For example, the carp biomass density I estimated for Center Lake in 2018 was used to set a mandatory quota of carp harvest for the commercial fishing operation who won the contract for that lake. Unfortunately, even 95% confidence intervals have a failure rate and neither the commercial anglers nor our sampling could capture carp relative to the previous year’s estimates. Another drawback of both approaches is the over-use of certain techniques or theories. These are valuable in the context of reproducible research, however, if mis-applied to a hypothesis or data set inferences could be drawn from false conclusions.

Natural resource ecology and management, at local, state, and federal levels directly benefits from the emphasis on applied ecological research questions. The major component of theoretical ecology is general applicability of theory among disparate taxa and environments. But testing those theories often is executed using localized and applied approaches in natural resource management. Our profession often pushes the envelope of ecological theory, such as my exploration of mechanisms that may drive eutrophication in shallow lakes, and how carp and buffalo might affect those mechanisms. Using applied ecology in natural resource management will always be constrained by time, funding, and political whims, but fortunately incremental changes from short-term and local studies can have a vast cumulative effect on the substance of ecological knowledge.

Applied ecology, in natural resources, uses very robust approaches to answer complex questions about how the world works, what impacts humans have on the environment, and how to sustain natural resources in a world of growing consumption. The evolution of statistics and modeling continues, and the wealth of digitized data in the future that was collected in narrow, applied studies may very well inform the next major ecological breakthroughs. In essence, applied ecology has strength in adaptability and replication, and sometimes using short-term data to draw immediate conclusions are necessary to answer direct, immediate questions. Long-term research studies of ecosystems, (e.g., the National Science Foundation’s Long Term Ecological Research Network) can take limited studies from applied natural resource management as pilot studies for broader experiments that expand applied theory through time and space. The structure of research among natural resource agencies, academic institutions, and non-government organizations is diverse enough to cover both realms of applied and theoretical ecology, which are not mutually exclusive!