The Theory of Conservation Biology

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Depending upon one's perspective, the discipline of conservation biology suffers from either an excess or a critical lack of theory. Detractors of theory perceive ecological theory to have limited applicability to "real-world" management problems, whereas others despair that the lack of conservation theory may ultimately hinder the development of a coherent scientific framework and the guiding principles necessary for managing complex systems. The emphasis on theory in conservation research has been attributed to the urgency with which managers must often act before requisite data are available, which has contributed to the perception of conservation biology as a "crisis discipline" (Soulé 1985). The condition of rarity itself, the main trait shared by species of conservation concern, precludes well-replicated study (Doak & Mills 1994). Theory provides a solid foundation to guide management activities and to facilitate transfer of "state-of-art research into practical management tools" (Edwards 1989). Nevertheless, theoretical generalizations in conservation biology have been criticized as being too weak to be usefully predictive, models are viewed as being too simplistic and untestable, and many theoretical generalizations have reached the status of dogma, which stifles further theoretical development and testing (Doak & Mills 1994 and citations therein).

The perception of conservation biology as a theoretical discipline has been reinforced by wildlife biologists. A survey of literature in the publications of The Wildlife Society (*Journal of Wildlife Management and Wildlife Society Bulletin*) and *Conservation Biology* led Bunnell and Dupuis (1995) to conclude that "conservation biology is more theoretical while wildlife management is more empirical." Some 20% of papers published in *Conservation Biology* from 1990–1992 were categorized as theoretical in this survey (compared to only 2% and 10% for *Wildlife Society Bulletin* and *Journal of Wildlife Management*, respectively). This is consistent with a previous survey of literature published in the first five volumes of the journal in which 16% of papers focused on modeling and theory (Jensen & Krausman 1993).

If an emphasis on theory is the trademark of conservation biology that distinguishes it from other applied ecological or resource management fields, it would be instructive to survey the literature published in the two major conservation journals, *Conservation Biology* and *Biological Conservation*, and assess the extent to which theory is utilized in conservation research. My review of the published literature reveals not only a dearth of theory used explicitly in conservation research, but also a lack of theoretical development explicitly for conservation management.

Methods

I surveyed research papers and notes, excluding editorials, essays, and commentaries, published in 1994–1996 of *Conservation Biology* (volumes 8–9 and volume 10, issues 1 and 2) and over a similar period for *Biological Conservation* (volumes 69–71). I skimmed the text of each paper and categorized as theoretical, methodological, and/or analytical and statistical the approaches employed in each paper. I also evaluated whether the paper was couched in some theoretical framework, and if so, classified the type of theory and whether the use of theory was *explicit* (data were collected to address a specific question or prediction of theory) or *implicit* (study was loosely based on some conceptual framework). For example, studies of genetic diversity among populations frequently assume metapopulation structure, but do not directly apply metapopulation theory; this represents an *implicit* use of theory. On the other hand, the evaluation of relative heterozygosity among populations or estimation of inbreeding depression within populations represents *explicit* use of theoretical population genetics.

Results and Discussion

Despite the general perception of conservation biology as a discipline with a strong theoretical focus, only 4% of papers published in *Conservation Biology* (n = 267)

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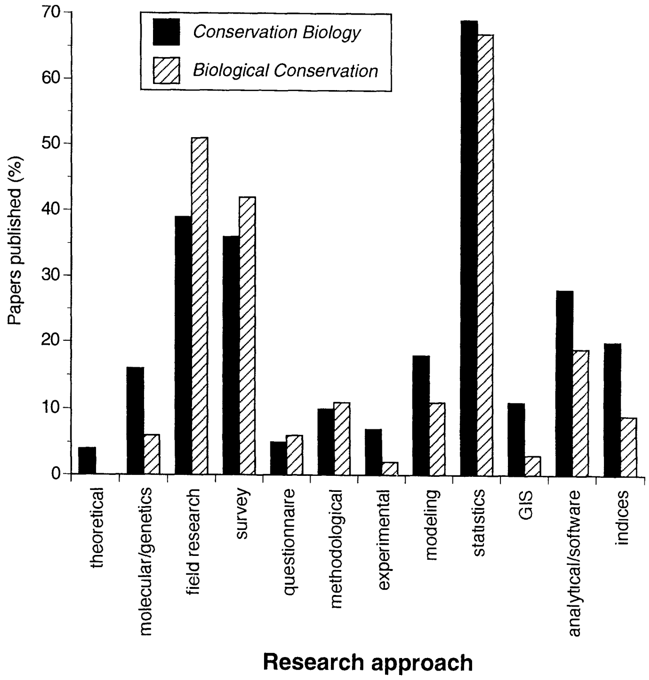

Figure 1. Research approaches in conservation biology as quantified by a literature survey of papers published in Conservation Biology *(n = 267) and* Biological Conservation *(n = 304) during 1994–1996. Categories do not tally to 100% for each journal because more than one approach may have been employed in individual papers.*

were actually directed at theoretical development; no papers in *Biological Conservation* (*n* = 304) were devoted to development of theory for management applications (Fig. 1). This is not to say that conservation research does not have a theoretical foundation. About 40% of papers in *Conservation Biology*, but only 29% of papers in *Biological Conservation*, were founded on ecological theory, with only 22% and 18% of papers from these two journals making explicit use of theory, respectively (Fig. 2). The majority of papers published in the leading conservation journals are thus not grounded in any apparent theoretical framework.

Why the discrepancy with other reports on the use of theory in conservation biology? Partly this is attributable to my restrictive classification of theoretical papers; only papers that were specifically directed at theoretical development (as opposed to applications of theory) were classified as having a theoretical focus. Otherwise, if one considers only those papers that made explicit use of ecological theory, the percentage of papers with a theoretical focus (18–22%) is comparable to that reported by other authors (16–20%: Jensen & Krausman 1993; Bunnell & Dupuis 1995). Nevertheless, these surveys are not directly comparable given the different criteria as to what constituted theory. Bunnell and Dupuis (1995) identified articles with a theoretical focus as those "presenting ideas or concepts without reproducible methods." While this is perhaps similar to my definition of *implicit* use of theory, it also implies that theoretical development does not constitute robust science. This is borne out by the authors' assertion that research published in the *Journal of Wildlife Management* shows greater rigor because of adherence to falsifiable hypotheses and because it places a greater emphasis on methodology than does conservation research. Again, this was determined by the presence or absence of a methods section in the papers surveyed (of which about a third of papers in *Conservation Biology* apparently lacked, compared to

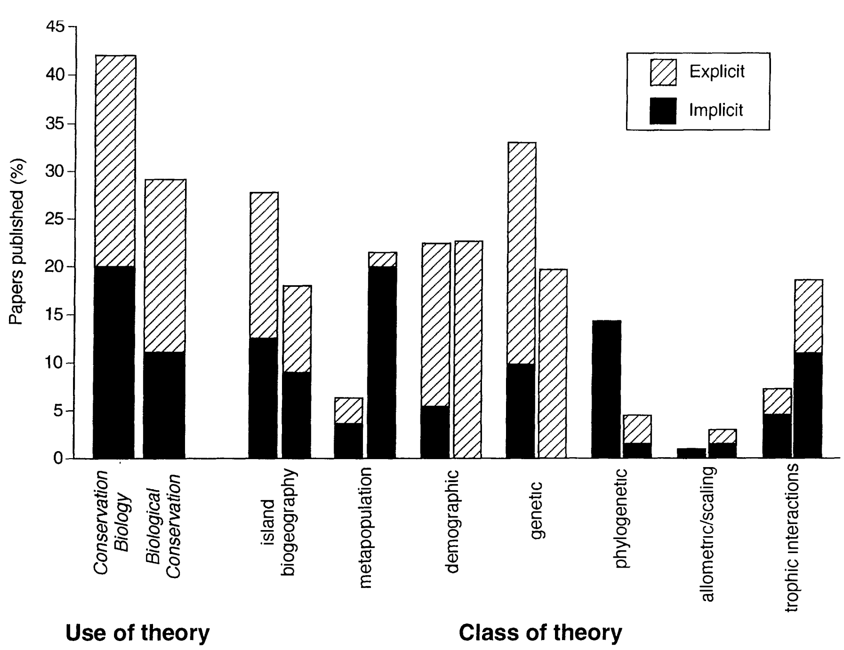

Figure 2. Percentage of papers published in Conservation Biology *(n = 267) and* Biological Conservation *(n = 304) during 1994–1996 that were grounded in ecological theory and the class of theory utilized (first bars in each comparison are* Conservation Biology*). Explicit use of theory involves actual testing of hypotheses, whereas implicit use of theory means that study was loosely couched in or made reference to ecological theory. Categories of theory do not sum to 100% for each journal because a paper may have utilized more than one class of theory.*

<10% for the publications of The Wildlife Society), which is perhaps not the most rigorous assessment of the relative importance of theory in these two disciplines. Jensen and Krausman (1993) lumped papers as "theory and modeling" rather than making a distinction between the two. While the distinction between theory and models is sometimes difficult to discern, given that much of ecological theory is expressed in the form of mathematical models, not all models are theories and not all theory involves mathematical models (e.g., the theory of natural selection is not based on an analytical framework).

Much of conservation theory is purported to center on island biogeographic theory, metapopulation theory and population viability analysis, and population genetics (Simberloff 1988; Doak & Mills 1994). This certainly accords with the results of my survey, in which 17–27% of articles focused on applications of the theory of island biogeography, nearly 25% were couched in either metapopulation or demographic theory, and 20–33% applied theoretical population genetics (Fig. 2). This represents only a minuscule portion of ecological theory, however. At the joint meeting of the Society of Conservation Biology and the Ecological Society America at Providence, Rhode Island in 1996, a symposium was hosted on the interface of theoretical ecology and conservation biology to explore innovative applications of ecological theory for conservation.

If much of conservation research is not grounded in theory, what are conservation biologists doing? Conservation biologists are clearly an empirical bunch, with 39–51% of studies published in the two journals involving field research or existing databases (36–42%, "survey"); papers in *Biological Conservation* tended to be more empirical (Fig. 1). Modeling was only a small component of published research (18% in *Conservation Biology*, 10% in *Biological Conservation*); the percentage of papers directed at modeling in *Biological Conservation* was enhanced by a special issue that was devoted to population viability analysis volume 73, issue 2). Nevertheless, papers detailing techniques ("methodological") comprised about 10% of papers published in the two journals and experimentation represented only 2–7% of conservation research (Fig. 1).

Are conservation biologists applying a rigorous hypothetico-deducto approach to research? Nearly 70% of all published papers in *Conservation Biology* and about 65% in *Biological Conservation* employed statistics (Fig. 1). Parametric statistics (*t* tests, ANOVA) were utilized in 36%/38% of papers (*Conservation Biology*/*Biological Conservation*), chi-square or loglikelihood analysis in 30%/33%, non-parametric statistics (Mann-Whitney, Kruskal-Wallis, Spearman rank correlation) in 21%/16%, regression analysis (linear, logistic, quadratic) in 21%/15%, and multivariate analyses (PCA, MANOVA, DFA) in only 8%/7% of conservation research. Of the 30% or so papers that did not apply statistical techniques, many of these involved simulation modeling, where statistical analysis is not required, or reported on the status or distribution of a particular species. Analytical approaches and the application of software packages (e.g., ALEX and VORTEX for population viability analysis; PAUP for phylogenetic analyses) to problem solving were evident in 20–30% of papers (Fig. 1). Descriptive indices were applied in nearly 20% of the papers in *Conservation Biology*, but in only half that many in *Biological Conservation*. Interestingly, the "high-tech" applications such as Geographical Information Systems and molecular/genetic techniques made up a fairly small proportion of research methodologies in conservation research (Fig. 1).

Research topics in conservation biology can be grouped into seven major arenas: (1) threats to biodiversity; (2) biodiversity and species status; (3) species ecology; (4) population modeling and analysis; (5) genetic and molecular approaches; (6) conservation management; and (7) risk assessment and policy (Table 1). The two journals differed in their major research focus. Nearly 40% of papers addressed threats to biodiversity in *Conservation Biology* (38.7%), whereas species ecology was the focus of 35.8% of the papers published in *Biological Conservation*. Other emphases in *Conservation Biology*, by order of importance, were species ecology (25.9%), biodiversity and species status (22.4%), and genetic and molecular approaches (21%). In contrast, threats to biodiversity (29.6%), biodiversity and species status (26.3%), and conservation management (23.3%) were featured in papers published in *Biological Conservation*.

The focus of both journals was thus centered on the first three major research topics, but they differed in the greater representation of genetic and molecular research in *Conservation Biology* and in increased attention given to conservation management in *Biological Conservation* (especially in terms of habitat restoration and reintroductions). Compared to a resource management field like wildlife biology, *Conservation Biology* was found to publish more papers on human influences, species status and distribution, and theory and fewer papers on species ecology and techniques than *JWM* (Bunnell & Dupuis 1995). This is in general agreement with the results of my survey, although both conservation journals publish a high percentage of papers focusing on species ecology (25–36%). Of the two, *Biological Conservation* was the most similar in content to *JWM*, with many papers devoted to basic species ecology, resource management, and biocontrol. Although there has been concern by wildlife biologists that conservation biologists are duplicating their efforts and that "what the [SCB] proposes to be, the profession of wildlife ecology has been for all its history" (Teer 1988), conservation biology has been seen to fill an "open niche" because the Society for Conservation Biology was born in response to the biological diversity crisis (Edwards 1989). *Biological*

Table 1. Topics of research papers and percentage of papers representing these topics published in the journals *Conservation Biology* (*n* = 267) and *Biological Conservation* (*n* = 304).

Research paper topics	Conservation Biology*	Biological Conservation*
Threats to biodiversity		
Habitat loss/degradation; land-use change; global change; disturbance (natural or anthropogenic)	13.5	14.8
Fragmentation effects; edge effects; corridors; landscape structure; heterogeneity	13.9	7.9
Effects of exotic introductions; hybridization	7.5	2.6
Effects of harvesting/hunting/poaching/extraction/trade/ecotourism	3.8	4.3
Biodiversity and species status		
Biodiversity; hotspots; species richness; indicator/umbrella species; biotic integrity	8.2	4.9
Density trends; distribution; species status; species monitoring; patterns of rarity	14.2	21.4
Species ecology		
Species interactions (competition, predator-prey, host-parasitoid, pollinator availability; herbivory); trophic cascades; guild interactions	7.1	6.6
Species ecology; sensitivity to disturbance; survivorship; mortality factors	9.4	17.4
Habitat use/association/selection; habitat suitability; area requirements	9.4	11.8
Population modeling and analysis		
Species persistence; population modeling; extinction risk; minimum viable population	5.2	2.3
Population viability analysis	4.1	3.6
Genetic and molecular approaches		
Taxonomic distinctiveness; phylogeny	4.9	1.6
Genetic diversity; variation	9.0	11.8
Effective population size	1.9	1.3
Inbreeding depression; rare alleles	5.2	1.3
Conservation management		
Reserve design; selection criteria; prioritization; land-use planning; land management; management conflicts	6.4	7.6
Gap analysis	1.9	0.3
Captive propagation	1.5	0.6
Ecological restoration; genetic restoration; reintroductions; regeneration; translocations	2.6	10.5
Success of conservation efforts; adequacy of reserves/recovery plans	6.7	4.3
Risk assessment and policy		
Risk assessment; recovery planning; decision making	1.9	0.3
Policy; public perceptions; economics; incentives; values; attitudes	2.6	0.7
Conservation; importance; factors to consider; measures; history; legal aspects	0	1.3

**Percentages do not sum to 100% within a particular journal because a given paper may have focused on more than one topic.*

Conservation is now more of an amalgamation of wildlife ecology and conservation biology.

Conclusions

What is conservation biology, in theory? Although conservation biology has been recognized as a formal discipline for 10 years (at least since the inception of the Society for Conservation Biology and the publication of *Conservation Biology*), I submit that it is still feeling the growing pains of an emerging discipline. Like many emerging disciplines, conservation biology is dominated by descriptive research: 60–80% of papers published over the past 2 years were not grounded in ecological theory. For example, the field of landscape ecology emerged about the same time as conservation biology and a review of the first five volumes of *Landscape Ecology* also revealed an emphasis on descriptive research or conceptually based theory (Wiens 1992). Does conservation biology qualify as a rigorous science then? Research in conservation biology is largely empirical and methodological. Experimental protocols are seldom used, and most theory is used in a heuristic rather than predictive fashion, but two-thirds of published papers at least employ statistical hypothesis testing or other quantitative analyses. The perception of conservation biology as a discipline with a strong theoretical focus thus may be overly optimistic at this point.

Unlike other emerging disciplines, conservation biology may not be able to afford the luxury of theory maturation because of its unique status as a crisis discipline (Loehle 1987). Fortunately, conservation biology inherited a wealth of existing theory from its parent disciplines such as community ecology and population biology (Simberloff 1988). Much of the theory underlying conservation biology was not developed for management applications, however. The debate over the utility of theory in conservation research has generally failed to acknowledge that the problem lies not with theory per se, but with the application of theory and the failure to understand or address the underlying assumptions that may constrain the use of theory in practice (Doak & Mills 1994). The development of theory specifically for conservation is a virtually nonexistent activity, at least within the pages of the leading conservation journals. "Theory is too important to leave to theoreticians" (Bunnell & Dupuis 1995), and yet papers devoted solely to theoretical development are generally published elsewhere, where they may be overlooked by practitioners (e.g., *American Naturalist*). The gap between theory and application must be bridged, and perhaps the pages of the leading conservation journals are a good place to start.

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