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RESEARCH ARTICLE

Conserving biodiversity takes a plan: How planners implement ecological information for biodiversity conservation

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Abstract Conserving biodiversity is critical to the sustainability of human settlements, and stands to benefit from collaboration between ecologists focused on understanding natural systems and planners balancing social, environmental, and economic priorities. Drawing from the socially-situated definition of 'sustainability', we sought to understand the relationship between ecologists and planners by probing how planners in the southeastern US prioritize and engage with biodiversity conservation and ecological information, and how context influences these decisions. We find that context matters, e.g., higher jurisdictional population density was positively associated with prioritizing tree cover and diversity. We find, also, that while biodiversity conservation and ecological information are valuable to planners, planners rely heavily on their colleagues to inform conservation-related activities and prioritize conservation topics that differ from ecological research foci. Improved communication by ecologists and context-specific transdisciplinary sustainability research, especially that which incorporates the primary role of elected officials in biodiversity conservation, may help to integrate ecological science and planning practice.

Keywords Conservation policy · Ecological guidelines · Land use planning · Socio-ecological systems · Sustainability

INTRODUCTION

Over the past three decades, researchers and policy-makers from around the world have articulated the imminent importance of conserving life-supporting ecosystem services without undermining the health and lifestyle benefits that accompany economic growth (World Commission on the Environment and Development 1987; Kidd 1992; Rees 1995; Daly 1996; McDonough and Braungart 2002; Robinson 2004; Jackson 2009; Orr 2011). At the core of such declarations is that levels of pollution and habitat destruction threaten to breach critical and sometimes irreversible limits, but that simply upending the economic processes at the root of global environmental damage would threaten the livelihoods and well-being of billions of humans. Rather, they explain, policy-makers must seek alternative *sustainable* pathways that reconcile these otherwise competing priorities.

In the intervening years, policy for sustainability or Sustainable Development has diffused from international declarations and scholarly observations to local comprehensive plans, demanding that planners and policy-makers strike a balance between competing environmental, economic, and social priorities (Campbell 1996; Saha and Paterson 2008; Portney 2013). Where, how, and by whom these different priorities *get reconciled* remain questions without extensive scrutiny, but with important theoretical implications nonetheless.

This paper applies a sustainability framework developed by Boyer et al. (2016) to scrutinize the specific work of planners in the southeastern United States, including the extent to which professionals responsible for a diverse palette of local issues—of which biodiversity conservation is only one—use the scientific prescriptions of ecologists. While a few planning specialists are tasked specifically with attending to biodiversity conservation, most planners work as generalists to balance multiple priorities in jurisdictions with unique histories and political considerations. It is therefore worth understanding how planners interact

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with the domain of ecology by means of published research findings, if at all. A clearer understanding of this interaction can help ecologists design research processes that are accessible and useful to professional planners.

Boyer et al. (2016) outlined five different approaches used to integrate the 'social' pillar of sustainability, illustrating through a review of scholarly literature that the social pillar has been framed in five different ways: (1) as a cache of policy actions that stand alone without necessarily interacting or in any way competing with environmental or economic priorities; (2) as a constraint upon economic and environmental priorities; (3) as a precondition for thriving economic and environmental systems; (4) as a stimulant of environmental and economic change; and finally, (5) as a fully-integrated, locally-rooted, process-oriented approach to sustainability. In this fifth framing of social sustainability, the theoretically distinct 'pillars' of sustainability dissolve, and the authors describe sustainability as an interpersonal social process that uses "… innovative governance approaches to bring together multiple perspectives, and to encourage local ownership of ideas and processes" (Boyer et al. 2016).

It is critical that public policy responds to the particular perspectives of local constituents amidst escalating tensions around resource decisions and an exaggerated—but politically consequential—discourse that a global scientific agenda has hijacked local planning decisions (Hurley and Walker 2004; Frick et al. 2015). It is understandable, for example, that a community in *region A* might be skeptical of the results of biodiversity research conducted in *region B*, particularly if the prescriptions of such research challenge other local priorities (e.g., economic growth) (McNie 2007).

We are thus motivated by the following questions. Firstly, to the extent that planners value biodiversity conservation as individuals, what local conditions and local actors influence whether jurisdictions *act* to conserve local biodiversity? By local conditions, we mean both support from colleagues and elected officials as well as contextual variables that might condition the extent to which remaining biodiverse landscapes are experiencing development pressure. Secondly, if urban planners are implementing policy that aspires to conserve biodiversity, what types of tools, techniques, and/or policies are they using, and what information resources are guiding these efforts? In other words, is planners' understanding of 'what counts' as conserving biodiversity the same as ecologists' understanding? Finally, armed with an understanding of whether and how planners are acting on ecological information, we ask how ecologists can best frame their research processes and research findings so that they are useful to local planners. In this paper, we use the term 'ecological information' to refer to information produced by professional ecologists and published in academic journals.

In the following subsection we elaborate on the intersection of ecological information for biodiversity conservation and local land use planning. Then, drawing from a survey administered to over 200 planners in the southeastern United States, we probe the extent to which local planners value biodiversity conservation and what actions their jurisdictions are taking to conserve biodiversity, including their use of ecological information. We also investigate how contextual variables, such as jurisdiction population density, interact with the importance planners place on biodiversity conservation and the actions they undertake in its regard in order to better understand how the planning process, and in particular planners' use of ecological information, is influenced by local conditions that are likely to dictate planning priorities. Understanding whether and the extent to which the production of ecological knowledge for biodiversity conservation and planning practice align can help practitioners from both communities facilitate land use decisions that better integrate the specific prescriptions of ecologists into the complex and sometimes politically charged needs that planning professionals wrestle with in their workplaces.

Ecological information for biodiversity conservation and local land use planning

Since 1970, vertebrate populations across the globe have declined by an average of 58% (WWF 2016). Invertebrate populations may have fared even worse, as evidenced by a 76% decline in total insect biomass since 1989 in protected areas in Germany (Hallmann et al. 2017). These losses are commensurate with high proportions of species being listed as threatened [from 14% for birds to 40% for amphibians (IUCN 2019)] and extinction rates three orders of magnitude higher than they would be in the absence of humans (Pimm et al. 2014).

Land cover and land use change, in the form of agriculture, logging, and commercial and residential development, is a major cause of biodiversity loss (Baillie et al. 2010; Collen et al. 2012; Brummitt et al. 2015; Joppa et al. 2016). For example, habitat loss due to urbanization is the dominant threat to landbird species of conservation concern in North America (Rosenberg et al. 2016). In our study area, the southeastern United States, urbanization and the expansion of crop and pasture land are projected to lead to declines in the amount and connectivity of wildlife habitat. Up to 70% of terrestrial vertebrate species in the Piedmont ecoregion, one of the most speciose in the US Southeast, may lose at least 10% of their habitat in the next 30 years (Martinuzzi et al. 2015), whereas the numbers of large, contiguous core habitat areas for regionally significant species are expected to decline by 40% by 2100 (Leonard et al. 2017).

In the United States, most land cover and land use change is administered by local governments (OECD 2017). Local land use decisions are typically overseen by professional planners working within the framework of a comprehensive plan who use a suite of tools such as zoning, subdivision regulations, infrastructure investments, and plans made by other jurisdictions and organizations to shape outcomes in the built environment. These planning instruments can be effective conservation tools (Duerksen et al. 1997; Tan 2006; Steelman and Hess 2009). For instance, the use of canopy-conscious zoning increased canopy cover in counties within the Atlanta metropolitan statistical area (Hill et al. 2010). Thus, municipal- and county-scale planning can potentially play a major role in the conservation of biodiversity in the United States (Beatley 2000; Brody 2003).

To realize this potential, planners can benefit from access to useable ecological information. Ecological information can assist planners by informing and supporting their decisions regarding the distribution of development in comprehensive plans, for example, and their assessments of the impacts on the natural environment of subdivision and rezoning requests (Broberg 2003; Steiner 2016). Ecological information intended for planners is commonly presented as expert advice in the form of guidelines or recommendations for land use planning (Gagné et al. 2015). However, guidelines and recommendations are often not presented in a form amenable to planning practice (Gagné et al. 2015). For example, of 21 sets of ecological guidelines reviewed by Gagné et al. (2015), only two considered socio-economic constraints and only one listed guidelines in order of importance to biodiversity conservation. These shortcomings significantly limit the utility of existing ecological guidelines to planners because they make it difficult for planners to integrate guidelines into planning processes that demand the consideration of multiple, often competing, objectives (Broberg 2003; McNie 2007; Steiner 2016).

Rather, multiple sources now suggest that a more effective approach to the production of useable science involve close collaboration among scientists, practitioners, and other stakeholders (McNie 2007; Cook et al. 2013; Mauser et al. 2013). For example, translational ecology engages ecologists, social scientists, stakeholders, and decision-makers to "develop ecological research via joint consideration of the sociological, ecological, and political contexts of an environmental problem that ideally results in improved environment-related decision-making" (Enquist et al. 2017). Transdisciplinary sustainability research approaches such as translational ecology emphasize the validity of the perspectives, values, knowledge, and expertise of all stakeholders in a particular problem, professional scientist or otherwise (Cook et al. 2013; Mauser et al. 2013; Enquist et al. 2017). These approaches explicitly acknowledge that the production of science is a political endeavor and that scientists are not solely responsible for defining and solving environmental problems (Adams and Sandbrook 2013). The consideration of multiple sources of knowledge and expertise in the scientific process results in science that is credible, legitimate, and salient (McNie 2007; Cook et al. 2013). In other words, scientific information resulting from collaborative approaches such as translational ecology is perceived as believable and unbiased and is relevant to the spatial, temporal, administrative, political, and social contexts in which it is to be applied. As a result, it is more likely to be used by practitioners (McNie 2007).

MATERIALS AND METHODS

Study area and identification of potential respondents

Our study area encompassed ten states in the southeastern US: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. We identified potential respondents to our survey by randomly selecting counties and municipalities in the study area, stratified by state population size in 2016 (US Census Bureau 2016) and the proportions of jurisdictions in each state that were counties or municipalities. For each selected jurisdiction, we conducted an internet search for the email address of the senior staff planner, or if unavailable, the generic email address of the planning or development department. These procedures resulted in the identification of 1163 potential respondents.

In an effort to encourage responses to our survey, we also made note of the email addresses of the presidents of the state chapters of the American Planning Association (APA) in our study area, with the intent of asking these contacts to distribute our survey to their memberships.

Survey instrument

We used Qualtrics (Qualtrics 2017) to create an electronic survey. Using our professional experience and information from the literature, we devised 31 questions that addressed the importance of nature conservation, the drivers of nature conservation, how nature conservation is implemented, the information sources guiding the implementation of nature conservation, and the socio-demographic status of respondents, including gender, age, race, ethnicity, education, salary, and ideology (very conservative, conservative, somewhat conservative, middle of the road, somewhat liberal, liberal, or very liberal) (Appendix S1). Our survey also included a consent form that described the purpose of our research and our intent to keep confidential any information that might be used to identify respondents. We based elements in our survey in part on those used by Miller et al. (2009), namely our lists of ordinance aims, planning tools and techniques, nature conservation activities and concerns, sources used to inform conservation-related activities, and items that could be deemed helpful to promote nature conservation (Appendix S1).

We assessed the importance of nature conservation in general and of specific nature conservation concerns both to planners themselves and, in their estimation, to their jurisdictions. As professionals often tasked with interacting with diverse community constituents, we assumed that planners are perceptive to different general levels of concern for biodiversity (and other issues) in their jurisdiction, particularly if these levels of concern deviate from their own.

We employed the terms 'nature' and 'nature conservation' throughout our survey because the term 'biodiversity' may not be commonly used by planners (Stokes et al. 2010). We defined 'nature' at the beginning of the survey as "all non-human animals, plants, and other organisms, as well as the environments upon which they depend for food, water, and shelter" and 'nature conservation' as "the protection, preservation, or restoration of nature".

Before administering our survey, we assessed the survey's relevance to planning practice in the southeastern US, including in its use of terminology, by soliciting feedback by telephone interview from planners in our study area. Potential interviewees were selected in rural and urban counties and municipalities in each state in order to represent the diversity of planning experience in the study area. Urban jurisdictions were defined as those containing 50,000 or more people, irrespective of the size of the jurisdiction. Four planners responded to our interview request, two from urban municipalities in South Carolina, one from a rural municipality in West Virginia, and one from a rural county in Virginia. All interviews were carried out by telephone in a private office and were recorded and transcribed immediately upon completion. In response to interviewee feedback, we made minor changes to the wording of three questions to clarify their intent and to the format of the survey.

Survey protocol

Between June 27 and July 14, 2017, we used Qualtrics to send emails to potential respondents inviting them to complete our survey. Emails consisted of a prepared script that included the link to the electronic survey and the offer of a chance to win one of ten $50 Amazon gift cards. Reminder emails were sent to those who did not initiate the survey within 2 days, and again 1 week after initial contact. Survey questions, with the exception of those designed to be sequential, were randomized for each respondent. The survey was closed on July 27, 2017. The survey instrument, interview protocol, and survey protocol were approved by the University of North Carolina at Charlotte's Institutional Review Board (Study #17-0256).

Context variables

We measured four context variables: jurisdiction population density, jurisdiction population change, the proportion of jurisdictions in protected areas, and the proportion of jurisdictions encompassed by natural land cover. We used US Census population estimates (US Census Bureau 2016) to calculate the population density in 2016 and the population change between 2010 and 2016 of each jurisdiction. The proportion of jurisdictions encompassed by all terrestrial and aquatic protected areas of any status designation was calculated using the Protected Areas Database of the United States (US Geological Survey, Gap Analysis Program (GAP) 2016). We defined natural land cover as the sum of all 2011 National Land Cover Database classes except Developed and Planted/Cultivated (Homer et al. 2015). We measured context variables using ArcGIS, version 10.4 (ESRI 2015).

Analyses

We summarized responses to open-ended questions by assigning them to content categories. RHB reviewed responses and used an open coding system (e.g., Charmaz 2006) to define categories for each question. KBS, SAG, and five student volunteers then independently categorized responses as either consistent (1) or not consistent (0) with any category. We made the final determination to assign a response to a category if two or more individuals of the research team classified it as consistent with the category.

We used general linear models to test the effects of context variables on the importance planners placed on nature conservation in their survey responses as indicated by the number of hours planners dedicated to nature conservation per week and on the degree to which planners agreed that: (1) nature was adequately conserved in their jurisdiction; (2) nature conservation was important to them personally; and (3) nature conservation was important to the residents of their jurisdictions. Predictor pairwise correlations were < 0.70, the threshold above which collinearity may impair model fit (Dormann et al. 2013). All model residuals conformed to the assumptions of normality and homoscedasticity of variance.

We used redundancy analyses to test the effects of context variables on: (1) how often planners used various sources of information to inform conservation-related activities in their jurisdictions; (2) planners' level of agreement with characteristics intended to make scientific information more useful to them; (3) the conservation activities that planners were working on; (4) the conservation concerns that were important to planners; (5) the conservation concerns that were important to the residents of planners' jurisdictions; and the content categories of planners' responses to (6) "Please elaborate on your use of scientific information about nature conservation for planning in your jurisdiction."; (7) "With respect to the conservation activity that you spend most of your time on, what would you ask an expert if you had the chance?"; (8) "With respect to any important nature conservation concerns in your jurisdiction, what would you ask an expert if you had the chance?"; and (9) "What are the most feasible ways to address important nature conservation concerns in your jurisdiction?". We applied the arcsine square root transformation to the proportion of jurisdictions in protected areas or natural land cover to satisfy the assumption of linearity. We used the z-scores of all variables in analyses and tested the significance of constraining variables using permutation tests (N = 999). All analyses were performed in R, version 3.4.3 (R Core Team 2017).

RESULTS

We received 233 responses to our survey (response rate = 20%). Seventy-five percent of respondents completed the entire survey. For a given survey question, we report percentages of respondents who answered the question.

In general, respondents were located in states and jurisdictions in proportion to relative state population size and the relative number of each jurisdiction type in each state (Fig. 1). Ninety percent of respondents described themselves as either directors of planning departments, senior planners, or junior planners. Of those respondents who provided their socio-demographic information (76%), the majority were white (89%), non-Latino (94%), and male (60%), and held a Master's or equivalent degree as their highest level of education (70%). Age, income, and ideology were normally-distributed, with medians of

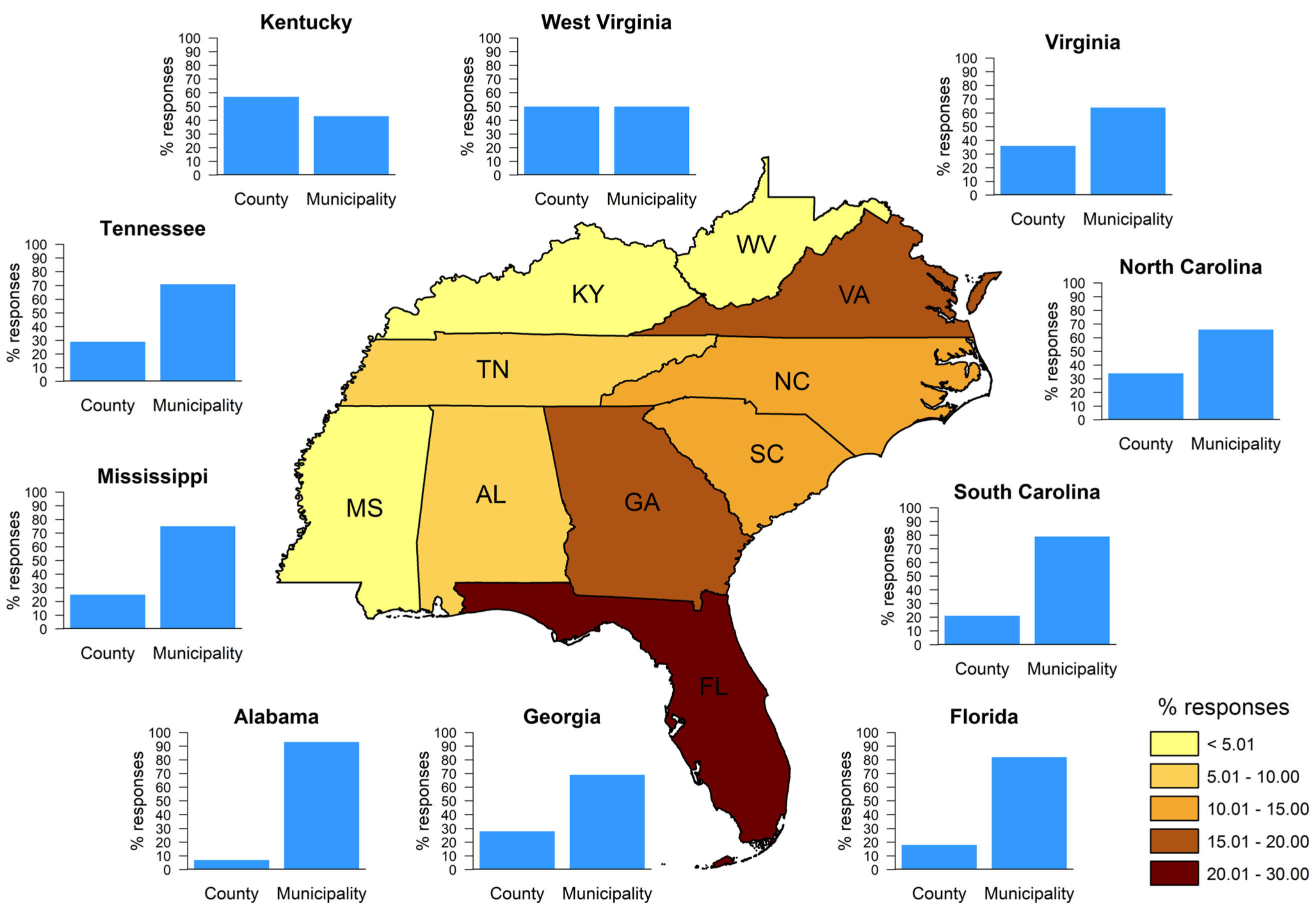

Fig. 1 The percentage of respondents (N = 233) located in each state. Histograms depict the percentage of respondents in each state working for counties or municipalities. *AL* Alabama, *FL* Florida, *GA* Georgia, *KY* Kentucky, *MS* Mississippi, *NC* North Carolina, *SC* South Carolina, *TN* Tennessee, *VA* Virginia, *WV* West Virginia

45–54 years, \$60 000–\$69 000, and “middle of the road”, respectively.

Importance of nature conservation

More planners agreed with the statement “Conserving nature is important to me personally” (78%) than with the statement “Conserving nature is important to my jurisdiction” (31%). Most planners (78%) agreed or somewhat agreed that nature conservation was an important factor in their professional decision-making. Approximately half of planners (56%) agreed or somewhat agreed that nature was adequately conserved in their jurisdiction whereas 28% disagreed or somewhat disagreed.

Eighty-one percent of planners reported dedicating at least 1 hour per week to nature conservation efforts, including 59% who spent 1–4 h, 12% who spent 5–8 h, and 10% who spent $\geq$ 9 h. A large majority of planners (88%) reported that it was very likely or somewhat likely that they would address one or more important nature conservation concerns in their jurisdiction in the next few years.

Drivers of nature conservation

Local legislation, state legislation, recreation, federal legislation, public feedback, and planners’ own professional values were the top drivers of nature conservation, with average importance scores $\geq$ 2, indicating that the average respondent considered these drivers ‘important’ or ‘very important’ (Fig. 2a). The entities involved in nature conservation in planners’ jurisdictions with average importance scores $\geq$ 2 were local elected officials, planners and/or their departments, state government, and nature conservation non-profit organizations (Fig. 2b). The top five items deemed the most helpful in promoting nature conservation were support from local elected officials, community support, additional funding, local legislation, and public outreach and education (Fig. 2c). All items except local, state, and federal non-binding guidelines had helpfulness scores $\geq$ 2, indicating that the average response to most items was ‘somewhat helpful’ or ‘very helpful’.

How nature conservation is implemented

The most helpful tools and techniques for nature conservation in planners’ jurisdictions, i.e., with helpfulness scores > 2, indicating that the average respondent found them to be ‘helpful’ or ‘very helpful’, were Geographic Information Systems (GIS), zoning, conservation easements, infrastructure planning, and land cover/land use data (Fig. 3). Conservation initiatives, such as protecting water quality and minimizing soil erosion, were enshrined in ordinances within comprehensive plans in > 50% of planners’ jurisdictions, with the exceptions of minimizing development density and protecting farmland (Fig. 4). Finally, 43% of planners identified new plans and policies and 34% identified greater awareness and education among the public and elected officials as the most feasible ways of addressing important nature conservation concerns in their jurisdictions (Appendix S2: Tables S1, S2).

The conservation activities that > 50% of planners were working on in their jurisdictions were minimizing soil erosion, improving water quality, and maintaining or increasing habitat in the form of tree cover, public parks, forests, wetlands, and/or riparian areas (Table 1). The protection of old fields, pasture and/or farmland was a much less common activity, cited by only 17% of planners. Also, relatively few planners (13–23%) were focused on the spatial arrangement and diversity of habitat elements in their jurisdictions. With the exception of controlling non-native plants and/or animals, species-specific activities were also relatively uncommon (listed by 5–26% of planners). The least common conservation activities were minimizing the use of pesticides and/or herbicides (indicated by 12% of planners), reducing mowing frequency or lawn area (indicated by 9% of planners), and reducing wildlife roadkill (indicated by 1% of planners) (Table 1).

The relative proportion of planners who thought that individual conservation concerns were important generally matched the relative proportion who were working on similar conservation activities. Nearly all planners (93%) considered poor water quality, soil erosion, and tree loss important conservation concerns—and about 80% thought that habitat loss was important–whereas relatively few planners (35–77%) considered the spatial arrangement and diversity of habitat, native species-specific concerns, and roadkill as important (Table 2). Notable exceptions to this congruence were the loss of ecosystem services and pesticide and herbicide use, which were considered important concerns by about 80% or more of planners but were being addressed in the professional activities of relatively few respondents (30% and 12%, respectively). In most cases, planners’ conservation concerns matched the perceived concerns of residents of their jurisdictions (Table 2). The exceptions to this were pest or overabundant wildlife, which ranked much lower in importance to planners (13th) than to residents (5th), and the loss of ecosystem services, loss of tree diversity, non-native plants and/or animals, and loss of plant and/or animal diversity, which ranked much higher in importance to planners (2nd, 3rd, 4th, and 5th, respectively).

In response to our requests for questions about the conservation activity they spent most of their time on or an

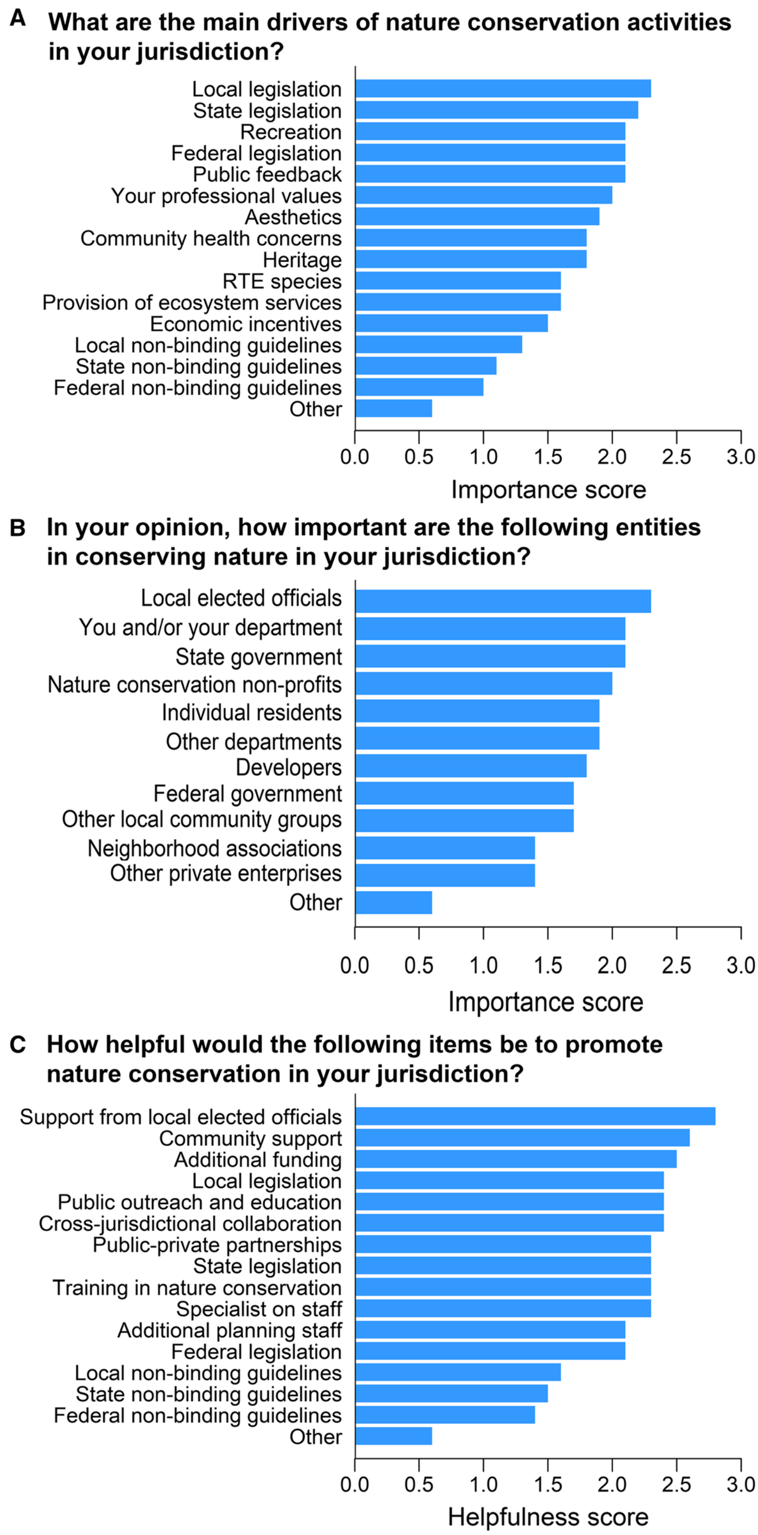

Fig. 2 The importance of different drivers of nature conservation (**a**) and different entities in conserving nature (**b**) and the helpfulness of items in promoting nature conservation (**c**) in planners' ($N \geq 178$) jurisdictions in the southeastern US. Importance and helpfulness scores are averages, weighted by percentage of respondents, of the following ranks: 0, Not important/Not helpful; 1, Somewhat important/Rarely helpful; 2, Important/Somewhat helpful; and 3, Very important/Very helpful. *RTE* rare, threatened, and/or endangered

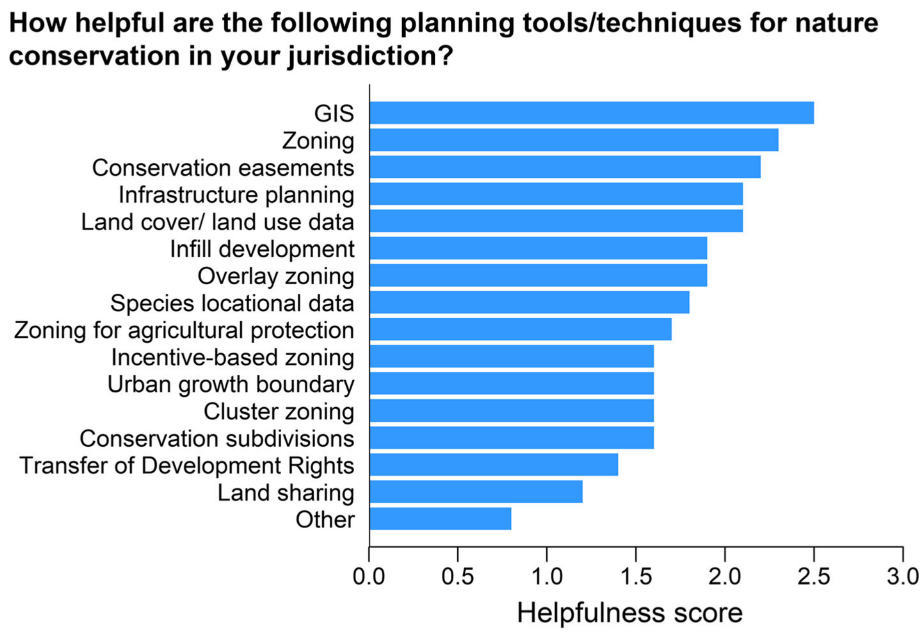

Fig. 3 The helpfulness of tools and techniques for nature conservation in planners' ($N = 218$) jurisdictions in the southeastern US. Helpfulness scores are averages, weighted by percentage of respondents, of the following ranks: 0, Not helpful; 1, Somewhat helpful; 2, Helpful; and 3, Very helpful. *GIS* geographic information systems

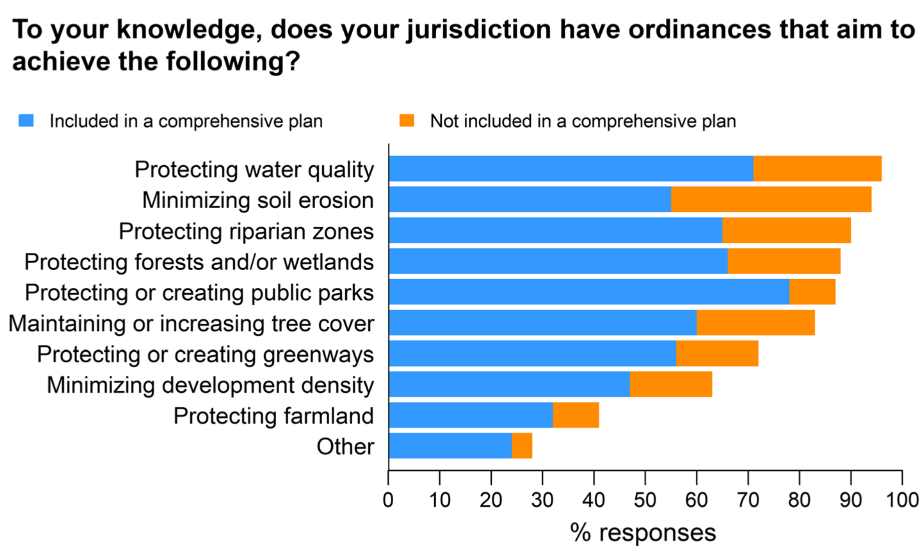

Fig. 4 The percentage of planners in the southeastern US ($N = 222$) whose jurisdictions had ordinances that aimed to achieve outcomes related to nature conservation

important conservation concern, most planners asked about best management practices (47–51%) and/or how to convince others of the importance of nature conservation (15–23%) (Appendix S2: Tables S3–S5).

Finally, when asked to elaborate on their experiences with nature conservation, 34% of planners described their conservation successes, although nearly as many (27%) discussed the political and economic challenges to nature conservation in their jurisdictions (Appendix S2: Tables S6, S7).

Information sources guiding the implementation of nature conservation

Scientific articles and/or journals were the fourth most commonly used source to inform conservation-related activities in planners' jurisdictions, following information from other colleagues, the news media, and a specialist on staff (Fig. 5). No source was used more than a few times a year on average. Two-thirds of planners agreed that information published in scientific outlets would be useful

Table 1 The nature conservation activities that planners in the southeastern US (N = 201) were working on in their jurisdictions in July, 2017. Activities in quotation marks are responses provided by individual planners. Personally identifiable information has been omitted from some responses

Activity	Percent of responses
Minimizing soil erosion	71
Maintaining or increasing tree cover	71
Improving water quality	69
Maintaining or increasing the size and/or number of public parks	64
Protecting forests and/or wetlands	57
Maintaining or increasing riparian habitat (land adjacent to streams, rivers, wetlands, lakes, or ponds)	51
Promoting the use of native plants in public or private gardens	49
Maintaining or increasing the amount of greenways, wildlife corridors, stepping stones, or other elements that may facilitate wildlife movement	49
Implementing green stormwater infrastructure, such as green roofs, permeable pavement, or bioswales	48
Maintaining or increasing tree diversity	47
Increasing public transit	43
Increasing the connection between residents and nature	41
Minimizing the negative effects of adjacent human activity or land use on protected areas	37
Controlling non-native plants and/or animals	33
Improving the environmental condition of contaminated or derelict sites, including brownfields	32
Maintaining or increasing the provision of ecosystem services, such as air pollution removal, air temperature reduction, and runoff reduction by trees	30
Restoring streams	27
Conserving rare, threatened, and/or endangered plants and/or animals	26
Promoting urban agriculture	26
Locating roads to minimize their negative effects on nature	25
Protecting or creating large areas of forest, wetland, old field, pasture, and/or farmland	23
Protecting rare habitat types	19
Protecting old fields, pasture and/or farmland	17
Maintaining or increasing habitat diversity	17
Minimizing the negative effects of recreational use on protected areas	16
Minimizing the isolation of or distances among protected areas of forest, wetland, old fields, pasture, and/or farmland	13
Reducing the use of pesticides and/or herbicides	12
Protecting areas with large wildlife populations	11
Reducing mowing frequency or reducing the area of lawn in public rights-of-way	9
Managing pest or overabundant wildlife, such as coyotes and deer	5
Reducing wildlife roadkill	1
“County enacted a tax on itself to protect our largest environmental asset”	1
“Use of Cemetery as greenspace as well as a cemetery”	1
“Transfer of Development Rights; Conservation Easements”	1
“Developing a walk/bike plan”	1
“re-nourishment of beach front area”	1
“Climate change”	1

Table 2 The importance of nature conservation concerns to planners (N = 176) and the residents of their jurisdictions in the southeastern US. Concerns were ranked in order of decreasing percentage of responses. Concerns in quotation marks are responses provided by individual planners. Personally identifiable information has been omitted from some responses

Concern	Important to you as a planner (% responses)	Important to the residents of your jurisdiction (% responses)	Not important (% responses)	Important to you as a planner rank	Important to the residents of your jurisdiction rank
Poor water quality	93	76	7	1	1
Degradation of streams and/or rivers	93	70	7	1	2
Tree loss	93	65	7	1	3
Soil erosion	93	53	7	1	4
Loss of ecosystem services, such as air pollution removal, air temperature reduction, and runoff reduction by trees	87	46	13	2	7
Reduced connection between residents and nature	84	50	16	3	5
Loss of tree diversity	84	40	16	3	11
Habitat loss	83	43	17	4	9
The negative effects of adjacent human activity or land use on protected areas	83	44	18	4	8
Non-native plants and/or animals	83	42	18	4	10
Loss of plant and/or animal diversity	80	36	20	5	12
Pesticide and/or herbicide use	79	42	22	6	10
Contaminated or derelict sites, including brownfields	77	36	23	7	12
Loss of large areas of forest, wetland, old field, pasture, and/or farmland	77	48	23	7	6
Loss of habitat diversity	76	30	25	8	15
Loss of rare habitat types	73	33	28	9	13
Small or declining populations of plants and/or animals	71	32	30	10	14
Human-wildlife conflicts	65	43	35	11	9
Reduced or impeded wildlife movement	65	25	36	11	16
Isolation of or increasing distance among areas of forest, wetland, old field, pasture, and/or farmland	64	20	36	12	19
Pest or overabundant wildlife, such as coyotes or deer	56	50	44	13	5
Recreational overuse of protected areas	47	23	53	14	17
Roadkill	35	22	66	15	18
"Declining finfish and shellfish harvests"	1	1	0	16	20
"Sea Rise"	1	1	0	16	20
"Frequency of floods/disasters"	1	0	0	16	21
"Reducing the amount of septic systems in high groundwater areas like ours"	1	0	0	16	21
"Restoration"	1	0	0	16	21

for implementing nature conservation in their jurisdiction, especially if it was more accessible, i.e., easier to find and free to access; included more relevant content, i.e., recommendations tailored to planners' regions that include other planning concerns; and was more utilizable in that practical recommendations are presented in order of importance (Fig. 6). We also asked planners to broadly elaborate on their use of scientific information. The most frequent types of responses described the central role of in-house experts in conservation efforts (26%) and/or that scientific information was rarely used (23%) (Appendix S2: Tables S8, S9).

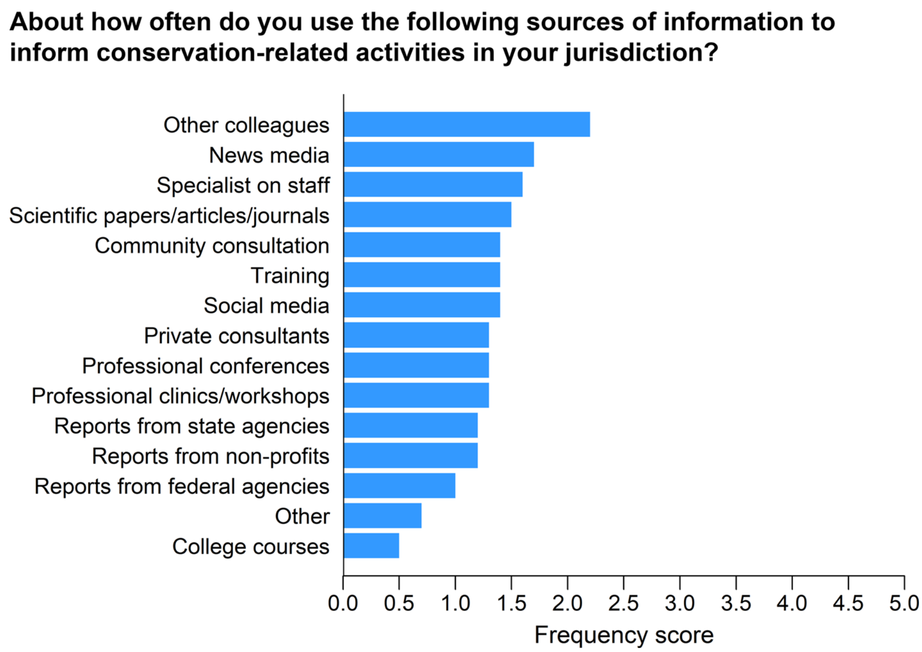

Fig. 5 The frequency that different sources were used by planners in the southeastern US (N = 223) to inform conservation-related activities in their jurisdictions. Frequency scores are averages, weighted by percentage of respondents, of the following ranks: 0, Never; 1, Once a year; 2, A few times a year; 3, About once a month; 4, About once a week; and 5, Daily

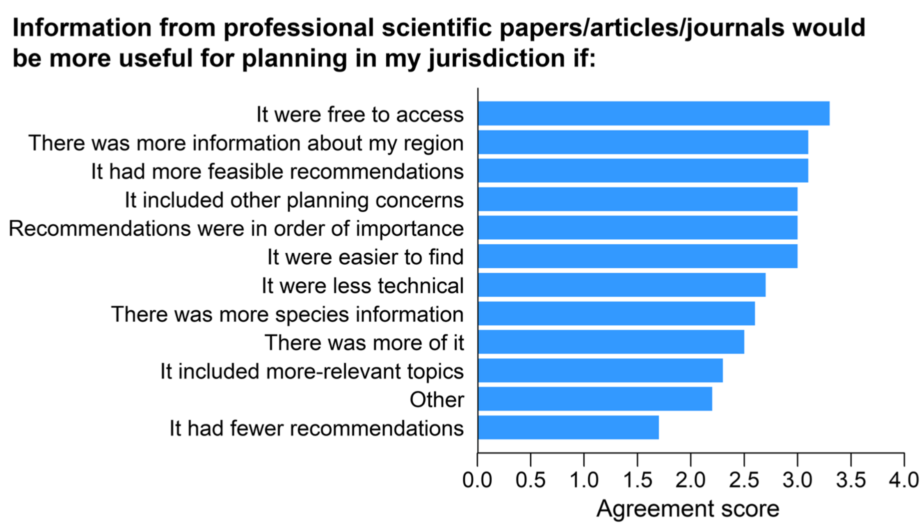

Fig. 6 The level of agreement of planners in the southeastern US (N = 182) with qualifiers to the statement "Information from professional scientific papers/articles/journals would be more useful for planning in my jurisdiction if". Agreement scores are averages, weighted by percentage of respondents, of the following ranks: 0, Disagree; 1, Somewhat disagree; 2, Neither agree nor disagree; 3, Somewhat agree; and 4, Agree

Effects of context

The proportion of jurisdictions encompassed by natural land cover had a nearly significant negative effect on the number of hours per week planners dedicated to nature conservation efforts ($\beta = -5.40 \pm 3.22$ (SE), $p = 0.10$), whereas planners agreed significantly more strongly that nature was adequately conserved in their jurisdiction if their jurisdiction experienced less population change ($\beta = -0.016 \pm 0.008$ (SE), $p = 0.05$).

Population density and the proportion of land in protected areas had significant effects on the frequency with which planners used different sources of information to inform conservation-related activities (population density: $F_{1,180} = 2.42$, $p = 0.03$; protected area proportion: $F_{1,180} = 2.39$, $p = 0.03$). Planners in jurisdictions with higher population densities employed private consultants, attended professional conferences, and used social media more frequently than planners in less dense jurisdictions (Appendix S3: Fig. S1). Planners in jurisdictions with proportionally more protected area used white papers or reports from federal agencies, state agencies, and nature conservation non-profits more frequently than those in jurisdictions with less protected area (Appendix S3: Fig. S1).

Planners' level of agreement with characteristics intended to make scientific information more useful to them was significantly affected by population change ($F_{1,141}$ = 2.73, p = 0.03) and nearly significantly affected by the proportion of jurisdictions in protected areas ($F_{1,141}$ = 2.18, p = 0.06). Planners in jurisdictions that experienced less population change agreed more strongly that scientific information would be more useful if it included recommendations listed in order of importance and there was more of it, whereas planners in jurisdictions with proportionally more protected land agreed more strongly that scientific information would be more useful if it were less technical and included more relevant topics (Appendix S3: Fig. S2).

All of the context variables had significant or near significant effects on the conservation activities that planners were working on (population density: $F_{1,172}$ = 1.57, p = 0.09; population change: $F_{1,172}$ = 1.55, p = 0.08; protected area proportion: $F_{1,172}$ = 1.72, p = 0.05; natural land cover proportion: $F_{1,172}$ = 2.64, p = 0.004). Planners in jurisdictions with higher population densities were more likely to be working on maintaining or increasing tree cover and diversity and implementing green stormwater infrastructure, such as green roofs, permeable pavement, or bioswales (Appendix S3: Fig. S3). Planners in jurisdictions with more population change were more likely to be working on conserving rare, threatened, and/or endangered species and maintaining or increasing habitat diversity, but were less likely to be working on improving water quality (Appendix S3: Fig. S3). Planners in jurisdictions with proportionally more protected area were more likely to be working on protecting forests and/or wetlands, protecting rare habitat types, and managing pest or overabundant wildlife, but were less likely to be working on restoring streams (Appendix S3: Fig. S3). Finally, planners in jurisdictions with proportionally more natural land were more likely to be working on protecting old fields, pasture and/or farmland and minimizing the negative effects of recreational use on protected areas (Appendix S3: Fig. S3).

The proportion of jurisdictions in natural land cover had a nearly significant effect on the content categories of planner responses to the question "With respect to the conservation activity that you spend most of your time on, what would you ask an expert if you had the chance?" ($F_{1,\ 172}$ = 2.05, p = 0.07). Planners in jurisdictions with proportionally less natural land tended to seek information about a specific species or group of species (Appendix S3: Fig. S4).

DISCUSSION

Our survey results demonstrate that nature conservation is a valued and important component of local planning in the southeastern US. However, our results also show that there exists a major disconnect between ecologists and planners when it comes to biodiversity conservation. Planners are pursuing or concerned with conservation issues that do not appear to align with ecologists' research priorities and rarely use the scientific literature to inform their activities. These results confirm that Sustainable Development priorities like biodiversity conservation ought to be developed and articulated alongside the specific social and political realities to which planners are responsible (Boyer et al. 2016). In other words, while the findings of ecological science might be understood as objective reality by ecologists, scientific information—as currently packaged and delivered—struggles to pass through a context-specific filter *despite* planners believing in its importance generally. We suggest that the disconnect between ecologists and planners can be narrowed by means of better practical interpretation of research results by ecologists as well as transdisciplinary sustainability research approaches, such as translational ecology (Stokols 2006; Wickson et al. 2006; Mauser et al. 2013; Enquist et al. 2017). Transdisciplinary research teams must include local elected officials and invite the participation of lay citizens given that their support is critical to the passage of policy that will enact conservation measures. The results of our survey constitute strong empirical evidence that partnerships among scientists, practitioners, and stakeholders are necessary to address the challenge of biodiversity loss.

If local land use planning in the southeastern US is to realize its potential to contribute to biodiversity conservation, then planners must consider conservation to be a worthwhile endeavor and engage in its pursuit. Nearly 80% of the planners that we surveyed personally valued nature conservation and considered it to be an important factor in their decision-making. This was corroborated by the large amount of time planners reported dedicating to nature conservation efforts—80% of planners spent at least 1 h per week and 22% spent at least 5 h per week—and the fact that most planners reported that they would likely address one or more important nature conservation concerns in the near future. In addition, planners appear to be motivated to engage in nature conservation if it is likely to be threatened: increasing population change and decreasing natural land cover resulted in planners more strongly disagreeing that nature was adequately conserved in their jurisdictions and spending more time on nature conservation efforts.

Local planning's conservation potential also depends on planner's use of ecological information (Yli-Pelkonen and Niemelä 2006). Our results indicate that ecological information is generally not being used by planners. Planners in the southeastern US reported relying most often on their colleagues as sources of information for their conservation-related activities and many commented that they rarely used scientific information in their work, corroborating the findings of surveys of planners elsewhere in the US and internationally (Azerrad and Nilon 2006; Sandström et al. 2006; Miller et al. 2009). Similarly, a survey of compilers of nature reserve management plans in the United Kingdom found that the majority of conservation actions were experience- rather than evidence-based (Pullin et al. 2004). The reliance on colleagues as sources of ecological information may be due to their expertise, as demonstrated in our results by planners' emphasis on the role of in-house experts as mediators of their use of ecological information, but it may also be indicative of biased and potentially ineffective policy-making (Walsh et al. 2015).

The reasons underlying southeastern US planners' lack of use of ecological information are reflected in their preferences for recommendations that are more accessible, more practical, and include content tailored to their regions that also addresses other planning concerns. These results echo existing findings that scientific information is rarely used by practitioners because it is difficult to locate and costly to acquire, does not address topics relevant to management, and is not presented in a manner that facilitates implementation (Pullin et al. 2004; Yli-Pelkonen and Niemelä 2006; McNie 2007; Walsh et al. 2015). We also found that the long-standing ecological research foci of habitat fragmentation, the ecologies of individual native species, roadkill, and ecosystem services were not among the conservation activities that most planners were working on or the conservation concerns most planners indicated were important, supporting the idea that the information that planners need for policy decisions does not align with the information articulated by ecologists. This result and southeastern US planners' lack of use of ecological information more generally point to a major disconnect between ecologists and planners when it comes to nature conservation (see also Nassauer and Opdam 2008; Ahern 2013).

To overcome this disconnect, we suggest that ecologists (1) improve their communication of research findings to planners and (2) employ transdisciplinary sustainability research approaches such as translational ecology that involve collaboration with planners. According to the planners we surveyed, the most useful change to ecological information for planning in their jurisdictions would be making it free to access. Ecologists' support of the open-access model of publishing accomplishes this. In addition, ecologists should more intentionally interpret research results for use by planners. One example of such interpretation is listing recommendations for land use planning in order of importance, the fifth most helpful change to ecological information according to southeastern US planners. Ecologists, rather than planners, are best positioned to interpret their research because they intimately understand its limitations (Yli-Pelkonen and Niemelä 2006). The ecological profession could build its members' communication skills by requiring science communication coursework in graduate degrees and outreach sections in theses and dissertations. The latter should compare the implications of the students' research to those of prior findings so that past knowledge is equally available to planners.

Transdisciplinary sustainability research involves scientists working intimately with stakeholders to understand socio-environmental problems and produce useable solutions (Stokols 2006; Wickson et al. 2006; Mauser et al. 2013). A recent example of such an approach that is geared towards ecologists is translational ecology (Enquist et al. 2017). Transdisciplinary sustainability approaches such as translational ecology are particularly well-suited to complex social, environmental, and political contexts, such as typify land use planning (Head and Xiang 2016). Importantly, they result in timely science that is easily understandable, perceived as legitimate, at spatial and temporal scales relevant to decision-makers, and easier to integrate with practitioner frameworks and processes, and consequently more likely to be used (McNie 2007; Meadow et al. 2015 and references therein; Campbell et al. 2016; Nel et al. 2016; Enquist et al. 2017).

As stated in the definition of translational ecology, stakeholders, such as the community and local elected officials, are included in the research process. Planners in the southeastern US emphasized the importance of community and local elected officials to nature conservation by listing local legislation as the most important driver of nature conservation; support from local elected officials, community support, and local legislation in the top five most helpful items to promote nature conservation; and greater awareness and education among the public and elected officials as one of the most feasible ways of addressing nature conservation. Prior surveys of planners reported similar results (Miller et al. 2009; Stokes et al. 2010). Stakeholder participation in the planning process, especially if it occurs at all stages, positively influences plan implementation and conservation outcomes (Burby 2003; Steelman and Hess 2009; Graversgaard et al. 2017). The specific inclusion of members of the community and local elected officials may be especially important because the former has a strong influence on the latter's decision-making (Webler et al. 2003; Hawkins 2011). However, it is important to recognize that stakeholder values and perspectives may differ from those of ecologists and professional planners, potentially resulting in ineffective outcomes (e.g., Schwartz 2013). Our results indicated that conserving nature was much less important to planners' jurisdictions than to planners themselves and that the conservation concerns of planners and the residents of their jurisdictions differed substantially. Also, planners reported significant resistance to scientific information in their jurisdictions and emphasized the political and economic challenges of carrying out conservation initiatives, issues of particular concern given that local elected officials were listed as the most important entity in conserving nature in planners' jurisdictions.

Planner responses to our survey highlight the need for a translational ecology approach and include many starting points upon which such an approach may be built. The need for collaborative research between planners and ecologists is supported by the significant effects of jurisdiction context on the degree to which planners agreed that nature was adequately conserved in their jurisdiction, planners' desire for scientific information with specific characteristics, and the conservation activities that planners were working on. Ecological information intended to inform planning is often structured in a uniform way, i.e., as a simple list of recommendations, and addresses topics that are assumed to be broadly relevant to land use planning. However, if planners' desire and preferences for ecological information differ among jurisdictions with differing contexts, e.g., population densities, then it would behoove ecologists to tailor their recommendations to particular audiences. In a similar vein, Azerrad and Nilon (2006) discovered that ecological guidelines were not being widely used by local planners because they did not address issues of local importance at a relevant spatial scale. The sharing of knowledge and mutual learning that are hallmarks of translational ecology can bridge this gap (Enquist et al. 2017). Together, planners and ecologists can determine the need for nature conservation, the specific research topics that are of importance, and the format of information that will be most useful to planning given a particular context. In fact, this context-specificity is necessary to produce useful information because it takes into account the spatial and temporal scales of policy and decision-making processes, the values and beliefs of stakeholders, the political landscape, and the manner in which information is communicated (McNie 2007). In the southeastern US, the conservation activities and concerns important to planners and their open-ended comments and questions related to these are good starting points for the translational ecology process. For example, ecologists' knowledge that improving water quality is a very common conservation activity that planners work on and that poor water quality ranks as one of the top conservation concerns of planners and the residents of their jurisdictions enables them to come to the table prepared to potentially tackle water quality problems or to identify the intersections between their research questions and water quality for maximum appeal to planners and stakeholders.

A context-specific approach to research carried out in collaboration with planners and stakeholders to solve practical problems may not appeal to ecologists, however. The current culture of ecological science, driven by review, promotion, and tenure (RPT) practices, favors positive results that expand a broad understanding of ecological systems. Simply put, local scale research that addresses applied problems is not as likely to get published, nor is research that addresses a problem solved elsewhere in a new context. Awareness of the need for a culture shift is increasing—the theme of the 2019 Ecological Society of America's annual meeting, 'Bridging communities and ecosystems: inclusion as an ecological imperative', emphasizes bridging theory and practice and incorporating diverse perspectives into ecological science—as are calls for the RPT process to consider diverse research products and their impact on policy and practice, e.g., the San Francisco Declaration on Research Assessment. In the meantime, practitioners of translational ecology may reap benefits from codifying and explaining the value of the research products that result from the approach.

CONCLUSIONS

We draw four main conclusions from the results of our survey: (1) nature conservation is important to planners in the southeastern US; (2) planners in the southeastern US, and arguably elsewhere in the country and internationally, are not using information disseminated by ecologists to inform conservation-related policies; (3) there is a major disconnect between planners and ecologists despite the former's desire for advice about nature conservation and the latter's assumption that the information they produce is useful; and (4) potential solutions, supported by our results, are improved communication of research results by ecologists and the use of transdisciplinary sustainability research approaches such as translational ecology that engage planners, ecologists, community members, local elected officials, and other stakeholders in a collaborative process that explicitly considers the social, ecological, and political context of nature conservation. We believe that ecologists can play an important role in land use planning for nature conservation and that the collaborative approaches that we suggest have the potential to produce the usable and effective science that is needed to address the challenge of biodiversity loss.

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