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Aligning Endangered Species Management with Fire-Dependent Ecosystem Restoration: Manager Perspectives on Red-Cockaded Woodpecker and Longleaf Pine Management Actions

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Aligning endangered species management with fire-dependent ecosystem restoration: manager perspectives on red-cockaded woodpecker and longleaf pine management actions

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Abstract

Background: Endangered species management has been criticized as emphasizing a single-species approach to conservation and, in some cases, diverting resources from broad-based, land management objectives important for overall biodiversity maintenance. Herein we examine perceptions on management for an endangered species whose habitat requirements largely depend on frequent fire, the red-cockaded woodpecker (*Leuconotopicus borealis* Vieillot). In doing so, we consider the alignment between species-specific population recovery actions and broader ecosystem restoration goals. Through semi-structured interviews with natural resource professionals (n = 32) in the Southeast Coastal Plain of the United States, we examined manager perspectives on the evolution of recovery efforts and the potential alignment of recovery efforts with other management goals and objectives on public lands.

Results: Participants described an evolution of approaches to manage red-cockaded woodpeckers, from an initial emphasis on intensive management actions with a single-species focus to reduce extinction risk (*e.g.*, artificial inserts and translocation of individual birds) to a broader focus on restoring forest conditions and the processes that maintain them (*e.g.*, fire). Most participants considered red-cockaded woodpecker habitat management to be compatible with other resource management actions (*e.g.*, prescribed fire, mechanical thinning). However, there were some notable exceptions as a smaller but substantive number of participants indicated that specific habitat management guidelines (basal area guidelines for foraging habitat) posed a barrier to implementing preferred ecosystem restoration actions (transitioning stands of fast-growing, short-lived pines to longleaf pine [*Pinus palustris* Mill.]). Overall, participants expected efforts to provide habitat for red-cockaded woodpeckers to continue regardless of its conservation status and that intensive, single-species management actions would likely decrease over time.

Conclusions: Providing for the specific needs of specialist species that are in decline is often necessary to prevent their extinction in the near term. Our findings suggest that the ability to connect long-term management actions to recover endangered species to other agency priorities may promote the willingness of managers to prioritize and continue long-term management of their habitats.

Keywords: ecosystem management, endangered species, fire, longleaf pine, Southeast Coastal Plain

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Resumen

Antecedentes: El manejo de especies amenazadas ha sido criticado por enfatizar el enfoque de la conservación en una sola especie y en algunos casos, distrayendo los recursos que desde una base amplia logren el objetivo importante del manejo de tierras para el mantenimiento general de la biodiversidad. Examinamos aquí las percepciones sobre el manejo para una especie amenazada cuyo hábitat requiere largamente de fuegos frecuentes, el carpintero de cresta roja (*Leuconotopicus borealis* Vieillot). Al así hacerlo, consideramos el alineamiento entre las acciones de recuperación de las poblaciones especie-específicas y los objetivos amplios de restauración del ecosistema. A través de entrevistas semi-estructuradas con profesionales en recursos naturales (n = 32) en las Planicies Costeras del Sureste de Estados Unidos, examinamos perspectivas de manejo sobre la evolución de los esfuerzos de recuperación y el potencial de alineamiento de esfuerzos de recuperación con otras metas y objetivos de manejo en tierras públicas.

Resultados: Los participantes describieron una evolución en los enfoques para manejar el carpintero de cresta roja, desde un énfasis inicial en acciones de manejo intensivo enfocado a reducir el riesgo de extinción de una sola especie (i.e., introducciones artificiales y translocación de pájaros individuales), a uno más amplio destinado a restaurar las condiciones del bosque y los procesos que las mantienen (i.e., fuego). La mayoría de los participantes consideraron que el manejo del hábitat del carpintero de cresta roja es compatible con otras acciones de manejo de los recursos (i.e., quemas prescriptas, raleos mecánicos). Sin embargo hubo algunas notables excepciones, cuando un número pequeño pero sustantivo de participantes indicó que las guías específicas para el manejo del hábitat (guías de base para el hábitat de forrajeo) implican una barrera para implementar las acciones preferidas para la restauración del ecosistema (la transición que implica el pasar de rodales de pino de especies de vida corta y rápido crecimiento, a rodales de pino de hoja larga [*Pinus palustris* Mill.]). Por sobre todas las cosas, los participantes esperaban que los esfuerzos para proveer de hábitat al carpintero de cresta roja continúen independientemente de su estatus de conservación, y que las acciones de manejo para conservar una sola especie decrezcan con el tiempo.

Conclusiones: El proveer de necesidades específicas a especies especialistas que están en declinación es frecuentemente necesario para prevenir su extinción en el corto plazo. Nuestros resultados sugieren que la habilidad de conectar acciones de manejo de largo plazo para recuperar especies amenazadas en lugar de otras prioridades de las agencias, pueden promover el beneplácito de los gestores para priorizar y continuar acciones de largo plazo en el manejo de sus hábitats.

Abbreviations

DoD: Department of Defense
ESA: The United States' Endangered Species Act of 1973
RCW: red-cockaded woodpecker, *Leuconotopicus borealis*
RCW Recovery Plan: Recovery Plan for the Red-cockaded Woodpecker (*Picoides borealis*)
Coastal Plain: Southeast Coastal Plain longleaf pine ecosystems
USFS: United States Forest Service
USFWS: United States Fish and Wildlife Service

Background

The United States' Endangered Species Act (hereafter, ESA) of 1973 was passed with the goal of recovering, and then conserving, threatened and endangered species and the ecosystems upon which they depend (16 U.S.C. §1531(b)). However, some have criticized the ESA for encouraging single-species approaches to conservation, arguing that dedicating substantial resources to addressing the specialized needs of a single species may detract from achieving broader goals and objectives that may better serve a larger number of species (Barnes 1993; Benson 2012). Others have suggested that it may be more effective to target the limited resources available for conservation towards species that may be more representative of the broader ecosystem (Simberloff 1998). Efforts to shift toward ecosystem management often emphasize management for ecological integrity (Barnes 1993; Grumbine 1997). Rather than focusing on one species, such efforts often prioritize maintaining ecosystem patterns and processes, especially in fire-dependent ecosystems (Barnes 1993).

For many endangered species, population declines can be attributed to the disruption of ecosystem processes. For example, in many forest ecosystems, fire suppression has altered vegetation structure and, in turn, negatively impacted populations of many species (Van Lear et al. 2005). However, applying restoration treatments (such as prescribed fire or mechanized thinning) in forests where protected species are found can be complicated. Because the ESA emphasizes extinction risk, including risks posed by management actions, the law may be viewed as restricting potential management options and encouraging adoption of actions considered safe even if they provide fewer benefits than more risky actions. At the same time, restoration treatments designed to benefit species in the long term may be viewed as posing too much risk of negative impacts to individuals or available habitat in the near term. If viewed in this manner, policy constraints imposed by the ESA may encourage risk-averse decision making. Indeed, previous studies have found that forest managers, especially those working with fire-dependent ecosystems, may avoid particular management approaches that they view as risky, even if doing so results in a failure to meet their management objectives (*e.g.*, Christensen 2003; Stankey et al. 2003; Wilson et al. 2009).

Listed in 1973, the red-cockaded woodpecker (*Leuconotopicus borealis* Vieillot, hereafter RCW) was among the first species listed under the ESA. Population recovery efforts for the species include intensive, species-specific management actions like installing artificial nest cavities (Fig. 1). More broadly focused conservation efforts are directed at restoring fire-dependent longleaf pine (*Pinus palustris* Mill.) ecosystems and the embedded RCW habitat (USFWS 2003). RCWs exclusively excavate and nest in live pine trees and, while they breed within a variety of pine ecosystem types across the southeastern US, RCWs show a preference for longleaf pine ecosystems with an open understory (Jackson 1994). Longleaf pine is a shade-intolerant species. Fire suppression leads to expansion of hardwood plant species, such as oaks (*Quercus* L. spp.), that shade out longleaf pine seedlings and create an understory used by RCW nest predators. Maintaining an open condition (Fig. 2) in these systems requires surface

Fig. 1 Artificial insert boxes used in red-cockaded woodpecker population recovery in the Southeastern Coastal Plain in 2015. These boxes allow red-cockaded woodpeckers to nest in trees that are typically too young for natural cavities. Pictured here are boxes prior to (left) and after (right) installation. Photographer credit: Shelby Weiss

Fig. 2 Restored longleaf pine forest occupied by red-cockaded woodpeckers in northern Florida, United States, 2015. Photographer credit: Shelby Weiss

fires every 1 to 5 yr. Historically, these fires were produced by spring and summer lightning strikes (Landers and Boyer 1999). Longleaf pine ecosystems, one of the most species-rich ecosystems in North America, once dominated the southeastern Coastal Plain, covering an estimated 94 million ha. Today these ecosystems occupy <5% of their original extent (Brockway et al. 2005; Jose et al. 2007).

Within longleaf pine and other pine ecosystems of the southeastern US, RCWs live in small, cooperative family groups that consist of a breeding pair and "helpers." Together, birds excavate and maintain multiple cavities within a territory, each cavity taking years to construct (Jackson 1994). RCWs prefer large (≥14 cm diameter of heartwood), older (>60 yr) pine trees (Rudolph and Conner 1991; USFWS 2003). Site occupancy is a product of the availability of quality foraging habitat, influenced by size, age, and density of overstory trees, as well as groundcover composition (USFWS 2003). Based on these characteristics, the Recovery Plan for the Red-cockaded Woodpecker (*Picoides borealis*) (hereafter, RCW Recovery Plan) outlines a specific recovery standard of quality foraging habitat that federal agencies are compelled, and state agencies are strongly encouraged, to manage for in order to grow populations (USFWS 2003: 187). The US Fish and Wildlife Service (USFWS) has statutory authority for the management of the RCW (and all federally listed threatened or endangered non-marine species) regardless of where populations occur. This situation can lead to a need to negotiate decision making between agencies that may have different missions (*e.g.*, USFWS and USDA Forest Service [USFS]) and potentially lead to tension between protection of listed species and achieving other agency-specific objectives.

Managing for endangered species within ecosystems that have been altered by fire suppression prompts the question of how managers balance species recovery efforts with ecosystem restoration activities. If threats to species are related to disruption of natural processes, it follows that any treatments to restore these processes may also benefit associated species. However, the recovery of an endangered species often requires that multiple threats, including those that may not all align with ecosystem management objectives, be addressed. Moreover, practices may result in different outcomes over time; for example, use of fire as a management tool may carry some near-term risks of loss of individuals or habitat while also having the potential to provide long-term benefits to protected species. Consequently, management decisions in such systems include several tradeoffs that merit consideration. In this paper, we report findings from semi-structured interviews with managers working on RCW recovery in order to address the following questions:

1. How has RCW management evolved and what factors have influenced changes in management?
2. Do managers identify tradeoffs or areas of compatibility between actions to protect and recover RCWs and other forest management objectives, particularly longleaf pine restoration?

In examining these questions, we identify lessons from the RCW case study that may help inform management of other endangered species and the ecosystems upon which they depend.

Methods

We used qualitative methods to explore the experiences and perspectives of managers with management efforts directed at RCW population recovery. We collected data through one-on-one, semi-structured interviews. While potentially less common than quantitative forms of social science data collection (*e.g.*, surveys), qualitative, case-study approaches allow an in-depth exploration of a particular topic (Rubin and Rubin 2005; Robson 2011). Such approaches are particularly useful when little is known about a topic area or when the complexity of decisions may not allow them to be adequately represented in a survey (for which, by design, questions must be simplified to ask across a broad audience; Pope and Mays 1995).

As described above, management of endangered species includes substantial risk and uncertainty. We determined that such complexity would be challenging to explore effectively through quantitative methods (*e.g.*, surveys) alone due to the multiple influencing factors and potential sensitivity given the high stakes associated with both extinction risks and legal requirements. Moreover, limited prior research has explored manager decision making associated with endangered species management, so this study presents a novel opportunity to capture the details surrounding this particular case. Based on these points, we decided that a semi-structured interview approach would be best suited to addressing our questions of interest.

We developed an interview protocol to guide our interviews. As is typical, this protocol consisted of a series of open-ended questions organized around the primary topics of interest, as well as more specific follow-up questions to use as needed when a particular issue of interest was not raised independently by participants, and neutral probes to encourage participants to elaborate on their responses. Semi-structured interviews allow for some deviation in the line of questioning if participants introduce new ideas or concepts that merit additional exploration. Rather than basing sample selection on allowing statistical generalization, our sampling approach was designed to allow in-depth exploration of the research questions and ensure that the full range of ideas were represented. For this study, interviews were completed with 32 individuals involved in various aspects of RCW planning and management.

RCWs occur across 11 states in the southeastern US; our study was limited to RCW management areas in seven states within Southeast Coastal Plain longleaf pine ecosystems (hereafter, Coastal Plain; Fig. 3). Public lands within the Coastal Plain contained sufficient diversity to represent the types of publicly managed properties in which RCWs occur; there is a range of resource management agencies operating within multiple states and variability in the size of RCW populations present on properties. Restricting our study to the Coastal Plain enabled us to explore these different management situations while keeping the environmental context relatively consistent (*e.g.*, properties in the Coastal Plain region might face a different set of ecological challenges from their counterparts in the Sandhills or Piedmont regions).

We sought to include a variety of individuals with first-hand experience working with RCWs within this region. In doing so, we used a purposive sampling method rather than randomly selecting participants to statistically represent a population (as one might do with quantitative survey methods). We selected participants that would provide a diversity of perspectives within our sampling area based on their role, geographic location, property ownership type, and property size. To ground our study, we reached out to a US Fish and Wildlife Service (USFWS) employee with extensive leadership experience in RCW recovery. We first discussed our study area and then we shifted to considering potential interview participants who were working within the region.

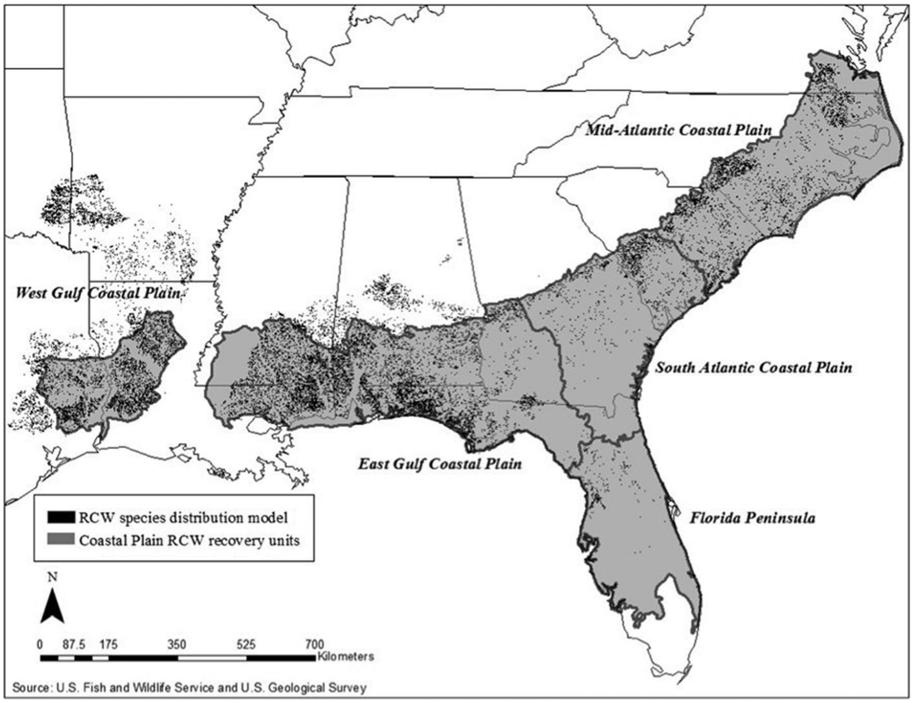

Fig. 3 Red-cockaded woodpecker Coastal Plain Recovery Units defined by the US Fish and Wildlife Service (gray) overlaid with the species distribution model for the red-cockaded woodpecker (black; USGS 2017)

Consulting with this individual in the early stages of our project provided important insight on how to define our study area and what the variability associated with property types was within a given region. Through this discussion, we developed an initial list of potential interviewees, including biologists, foresters, and other land managers actively involved in RCW management. Additional participants were added based on suggestions of interview participants (a technique known as snowball sampling, in which each interview participant was asked to suggest other potential participants).

The initial participant list focused on public properties with large RCW populations. Over time, representatives from properties with smaller populations were also included. Within the RCW Recovery Plan, the United States Forest Service (USFS) is responsible for managing the greatest number of properties for RCW in the Coastal Plain. Consequently, USFS employees represented 44% of the interviewees (Table 1). One private landowner was interviewed; however, this study was not designed to capture the perceptions and experiences of private land managers related to RCWs.

We completed interviews between January and July 2016 (interview protocol reviewed by The Ohio State University Institutional Review Board for projects including human subjects). Nine interviews were completed in person and 23 took place over the phone. Informed consent was obtained from each participant.

Table 1 Number of natural resource professionals interviewed regarding red-cockaded woodpeckers and longleaf pine management in the Southeastern Coastal Plain of the United States (2015 to 2016)

	Interviewees (*n*)
Management agency	
US Forest Service	14
US Fish and Wildlife Service	2
US Department of Defense	6
State agency	8
Private or other	2
Coastal Plain states represented	
Alabama	3
Florida	11
Georgia	3
Louisiana	3
North Carolina	1
South Carolina	9
Texas	2
Roles represented	
Property manager	3
Biologist or wildlife-related program personel	24
Forestry-related program personel	3
State ecologist	1
State fire specialist	1

When possible, we combined in-person interviews with field visits to directly observe examples of RCW management. Interview lengths ranged from 30 minutes to two hours and were audio-recorded with the permission of participants. We began with a brief description of the project before proceeding with a set of 20 scripted questions that established the role and extent of RCW experience, then addressed longleaf pine ecosystem restoration, history of RCW management actions, resource management goals, communication among managers and scientists, management strategies for RCWs, and views on the RCW conservation status (Additional file 1). The semi-structured nature of the interviews allowed flexibility to expand on these questions when merited, or to follow up on new concepts introduced by participants.

Interviews were transcribed verbatim and coded systematically (Rubin and Rubin 2005). We based our initial coding scheme on that of a related case study that examined another species of high conservation concern that relies on fire-dependent forest ecosystems (the Kirtland's warbler, *Setophaga kirtlandii* Baird) and expanded it according to new themes and ideas that emerged during our analysis (Myer 2012). Following methods suggested by Campbell et al. (2013), we assessed inter-coder reliability to verify that the coding scheme could be consistently applied and provided a valid depiction of findings. A subset of interviews were analyzed by two researchers: a member of the research team and another researcher who was not directly involved in the research but was trained in qualitative methods. Using the same coding scheme, both researchers coded a randomly selected interview and compared results. The resulting codes were compared and discrepancies discussed to better refine and clarify the initial coding scheme. Following this first round of comparison, additional interviews were randomly sampled, coded separately, and compared until a satisfactory level of agreement was reached (>80%) for the first two levels of codes (Campbell et al. 2013). This occurred after six interviews were compared. The primary researcher then used the same approach to code the remaining interviews. The final coding scheme consisted of the following primary codes, or overarching categories of codes: 1) behavioral decision making, 2) external influences on decision making, 3) communication or social influence, 4) recovery effects and consequences, 5) management approach, 6) management priorities, 7) benefits of fire, 8) conservation reliance, and 9) desired future management. Our approach allowed us to capture unanticipated ideas that emerged through conversation, unprompted by a scripted question (noted as "unprompted" responses, below).

Results

Evolution of RCW management

Throughout our interviews, many participants described the history of RCW management as having undergone a philosophical shift since first being listed under the ESA. Across interviews, there was remarkable consistency in the main RCW management strategies reported. As one participant stated, "it's one nice thing about working with red-cockaded woodpeckers, everybody knows what to do." While many of the strategies listed by participants have been used throughout the period of time during which RCWs have been listed, the idea of emphasizing more holistic strategies was described as being more pervasive today than it had historically. Strategies used to manage RCWs fell into two main overarching categories: strategies focused on preventing extinction and growing RCW populations; and those aimed at restoring longleaf pine, thus improving RCW habitat.

Strategies mentioned by participants that focused on growing RCW populations and preventing extinction included the installation or maintenance of artificial cavities and translocation of individual RCWs. Both were often referenced as being labor-intensive, time-consuming tasks. Artificial cavities ("inserts") were mentioned by 84% (n = 27; Table 2: row 2) of participants. Forest age poses a challenge to providing RCW habitat at many

Table 2 Red-cockaded woodpecker management strategies mentioned most frequently in interviews with natural resource professionals from the Southeastern Coastal Plain of the United States (2015 to 2016), listed in ranked order

	Interviewees (n)			
Management strategies identified by interviewees	Federal	State	Private	Percentage of Interviewees (%)
1. Fire				
a. Prescribed fire	23	8	1	100%
b. Managing unplanned ignitions	3	10	0	41%
2. Maintain and install artificial cavities	20	6	1	84%
3. Timber thinning	19	6	1	81%
4. Reduce midstory (non-fire methods)	15	7	0	69%
5. Convert shorter-lived pine species to longleaf pine	12	3	1	50%
6. Translocation of birds	13	3	0	50%

locations due to the limited number of trees old enough or large enough for excavation. One biologist with the Department of Defense stated how artificial cavities provide a remedy to this challenge:

Some Forest Service folks up in the Francis Marion National Forest developed a technique—the first technique—for drilling cavities into second-growth pine in order to stabilize the population after Hurricane Hugo. Subsequent [to] that, somebody else developed an artificial cavity insert technique, which was more applicable across the range because you didn't necessarily have to have trees with a large heartwood to sapwood ratio... It can be a relatively young tree with very little heartwood, and you can just slap that insert in there and you're good to go. So that has been the basis of the rapid growth that we've experienced...

One participant (with over 30 years of experience) referred to the development of artificial cavities as an important milestone in RCW conservation because they allowed RCWs to occupy trees that would otherwise be too young for them to excavate (birds target older trees with a certain level of internal decay to expedite excavation). This innovation has allowed managers to quickly install nests for groups of birds that would otherwise not be able to utilize these younger stands, and to grow their populations much faster than they otherwise would have been able.

Translocation of individual RCWs was mentioned by half (50%, n = 16; Table 2: row 6) of those interviewed. Translocation consists of moving young birds from a location with a high population to augment a population at another location. It requires significant coordination among managers and substantial monitoring, but was cited by managers as successfully contributing to the growth of many populations that may have otherwise been lost.

More holistic and broadly focused strategies used in RCW management that were reported included: the use of prescribed fire, thinning and harvesting to better resemble historic conditions, and reducing hardwood species in the midstory. Fire was specifically mentioned as an RCW population recovery strategy by all participants and was often referred to as an integral part of land management for pine ecosystems in general. Participants often made comments along these lines:

… if we weren't burning, we would get a lot of midstory encroachment in the pine stands. And, you know, burning here in the Southeast is ecologically important because of all these stands evolved with fire and they're dependent on fire to stay in the sort of natural habitat that encourages red-cockaded woodpeckers. So, we see it as critical for red-cockaded management and it's also important for us . . . to manage the timber for timber harvesting, to keep them open for outdoor recreation and aesthetics, and keep the fuel loads down to try to minimize the impact of any wildfires we might have here.

Participants emphasized throughout interviews that fire was important not only to RCWs, but to the broader goal of restoring longleaf pine—something that was not originally a priority when RCWs were first listed under the ESA.

When discussing fire use, managers talked primarily about prescribed fire; however, in some limited cases, they also mentioned taking advantage of unplanned ignitions. This was especially true for Department of Defense (DoD) lands, which participants described as having greater flexibility to let natural ignitions, or even ignitions inadvertently started by military training activities, burn for ecosystem benefits. Thirteen (41%; Table 2: row 1b) participants said that, on their respective properties, they were able to manage unplanned ignitions for ecological benefit under the right conditions, either by burning up to a specified boundary or by treating the fires as prescribed fires and allowing them to burn over a larger area than they would if engaging in suppression efforts.

Forest thinning and reduction of the hardwood midstory (through mechanical and chemical means) were both mentioned by the majority of participants (81%, n = 26 and 69%, n = 22, respectively; Table 2: rows 3 and 4). These activities were done in part to restore the open vegetation structure and better emulate historic conditions. At many locations, stands of longleaf pine had previously been cutover and planted with faster growing, shorter-lived species (*e.g.*, slash pine, *Pinus elliottii* Engelm.). Fifty percent of participants indicated that they desired to convert these planted stands back to longleaf pine (n = 16; Table 2: row 5).

When asked how strategies had changed over time, a pattern emerged across participants, with one of the most frequently listed responses being that efforts had moved from being focused on a single component (*e.g.*, RCW as a single species) to managing the entire ecosystem (28%, n = 9; Table 3: row 1). As one participant with over 20 years of RCW experience indicated:

…it used to be a lot more about inserts and a lot more about translocation. And now it's much more about ecosystem restoration… I feel like we used to treat the symptoms and now we're actually treating the disease.

Another participant with over 30 years of RCW experience talked about their agency (USFS) embracing ecosystem management as a "light coming on:"

Table 3 Responses from natural resource professionals in the Southeaster Coastal Plain of the United States (2015 to 2016) when asked, "how have RCW management practices change throughout your career?" (Additional file 1: question 18). Some interviewees gave more than one response

	Experience working with red-cockaded woodpeckers						
Response	0-5 yr	6-10 yr	11-15 yr	16-20 yr	21-25 yr	>26 yr	Total (*n*)
1. Managing whole ecosystems rather than individual components	1	3	1		3	1	9
2. Innovations in technology (*e.g.*, peeper cameras, development of artificial cavities)	1	1	2	1	3	1	9
3. Agency attitude towards RCW management now more positive	1		4			3	8
4. No change during their career	4		4				8
5. More prescribed fire		1		1	3	1	6
6. Translocation program has grown or improved			1		1	1	3
7. Greater knowledge of habitat needs		1	1		1		3
8. Increase in wildland-urban interface concerns					1		1
9. More inter-agency collaboration						1	1
10. Less demand for translocated birds	1						1
11. More staff resources devoted to RCW management activities						1	1
Total participants by experience	5	6	7	2	6	6	32

> *So that was kind of a light coming on is that if we would shift to longleaf, it would be more sustainable. It would embrace ecosystem concepts and I think it was the very beginning. The light wasn't…didn't have a lot of voltage or a lot of wattage. It was a little glimmer, but it was the beginning. And so that to me was where we started looking at how to fit species composition and structure to the land, as opposed to fighting all these perceived restrictions and to get a perceived quantity of timber out.*

Participants also noted how innovation and advancements in technology had changed over time (28%, *n* = 9; Table 3: row 2), often citing artificial cavities as an important development. A quarter of participants (25%, *n* = 8; Table 3: row 4) said that no changes had occurred in RCW management over the course of their career; however, all of these participants had 15 years or less experience with RCWs (Table 3: row 4). Other notable changes (with >2 total responses) included: an increase in the use of prescribed fire (19%, *n* = 6; Table 3: row 5), growth in the translocation program (9%, *n* = 3; Table 3: row 6), and an increase in knowledge of RCW habitat needs (9%, *n* = 3; Table 3: row 7).

According to those who had been engaged in RCW management the longest (12 managers had been involved for at least 22 years, about half as long as RCW had been listed), RCW management was not initially viewed favorably by most. Indeed, four of these highly experienced participants described an initial frustration in the early stages of recovery efforts within their agency related to RCW management, with the perception being that this would affect their agency's ability to harvest timber. Describing the changes that took place within the agency over the years, one USFS employee with over 20 years of RCW experience stated:

> *When I first started I [saw] a lot of resistance within the Forest Service to managing for woodpeckers. A lot of denial…where these days I think embracing woodpecker management is part of what the Forest Service [is] all about—restoring the forest to condition … active management is compatible and even necessary to sustain the species … certainly there is a conflict if you're going to do short rotation timber management. And there were a lot of folks when I started in the late 80s that still thought that's what the Forest Service ought to be doing on national forests, but we are way past that through adoption of ecosystem management … and I just don't see those conflicts anymore.*

Participants were also asked to look ahead and consider how management may change in the future once the species recovered (Additional file 1: question 20). There was general agreement among managers that habitat management activities would continue regardless of the federal status of the RCW (81%, *n* = 26; Table 4: row 1). One federal agency participant noted:

> *…we're always going to be doing management techniques, because you can't get fire on the ground any other way, but maybe not so heavy handed … I'm one of those if you build it they will come. If you create some good habitat where there's longleaf and [loblolly] shortleaf and you start managing with fire and*

Table 4 Most frequent responses by natural resource professionals in the Southeastern Coastal Plain of the United States (2015 to 2016) when asked, "if recovery (or delisting) were achieved for the RCW population at the property where you work, how would that influence your future management approaches?" (Additional file 1: questions 22 and 23)

	Interviewees (*n*)			
Anticipated management following recovery or delisting	Federal	State	Private	Percentage of Interviees (%)
1. Maintain current habitat management	20	5	1	81%
2. Less intensive management	12	3	0	47%
3. Change in monitoring	9	5	0	44%
4. Focus on other priorities or species	9	4	0	41%
5. Change in funding	11	1	0	38%
6. Greater flexibility with timber harvest	4	2	0	19%

> *continue those activities, then I'm looking at recover[y] being a success. And hopefully weaning off of having to do artificial cavities so heavily and replacements because that is very time consuming.*

Participants also speculated that the more intensive and species-specific strategies, such as installing artificial cavities or translocating birds, would become less important over time as forests continue to age and the number of potential cavity trees increases over time. Nearly half (47%, *n* = 15; Table 3: row 2) of participants indicated that they expected it would be possible to scale back these intensive, species-specific conservation actions over time. Other responses regarding anticipated changes in management should RCWs be considered recovered included: a change in the amount of monitoring done for RCWs (44%, *n* = 14; Table 4: row 3), focusing more time and resources on other species or priorities (41%, *n* = 13; Table 4: row 4), a change in funding (38%, *n* = 12; Table 4: row 5), and having greater flexibility with timber harvest (19%, *n* = 6; Table 4: row 6).

Compatibility and tradeoffs among objectives

Participants were asked to think about RCW management as it relates to other management objectives on their respective properties (Additional file 1: question 16). When participants were asked explicitly about conflicts between RCW management and their other objectives (Additional file 1: question 16b), more than one-third of participants, with representation across all property types, said that they did not experience conflicts between RCW management and other objectives (37%, *n* = 11; Table 5: row 2). However, throughout the entirety of the interviews, several sources of conflict between RCW management and other natural resource management objectives were mentioned at some point in conversation. Forty-four percent of participants identified instances for which the RCW Recovery Plan was not appropriate in all contexts (*n* = 14; Table 5: row 1). Other specific sources of conflict included: the RCW Recovery Plan foraging habitat requirements preventing longleaf pine restoration (32%, *n* = 10; Table 5: row 3), restrictions on timber harvest (30%, *n* = 9; Table 5: row 4), missions on Department of Defense-owned properties (17%, *n* = 5; Table 5: row 5), and restrictions on activities in occupied stands during the nesting season (10%, *n* = 3; Table 5: row 6).

Despite some areas of tension in satisfying RCW management goals and other objectives, in some cases, participants indicated that RCW presence on a property helped facilitate active management in other areas, such as longleaf pine forest restoration. Sixty-nine percent (*n* = 22) of participants indicated that, at some point during their interview (unprompted), current RCW management was compatible with longleaf pine restoration objectives and

Table 5 Sources of conflict with red-cockaded woodpecker management most frequently mentioned during interviews with natural resource professionals working in the Southeastern Coastal Plain of the United States (2015 to 2016), listed in ranked order. Two interview participants were not explicitly asked this question

	Interviewees (*n*)			
Sources of conflict mentioned	Federal	State	Private	Percentage of Interviewees (%)
1. RCW Recovery Plan is not appropriate in all contexts	12	2	0	44%
2. No conflicts	10	1	0	37%
3. Foraging habitat requirements prevent conversion to longleaf pine	9	0	1	32%
4. Timber harvest is restricted	3	5	1	30%
5. Mission conflicts (DoD)	5	0	0	17%
6. Activity within stands during the nesting season is restricted	2	1	0	10%

provided benefits to other species. One participant from USFS said:

> *Our objective is to restore native longleaf ecosystems and when we do that we're going to have RCW. And so I tend to think that our goal is to fit the management to the ecosystem. And then the endangered species will take care of itself … sometimes you have to do the things like inserts and those types of things to help out. But if it was a perfect world, we would manage the ecosystem and the woodpecker would take care of itself.*

In addition, many participants (44%, n = 14) elaborated (unprompted) that having RCWs on their land provided justification for the use of fire or mechanized thinning, and 39% (n = 9) of federal participants talked about the presence of the RCW as an impetus to engage in ecosystem restoration projects. One USFS biologist stated, "The pressure from the RCW pushed the agency to take care of this ecosystem better and more aggressively than if it were just managing for commodity."

Those participants who reported challenges in meeting some of the requirements outlined in the RCW Recovery Plan often referred to circumstances that would prevent them from meeting the specified foraging requirements. The RCW Recovery Plan recommends state and federal lands provide 120 acres (49 ha) of good quality foraging habitat per woodpecker group on medium- to high-quality sites, and 200 to 300 acres (81 to 121 ha) on lower productivity sites (USFWS 2003). Quality foraging habitat is defined within the RCW Recovery Plan according to region and gives specific basal area recommendations for stands occupied by RCWs (USFWS 2003:199-201). Some participants described how problems have arisen when there is a higher density of family groups nesting in an area. When this happens, managers may find it difficult to provide the designated amount of foraging habitat to each cluster. This also prevents managers from harvesting as much timber as they might have otherwise. Interview participants at these sites described their properties as having greater site productivity and arthropod abundance, allowing more groups to occupy an area than was considered possible when the RCW Recovery Plan was developed. One USFS biologist stated that:

> *…in a lot of areas, you'll see RCWs have a territory of anywhere from 150 to 500 acres, because they need that foraging habitat... We've got areas of the forest you can stand in one spot and see four clusters. So essentially, they're packed in very tightly. So we're almost getting to the point in some areas where we're reaching carrying capacity. And that's just because of the quality of the habitat has been improving… they didn't anticipate us having this many birds. So essentially, we have difficulty because we have so much overlap in the foraging partitions for our birds because they're just packed in so tightly. It becomes difficult to manage timber sometimes.*

Some participants also reported that this issue affected their ability to make progress with longleaf pine restoration efforts. Stands composed of shorter-lived, planted pine species, although usually not used for nesting, can provide foraging habitat for RCWs. Managers wishing to convert these aging stands to longleaf pine are faced with a dilemma: clear-cut these stands and replant to longleaf pine, progressively thin stands as a more gradual transition to the desired condition, or to leave them as is to contribute to meeting the requirements for quality foraging habitat. One manager articulated the problem this way:

> *So that's a challenge, it really is… Some people probably lean more heavy into managing more aggressive for longleaf restoration while biologists probably say, "No we need to do more to preserve what we have and manage for the red-cockaded woodpecker we currently have and the habitat we currently have." Because if you clear-cut it … that's going to be basically unsuitable for foraging for at least 30 years and unsuitable for nesting for at least 60. So you just took it out for at least 30 years for even being utilized by RCW.*

Participants described how the habitat requirements in the Recovery Plan prioritized the provision of foraging habitat in the near-term over the benefits that could result in the long-term from restoring longleaf pine (albeit with some near-term loss of foraging habitat).

While participants identified issues related to the compatibility of RCW management with other natural resource management objectives, many also felt that they would have an opportunity to resolve issues through consultation with USFWS, which has statutory authority with responsibility to administer the ESA and related protections in regard to the RCW. Unprompted by a question in the interview guide, 44% (n = 14) of participants mentioned having successfully resolved an issue with USFWS in the past, and several (12.5%, n = 4) said that they were planning to consult with USFWS over an issue that they were having, at some point in the future. Identified issues were either related to property population recovery thresholds or another property-specific management issue.

Discussion

RCW population recovery efforts have evolved over the 40+ years that they have been listed under the ESA.

Recovery and management efforts have been characterized by two distinct phases thus far: 1) an initial phase following the listing of RCWs under the ESA that was primarily motivated by preventing extinction; and 2) a second phase, in which management has shifted, or is beginning to shift, to incorporating RCW conservation into broader ecosystem management efforts. While participants frequently described current management as including a combination of strategies, most described a shift away from those entirely RCW-focused toward others that are more closely aligned with longleaf pine restoration. One participant described this as shifting from treating symptoms (*i.e.*, reduced numbers of RCW individuals) to treating the underlying causes (*i.e.*, fire suppression).

Navigating decision making and policy surrounding environmental issues is often fraught with uncertainty, particularly in relation to the outcomes of management options available (Farber 2003; Polasky et al. 2011). This is, in part, due to the nature of these types of issues; often ecological systems may include interacting components for which knowledge of inter-relationships is not complete (Farber 2003). Often, managers and other natural resource professionals must still move forward with decision making and planning in the absence of sufficient information with potentially dire consequences (Polasky et al. 2011). For example, when making decisions about managing wildfire events in circumstances that may warrant wildland fire use to achieve multiple management objectives, managers are faced with high levels of uncertainty and decision complexity. Risk aversion has been well documented among fire managers, who have been shown to rely on decision heuristics, more often choosing the most immediately safe option (*i.e.*, suppression) at potential cost to long-term goals (*e.g.*, fuels reduction; Wilson et al. 2010). Under these circumstances, there are rarely rewards for experimentation or for adapting established methods. Further, any negative consequences incurred from taking a risk usually reflects poorly on the individual rather than resulting in an analysis of the decision itself (Maguire and Albright 2005).

The risk associated with this uncertainty is amplified for endangered species management decisions for a number of reasons. For instance, there may be limited data to inform recovery decisions for threatened or endangered species, particularly when they are first listed; however, there is the potential for irreversible damage (*i.e.*, extinction) if the wrong decisions are made (McGarvey 2007). This is why listing decisions for species are typically governed by the precautionary principle, whereby conservation measures are put in place for species suspected to be at risk of extinction even when there is incomplete knowledge about the relationship between the species in question and a potential risk (Ruhl 2004; Prato 2005). This minimizes the potential for overlooking a species in need of immediate conservation action. Then, once a species is listed, agencies managing the associated habitat have specific legal obligations to prevent harm (16 U.S.C. §1538), and so have a strong incentive to minimize uncertainty and extinction risk to the greatest extent possible. While such an approach may be effective at reducing near-term extinction risk, the risk-averse decision environment, however, can also limit experimentation in approaches, particularly early on when knowledge about the species may be limited and uncertainty is high (Mealey et al. 2005).

Along these lines, many of our interview participants described initial RCW management as consisting of highly intense efforts with a nearly singular focus on growing populations of RCWs to reduce their likelihood of extinction. However, over time, many noted that the thinking surrounding RCW management had shifted. Participants indicated that knowledge gained through study and implementation of recovery efforts had substantially reduced the perceived uncertainty related to consequences of management decisions. In addition, a growing number of properties are now managing populations of RCWs that have met their initial goals outlined in the RCW Recovery Plan, and so the threat of extinction is less acute than in previous years. Our participants expressed a reduced urgency to allocate their time and resources to continue to emphasize species-specific efforts, saying that, as long as they prioritized their prescribed fire program and maintained the appropriate stand structure, RCWs would be able to persist.

Since the initial listing of the RCW, the USFS has also shifted its priorities and explicitly adopted an ecosystem management approach (originally known as "New Perspectives"), with the intention of encouraging more holistic land management and greater integration of ecological, social, and economic factors (Salwasser 1991; Thomas 1996; MacCleery 2008). Several USFS participants specifically discussed how adoption of ecosystem management within their agency changed the way they operated and prioritized objectives. Along with this change in policy, participants from the USFS described an associated change from conceptualizing RCW management and forest management goals as competitive, to increasingly recognizing the compatibility between the needs of the RCW and the agency's new direction toward managing whole ecosystems (with an emphasis on longleaf pine recovery in our study locations).

This transition from an initial extinction prevention phase to a more broadly focused ecosystem management phase has not been without challenges, however. Those instances in which managers reported conflicts between

RCW protection and longleaf pine restoration serve to highlight the difficulties that can be experienced in balancing needs of protected species and ecological restoration. Conflicts reported by participants primarily occurred in situations in which they wanted to convert shorter-lived pine stands that were currently being used for foraging habitat. In such cases, some felt constrained to manage for the near-term foraging benefits provided by these stands, even though they would eventually deteriorate and no longer serve RCWs. Substantial research has revealed a tendency among managers to be unwilling to adopt an action that carries immediate risk, even if it is more likely to provide long-term benefits and mitigate long-term threats (*e.g.*, Christensen 2003; Stankey et al. 2003; Wilson et al. 2009). Such a tendency is referred to as "certainty bias" (Kahneman and Tversky 1979), and the broader literature has shown that this may result in a failure to recognize the risks that are carried by inaction over a longer time frame. For example, clear-cutting shorter-lived pine species to initiate a transition to longleaf pine results in a near-term reduction in RCW foraging habitat but, ultimately, will provide longer-term improvements in habitat quality.

This same aversion to taking near-term risks and the resulting paradox has been documented in the progression of management for the endangered northern spotted owl (*Strix occidentalis caurina* Merriam). Little active forest management occurred within areas designated as critical habitat for the northern spotted owl habitat (old-growth coniferous forest), including treatments to reduce stem densities with the goal of preventing a catastrophic wildfire (Mealey et al. 2005). In this type of situation, decision makers may fail to recognize long-term risks posed by inaction, such as the deterioration of stands composed of shorter-lived pine species. When larger-scale restoration efforts are needed within habitat designated for an endangered species, this type of situation has the potential to occur and act as a roadblock to providing quality habitat further into the future.

Considering endangered species management beyond near-term actions and consequences can be challenging not only psychologically but also logistically and administratively. For many listed species, active management may be required in perpetuity, particularly if their habitats are created or maintained by processes, such as fire, that are no longer intact within their habitat and so require human intervention to be sustained. Goble et al. (2012) define this type of condition as "conservation reliance," by which species threats "cannot be eliminated, but only managed." Even if that species has exceeded the specified recovery threshold, managers and authorities may not feel comfortable moving forward in delisting a species if they cannot ensure that threats to the species will be sufficiently addressed in the long term. In an analysis of 311 recovery plans, Foin et al. (1998) found that more than half recommended restoration of habitat or some form of active management beyond simply preserving habitat. Ultimately, this suggests that, for many listed species, ongoing active interventions will be required to maintain recovered populations. In the case of RCWs, managers readily acknowledged that RCWs would require habitat management into the future. However, participants were generally positive about ongoing availability of resources to support these efforts because habitat management was compatible with, and in some cases provided justification for, longleaf pine restoration activities. In many cases, participants cited this alignment of RCW conservation and ecological restoration efforts as being key to their success in ensuring the long-term recovery of the species.

Conclusions

Recognizing connections between single-species strategies and broader restoration strategies may help managers to support long-term management for species even after population recovery is officially achieved. This is especially important for many other species like the RCW that could be considered "conservation reliant." For these species, specific management interventions are necessary to prevent population declines (Goble et al. 2012). In the case of RCWs, by viewing strategies as mutually beneficial to RCWs and longleaf pine restoration, managers expected that resources to engage in ongoing management would continue to be allocated long term. RCW habitat needs and longleaf pine restoration may be more closely aligned than may be expected for other protected bird species of fire-dependent forest ecosystems. For instance, in jack pine (*Pinus banksiana* Lamb.) ecosystems of northern Michigan, USA, the Kirtland's warbler, unlike the RCW, evolved under a high-severity, infrequent (>50 yr) fire regime. Currently, however, most birds breed in even-aged, young jack pine plantations, rather than stands regenerated by fire (Donner et al. 2008). Myer (2012) found that prescribed fire had largely been excluded from recovery efforts, with high levels of risk aversion to using fire in this context among natural resource professionals. Recovery efforts for this species to date have been primarily characterized by use of intensive mechanical interventions to provide a reliable method to develop and maintain suitable habitat (Barnes 1993; Corace and Goebel 2010; Corace 2018). These methods tend to provide a higher proportion of young stands of jack pine on the landscape than would have been seen historically (Tucker et al. 2016), and some have suggested altering the timing and the replanting pattern of jack pine plantations, as well as retaining biological legacies such as standing dead trees and coarse woody debris (Spaulding and Rothstein 2009; Corace and

Goebel 2010) to more closely resemble the patterns produced by wildfire and help meet the needs of a broader suite of species. Recognizing areas of overlap between endangered species management and other objectives could help to ensure that efforts to maintain quality habitat for species continue to be prioritized long term.

This study supports the value of considering endangered species management within the context of broader ecosystem management goals. Manager perceptions of the potential risks and benefits of their actions ultimately affect the approach that is taken for the conservation of a threatened species. The RCW case demonstrates a potential evolution from initial single-species efforts to reduce near-term extinction risk toward longer-term focus on more holistic strategies as populations begin to stabilize. This type of approach balances risks and benefits over the near and long term. The conflicts related to balancing near-term and long-term needs are not unique to RCWs but have been identified as applying to other endangered species as well (Meretsky et al. 2000; Mealey et al. 2005). Particularly when threats to species are directly linked to ecosystem processes, it may be advantageous to integrate species conservation into a broader ecosystem restoration approach. For the RCWs, participants reported that emphasizing habitat management strategies that emulate or restore natural disturbance processes allowed for extended benefits to other species and the ecosystem as a whole. We recognize that the ability to address process-based threats, such as fire suppression, will depend on a complex set of ecosystem factors (*e.g.*, the process in question or discrete factors such as invasive species), as well as a degree of risk tolerance by both managers and nearby human communities to potential risks that may be posed by restoring ecosystem processes. While human communities are often cited as a constraint to using strategies such as prescribed fire, substantial research has demonstrated high levels of understanding and support for management use of fire across the country (*e.g.*, see summary in Toman et al. 2013).

Limitations

Several limitations of this study merit consideration. First, by examining manager perspectives of a single species, any insights and inferences must be looked at in light of these species-specific contexts. Our findings also reflect perceptions of managers and do not represent a review or analysis of management actions themselves. We primarily sampled individuals who worked on public lands, with the majority working for federal agencies, and results do not reflect the views of those involved in management of RCWs on other landownership types. Additionally, the qualitative nature of the data also prevents the use of formal statistical analyses beyond descriptive statistics for this particular group of managers. The percentages reported reflect the number of participants who raised each concept or idea rather than the proportion of the broader management population who may hold a particular perspective. Although this approach does not allow broader inferences to other populations to be made, it allowed for a greater depth of information to be collected from participants.

Additional file

Additional file 1: Interview guide used to guide conversations with natural resource managers involved in red-cockaded woodpecker management in the Southeastern Coastal Plain of the United States (2015 to 2016). Interviews were semi-structured and not all questions were asked verbatim or posed to all participants. (PDF 227 kb)

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Availability of data and materials
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Authors' contributions
SAW was responsible for study design, collecting interview data, data analysis, and drafting this manuscript. ELT was responsible for study design, reviewing interview protocol, overseeing analysis, and providing feedback and revisions to manuscript drafts. RGC III was responsible for initial project idea, providing feedback on the study design, facilitating contacts for field visits, and providing feedback and revisions to manuscript drafts. All authors read and approved the final manuscript.

Ethics approval and consent to participate
The interview protocol used was reviewed and approved by The Ohio State University Institutional Review Board for research including human subjects. Informed consent to participate in the study and permission to audio record was obtained from each participant.

Consent for publication
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Competing interests
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