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Invited Paper

Transferring Research to Endangered Species Management

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ABSTRACT In the natural resource and wildlife profession, we face difficulties in the production, diffusion, and transfer of rigorously tested science, especially when facing entrenched management paradigms. We present 3 case studies to illustrate the challenges in changing entrenched management paradigms for endangered species. Here we examine specifically what factors helped or hindered the adoption of management practices through the theoretical framework developed for the dissemination of technologies. An examination of 3 case studies suggests that active communication and advocacy of scientific findings, along with simple, visible results, will aid researchers in the acceptance and adoption of their research. Management agencies that increase openness and communication with outside experts, reduce bureaucratic procedures, and localize decision making increase the likelihood that new scientific ideas will be adopted by the agency. We also suggest adaptive resource management as a strategy for endangered species management may foster many of the characteristics that aid in the adoption of scientific ideas into management activities. (JOURNAL OF WILDLIFE MANAGEMENT 71(7):2134–2141; 2007)

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For many of our advances in science, the acceptance of new, useful information has not always come in a timely or orderly fashion. Revolutionary ideas and findings from scientists have often been slow to disseminate and become accepted and used by society (Rodgers 1995). In the natural resource and wildlife profession, we face similar difficulties in the transfer of science into management activities (Healy and Ascher 1995). This challenge has been exacerbated in part by shortcomings in the production of rigorous science that has given rise to a number of suspect management practices (Romesburg 1981). From the inception of wildlife sciences, poorly designed research and expert opinion have produced many dogmatic management paradigms that have been perpetuated by authority, rhetoric, and repetition, despite the fact that many of these ideas have never been adequately tested (Romesburg 1981, Macnab 1985). The magnitude and implications of managing wildlife resources under assumptions that have never been tested were brought to the forefront almost 25 years ago. Romesburg (1981) likened this phenomenon to building a house on a false foundation of knowledge that was bound to crumble.

Although problems caused by a lack of rigorous science are still with us, the scope of the problem and ways to improve the collection of reliable knowledge has been addressed repeatedly in published literature (Gill 1985, Macnab 1985, Peterson 1991, Sinclair 1991, Anderson et al. 2003). Unfortunately, the production and publication of new rigorous science alone cannot overturn entrenched management paradigms that have gone unchallenged (Gotham 2003). Ideas fostered by sound research are not always accepted and used by managers (Healy and Ascher 1995), especially when new ideas contradict dogmatic beliefs. Nonetheless, there is a paucity of published accounts on why research results are not incorporated into management activities (e.g., Sinclair 1991, Healy and Ascher 1995, Bunner and Clark 1997) and how the incorporation of research into management decisions can be improved. Research scientists and managers in the field of natural resource sciences will be better prepared to counteract the status quo and bridge the gap between science and management if they understand what specifically increases or decreases the adoption of scientific findings into management decisions.

The inclusion and acceptance of ideas and innovations into practice can often be laborious, but this does not have to be the case (Rodgers 1995). Research on diffusion of innovations (the process whereby innovations are transferred over time; Rodgers 1995) and the variables that affect the adoption of new ideas have been helpful in speeding the acceptance of new medical treatments (Solan et al. 1986) and high-tech products (Cusumano and Elenkov 1994, Murtha et al. 2001). Researchers have pointed to several broad categories (comprised of multiple variables) that correlate to whether and at what rate innovations are adopted (Gotham 2003). Three categories pertinent to the dissemination of natural resource sciences are 1) the strategies of dissemination, 2) attributes of the technology, and 3) the characteristics of the adopters and organizations (Rodgers 1995, Gotham 2003). Strategies of dissemination are concerned with how information about an innovation is presented and communicated (e.g., mass media, word of mouth). It has been shown that active communication strategies (direct personal contact, training workshops, and videos), for example, are more effective in disseminating information than written communication and journal articles (Gotham 2003). The second area, perceived attributes of innovations, is comprised of 5 variables (Rodgers 2003): 1) what is the advantage of the innovations, 2) how complex is it, 3) is it compatible with values and past experiences, 4) can you experiment with it, and 5) are the results of the idea easily observable. Lastly, at times

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organization and groups fail to consider favorable alternatives so that group members can maintain status or keep group cohesion (Kim 2001). In addition, groups and organizations in fields from politics to science have been shown to make decisions that favor familiar and known commodities in a phenomenon duly named the status quo bias (Samuelson and Zeckhauser 1988, Cramer 1998). Nonetheless, there are characteristics of organizations and groups that correlate to the rate at which innovations are adopted (Rodgers 1995). Large organizational size (Rodgers 2003), organizational complexity (relative degree of knowledge and expertise possessed by an organization's members), and system openness (the degree to which members interact with and exchange information with individuals outside of the organization) have all been positively correlated with adoption of innovation (Rodgers 1995) and creation of an environment that is receptive to new ideas. On the other hand, centralization (the degree to which power and control are concentrated) and formalization (organization emphasis on procedures and rules) help perpetuate the status quo and are negatively correlated with the adoption of innovations (Rodgers 1995). In addition, government agencies, which usually have high levels of centralization and formalization, have historically also shown a lack of support for creative thinking, thus further hindering their ability to adopt innovations (Von Oech, 1998).

Here we will present 3 case studies to illustrate some of the difficulties in overturning entrenched management paradigms and incorporating scientific findings into the management of species that are threatened with extinction. We recognize there are many other examples that could be used or cited; however, we were personally involved with these 3 case studies, and therefore we will only use these 3 to demonstrate the challenges in changing entrenched paradigms. We will focus first on obstacles and problems from current or previously held management paradigms. Then, through the theoretical framework developed for the dissemination of technologies, we will examine specifically what factors helped and hindered the adoption of new rigorously tested management practices. Through this process we hope to illuminate mistakes, as well as highlight successes, in the hopes that others can more easily navigate the frustrating process of transforming research into action.

LESSER PRAIRIE-CHICKEN

Since the late 1800s, the range and numbers of prairie-chickens (*Tympanuchus* spp.) have been reduced considerably from historically occupied regions of eastern New Mexico, southeastern Colorado, southwestern Kansas, western Oklahoma, the Texas Panhandle, and possibly southwestern Missouri and southwestern Nebraska, USA (Crawford 1980, Taylor and Guthery 1980, Giesen 1998). Rangewide declines (>97%) in abundance have resulted primarily from habitat loss (Crawford 1980, Taylor and Guthery 1980). Though considerable research has been conducted on lesser prairie-chickens, declines throughout their range and populations have continued over the past 60 years.

In 1995, the United States Fish and Wildlife Service (USFWS) was petitioned to list the lesser prairie-chicken (*Tympanuchus pallidicinctus*) as threatened under the Endangered Species Act, and in 1998 a "warranted but precluded" listing was given (U.S. Department of the Interior 1998:31400–31406). In Texas alone, Litton (1978) estimated up to 2 million prairie chickens prior to 1900. By 1974, the estimated number of lesser prairie-chickens in Texas was 17,000 birds (Litton 1978), and today <3,500 birds remain (S. DeMaso, Texas Parks and Wildlife Department, unpublished data). Concerns of lesser prairie-chicken extinction in Texas arose in the 1930s, when population levels reached record lows; thus, a ban on hunting was enforced from 1937 until 1967 (Litton 1978), after which hunting was permitted. In 1940, lesser prairie-chickens inhabited portions of 20 counties (approx. 1.4 million ha) in the Texas Panhandle, but by 1989 occupied range had decreased by 58% (573,230 ha) and prairie chickens were restricted to portions of 12 counties (Sullivan et al. 2000). Though numbers of lesser prairie-chickens in Texas increased to huntable levels in the 1960s, populations declined in the 1990s due to drought and continued habitat loss (Sullivan et al. 2001).

In Texas, previous research on lesser prairie-chickens occurred primarily in the shinnery oak (*Quercus havardii*) rangelands of the southwestern Texas Panhandle (Sell 1979, Crawford 1980, Haukos and Smith 1989, Olawsky and Smith 1991); therefore, much of the habitat needs of lesser prairie-chickens are based on this research. For example, Crawford (1980:4) stated that "brush species such as shinnery oak or sand sagebrush (*Artemisia filifolia*) and tall grasses like sand bluestem (*Andropogon hallii*) constitute the critical components of lesser prairie-chicken habitat." Similarly, Jones (1963), working in Oklahoma, noted that based on actual use by lesser prairie-chickens, the habitat of lesser prairie-chickens consisted of small units of short-grass prairie intermixed with larger units of shrub or half-shrub vegetation. Jackson and DeArment (1963) believed the removal of shinnery oak and sand sagebrush with herbicides to be one of the major factors affecting lesser prairie-chicken populations. Although Taylor and Guthery (1980) noted the original habitat requirements of lesser prairie-chickens were poorly documented, they reported that 2 general vegetation types (sand sagebrush and shinnery oak) were suitable for lesser prairie-chickens.

Today, many biologists working on lesser prairie-chickens believe that managing shinnery oak habitat is important to increasing prairie chicken populations (Boyd and Bidwell 2001, Hagen et al. 2004, Bell 2005). This paradigm has become entrenched because most previous lesser prairie-chicken habitat research in Oklahoma, New Mexico (Jones 1964, Donaldson 1969, Wisdom 1979, Riley and Davis 1993, Riley et al. 1993), and Texas (Sell 1979, Crawford 1980, Haukos and Smith 1989, Olawsky and Smith 1991) has been conducted within the shinnery oak areas. Nonetheless, most of the lesser prairie-chickens' former range that was not in shinnery oak had been placed into cultivated agriculture long before the bird was studied. Because shinnery oak is found only on deep-sand range sites and is not cultivated, today's remnant populations are relegated to these sites.

When researchers began to study lesser prairie-chicken habitat use, the only vegetation types remaining in use were the sandy-range sites supporting shinnery oak or sand sage, and not surprisingly, these sites were determined to be preferred habitats. What biologists have failed to consider are the vegetation types that covered the 92% of the area lost to lesser prairie-chickens since the 1800s (Taylor and Guthery 1981). As noted by Silvy et al. (2004), lesser prairie-chickens are currently found in the submarginal vegetation types because the preferred types were placed into cultivation long ago.

This problem has been exacerbated because many managers are not familiar with the historical or current literature. For example, Copelin (1963) noted that lesser prairie-chickens were widely distributed in western Oklahoma before the prairie sod was tilled. He stated the occupied range of lesser prairie-chickens was greatly reduced by cultivation of most of the land, which began with settlement in 1890. Jones (1963), working in Oklahoma, noted that most display grounds of lesser prairie-chicken were on the short-grass association and the only nest he was able to locate was in a short-grass community consisting of purple three-awn (*Aristida purpurea*) and sand sagebrush. Baker (1953) noted lesser prairie-chicken in Kansas prior to the drought of 1930–1940 occupied areas supporting tall grasses. He noted these tall grasses were eliminated over wide areas and were replaced by sagebrush (*Artemisia* spp.) due to overgrazing; however, in nongrazed areas, tall grasses were crowding out sagebrush, but in thousands of acres of rangeland, sagebrush and short grasses still predominated. Today, lesser prairie-chicken in Colorado are found in areas without shinnery oak (Peterson and Boyd 1998). Hoffman (1963) noted that overgrazing changed many of the mixed-grass plant communities to short-grass prairie.

If lesser prairie-chicken were historically found in Missouri and Nebraska as stated by Crawford (1980), then these states also did not have shinnery oak habitat. Kansas also has no areas of shinnery oak and probably today supports more lesser prairie-chicken than any other state. Recently their occupied range has increased as croplands have been placed into native grasses (Jensen et al. 2000) through the Conservation Reserve Program. Robb and Schroeder (2005) also noted that conversion of native grassland for production of row crops was believed to be largely responsible for the range-wide decrease in occupied habitat.

Although research was available indicating shinnery oak control using herbicides increased lesser prairie-chicken use (Donaldson 1969), this myopic view of a need for shinnery oak habitat by lesser prairie-chickens has and will continue to hamper management of lesser prairie-chickens throughout their range. Peterson and Boyd (1998) estimated that <607,000 ha of shinnery oak habitat have been lost in historic times, whereas Crawford (1980) estimated that 97% of the lesser prairie-chicken population has been lost since historic times. It is inconceivable that >97% decline in lesser prairie-chicken abundance in the United States was associated with a loss of shinnery oak habitat, yet today many still hold to this belief. Did all of the 97% lost lesser prairie-chicken occupy the 607,000 ha of shinnery oak that was lost? Nonetheless, changing the entrenched paradigm of shinnery oak as a preferential habitat has not been as easy as simply illuminating historical information. Still, there are several reasons to be optimistic.

First, the current dissemination strategy for the idea that lesser prairie-chicken are not dependant on shinnery oak habitat has been highly active and interpersonal. The ideas expressed in this section of the article have been presented at scientific meetings, technical working group forums, and discussed directly with the people who have the ability to change the present thinking. Additionally, it has been difficult to observe the benefits to lesser prairie-chicken of converting existing cropland to prairie habitat; however, through the federal Conservation Reserve Program it should become easy to test the effects of this conversion on lesser prairie-chicken populations. Testable and observable results would greatly improve the chances for dissemination and acceptance of a new habitat paradigm. Another advantage is the fact that there has been only a handful of biologists and managers who research, manage, and perpetuate the current beliefs pertaining to preferred lesser prairie-chickens habitat, thus reducing the amount of formalization and centralization in decision making.

Alternatively, one of the hurdles in changing this paradigm will be that small groups often do not have a high degree of openness and frequently do not consider alternatives that risk group cohesion or might harm individual status (Kim 2001), making it difficult for new ideas, especially those of outsiders, to be heard or accepted (Rodgers 1995). Another hurdle in the acceptance of a new lesser prairie-chicken habitat paradigm is that there has been minimal advantage to its acceptance. As previously discussed, most of the remaining habitat available for lesser prairie-chicken is shinnery oak; if this is not their preferred habitat, managers will have to start creating or restoring habitat, instead of just protecting what is currently available.

KEY LARGO WOODRAT

The Key Largo woodrat (*Neotoma floridana smalli*), a medium-sized, nocturnal, forest dwelling rodent, has been classified as federally endangered by USFWS since 1984 (U.S. Department of the Interior [USDI] 1984). Of the habitat within the woodrat's historic range, 47% has been lost since 1973 (Strong and Bancroft 1994), confining the Key Largo woodrat to approximately 850 ha of remaining tropical hardwood forest on the northern third of Key Largo, Florida, USA (Barbour and Humphrey 1982). Most of these 850 ha are within the bounds of 2 protected areas: Dagny Johnson Key Largo Hammock Botanical State Park and Crocodile Lake National Wildlife Refuge. The Key

Largo woodrat has declined over the last several decades; recently, the woodrat population was estimated to be <100 individuals (McCleery et al. 2006*b*), and a population viability analysis predicted a >70% chance of extinction for woodrat within the next 10 years if no management actions are taken (McCleery et al. 2005).

The management of the Key Largo woodrat's habitat has been driven by the original descriptions of Key Largo woodrat habitat. The first studies examining Key Largo woodrat habitat use stated that woodrats used mature or climax hammock habitat (Brown 1970, Hersh 1978), even going as far as to say, "The Key Largo woodrat occurs only in mature hammock-type forest. Young and medium aged stands lack woodrat populations" (Brown 1978:11). These beliefs have been perpetuated throughout the literature as secondary sources (Barbour and Humphrey 1982; USDI 1984; Humphrey 1988, 1992; USFWS 1999) over the last 30 years.

The premise that Key Largo woodrats only use climax forests was based on studies that trapped exclusively in older hammocks where researchers found high densities of woodrat stick-nests (Brown 1978, Hersh 1981, Barbour and Humphrey 1982). However, a study of habitat preference or even of habitat selection has never supported this paradigm; more recent studies have eroded the logic of woodrats exclusively using old hammock by showing that woodrats have used hammocks of varying degrees of succession (Keith and Gaines 2002, Sasso and Gaines 2002, McCleery et al. 2006*b*) and commonly used nesting refugia other than stick-nests such as rock piles, burrows, fallen trees, and even piles of trash (Humphrey 1992, McCleery et al. 2006*a*).

A recent study, the first to trap extensively in hammocks of varying ages, found that early successional forests yielded considerably more woodrat captures (McCleery et al. 2006*b*). In addition, a telemetry study (McCleery et al. 2006*a*) found woodrats overwhelmingly selected early successional forest for foraging and refugia. The results of these studies were congruous with research on other eastern woodrats in Florida and the southeastern United States that showed higher trap success and use of ecotonal areas and areas of dense understory vegetation (Pearson 1952, Neal 1965, Haysmith 1995, Wilson 1999). Finally, at the time that Key Largo woodrats were discovered, their population appeared to be thriving (Small 1923) and historical accounts suggest that the forests of Key Largo would not have been exclusively climax forests. For approximately 250 years prior to the woodrats discovery, the forests of Key Largo had been altered by lumbering and agriculture (Strong and Bancroft 1994). Prior to human alteration the forests of Key Largo would have experienced the natural disturbance regimes of fire and wind, especially hurricanes (Ross et al. 1995), which would have created forest stands of varying ages. Nonetheless, in keeping with management plans over the past 25 years, state and federal agencies (USFWS 1999) have let the forests of north Key Largo mature, increasing the acreage of mature hammock and reducing the portion of young forest to <13% of the forest available to the woodrats (McCleery et al. 2006*b*). Unfortunately, the woodrats did not respond positively to the maturing forest; instead, woodrats showed a rapid decline in the population over the same time period (McCleery et al. 2005).

The first challenge toward creating a new paradigm where woodrats use a variety of forest ages was overcoming the dogmatic belief that they exclusively use mature hammock. Another hurdle to the acceptance of a new management paradigm was the fact that management strategies and means for disseminating the information presented in the previous section were limited almost exclusively to written reports and publications. At the beginning of the recent research initiatives (2001) on the Key Largo woodrat, there was extensive and productive interpersonal communication between researchers and agency personnel. As the process continued, agency employee turnover and reassignment created a new dynamic and almost all communication became written. Within the context of research on the diffusion of innovations, this lack of active communication (i.e., direct personnel contact, training workshops, and videos) could have hindered the adoption of a new habitat management strategy for Key Largo woodrat (see Muiznieks 2006 for most recent description of management strategies).

Additionally, there are some aspects of the actual idea (i.e., attributes of the technology) that could have prevented its acceptance as a new management paradigm for the Key Largo woodrat. The idea that Key Largo woodrats might select younger hammock was not compatible with the conservation ethic for north Key Largo. For example, in the last 30 years there has been a controversy regarding development versus the preservation of hardwood hammocks on north Key Largo (see Schaff and Humphrey 1988). A small but powerful group of local preservationists (e.g., Izaak Walton League, and other grassroots groups) adopted the idea that hammock forest should be protected in a pristine state of mature hammock. Through the passing of time and the continuing threat of development on Key Largo, the idea of a mature forest became almost sacred and the Key Largo woodrat became a symbol for the protection of mature forest. Similarly, a switch to a new management paradigm based on hammocks of various age-classes held no advantage in ease of implementation over the old paradigm. It was much easier to preserve habitat than to actively manage it for differing degrees of succession. Additionally, it would have been more difficult to manage, work with, and educate those stakeholders who had advocated a mature forest if a new forest paradigm were to be introduced.

It is possible the organizational structure of USFWS, the primary agency responsible for the management of the Key Largo woodrat, by its very nature may have created obstacles to the acceptance and adoption of new paradigms for Key Largo woodrat habitat simply through its institutional structure. The USFWS has been a traditional bureaucracy, and with that comes a relatively high amount of centralization and formalization of procedures and rules, both of which have been negatively correlated with the adoption of new innovations (Rodgers 1995). We are not suggesting that USFWS would intentionally prevent the implementation of new ideas; however, this type of institutional structure can serve as a barrier in the acceptance of a new management paradigm or innovation because of the magnitude of paperwork and documentation necessary to initiate a change; additionally, the numerous levels of management hierarchy must be convinced that change is needed.

Finally, as we stated previously, limited complexity, or in this case lack of knowledge and expertise in small mammal biology, can make the transfer and acceptance of new ideas all the more difficult (Rodgers 2003). As of March 2006, the USFWS did not have an on-staff small mammal biologist working directly with Key Largo woodrat recovery.

FLORIDA KEY DEER

The endangered Florida Key deer (*Odocoileus virginianus clavium*) are endemic to the Florida Keys, a 100-km chain of islands on the southern end of peninsular Florida (Hardin et al. 1984). Since the 1960s, urban development and habitat fragmentation in the Florida Keys has been viewed as a threat to the Key deer population (Lopez et al. 2004). In addition to a loss of habitat, an increase in urban development is of particular concern because highway mortality accounts for the majority (50%) of the total deer mortality (Lopez et al. 2003*b*). In fact, approximately 70% of the total Key deer mortality is due to human-related causes (Lopez et al. 2003*b*).

Significant changes in Key deer population density have occurred in the last 75 years. In the 1930s, it was estimated that <50 Key deer were in existence throughout their range (Dickson 1955). Increased law enforcement and the establishment of the National Key Deer Refuge in 1957 provided protection for the deer and its habitat. Consequently, the deer population grew to an estimated 300–400 animals in 1970 (Klimstra et al. 1974) and 600–700 deer in 2000 (Lopez 2001, Lopez et al. 2003*a*). Despite building restrictions within the Key deer's range, the human population also continued to increase. For example, the human population on Big Pine and No Name keys (the core of Key deer habitat) increased from 500 residents in 1970 to the current estimated 5,000 on these 2 islands (Lopez et al. 2004). For nearly 50 years, urban development has been viewed as the primary threat to Key deer (e.g., Hardin 1974, Silvy 1975, Folk and Klimstra 1991, Lopez et al. 1999, Peterson et al. 2002) despite observed deer population increases (Lopez et al. 2003*a*). Thus, the management paradigm for Key deer has been to minimize or restrict all urban development throughout the range of the deer because of these threats.

Research in the last 10 years has refuted the idea that all urban development is detrimental to the Key deer population (Lopez et al. 2004, Peterson et al. 2005). Research over this period has shown 1) parallel increases observed in both Key deer population densities and urban development over the last 30 years (Lopez et al. 2003*a*) and 2) new scientific information that provided an explanation for observed increases (Lopez et al. 2004). Intuitively, if urban development is a threat to Key deer then the relationship between urban development and deer densities should be negative. Why is this not the case? The answer lies in reviewing where and how development occurred. Historically, urban development occurred in tidal areas (e.g., mangrove, buttonwood), which were considered to be marginal habitat for Key deer (Lopez et al. 2004). Thus, prior to the mid-1980s, urban habitat in the Florida Keys actually improved with development, which resulted in upland habitats selected by Key deer (Lopez et al. 2004). Lopez et al. (2004) hypothesized that islands with high deer densities were those with a substantial upland component, while islands that were mostly tidal (e.g., Summerland, Ramrod) supported fewer deer than similar-sized islands with more upland area. Empirical data supported this idea, and the change in the amount of useable space (upland area that is readily available to Key deer; Guthery 1997, Lopez et al. 2004) explained the increase in Key deer numbers in the last 50 years (Lopez et al. 2003*a*). Like other subspecies of white-tailed deer, the response of Key deer to urban development was favorable (McShea et al. 1997). With changes in federal and state laws in the mid-1980s prohibiting the development of tidal or wetland areas, urban development pressure shifted towards upland habitats. Assuming that upland areas (e.g., pinelands, hammocks, and urban areas to a certain degree) are correlated with Key deer densities, Lopez et al. (2004) predicted the conceptual model between Key deer density and urban development would be bell-shaped. Lopez et al. (2004) added the caveat that urban development was not equivalent, however, to natural uplands such as pinelands and hammocks. Urban development does not necessarily provide for all the Key deer's life history requirements (e.g., fawning areas) as compared to pinelands and hammocks (Folk 1991). Thus, continued urban development would decrease the amount of useable uplands, which in turn would decrease Key deer numbers and increase secondary impacts such as road mortality and fence entanglement (Lopez et al. 2003*b*, 2004).

The idea that all development is not detrimental to the Key deer population has been accepted and integrated into management after 10 years research and advocacy. In 2004, this paradigm was incorporated into a new Habitat Conservation Plan that recognizes the basic tenets of Key deer research previously discussed. By examining the processes and factors behind the dissemination of Key deer research, we can clearly see how this case study succeeded where the 2 previous case studies have not.

The first, and possibly the most disconcerting, difference between the Key deer and the previous 2 case studies was time. It took 10 years for the recognition and implementation of a new habitat paradigm, compared to the to 3–4 years of work on the Key Largo woodrat, and 2 years of advocacy for a new habitat paradigm for the lesser prairie-chicken. Fortunately, the Key deer population has continued to increase, whereas the lesser prairie-chicken and Key Largo woodrat have not been so lucky.

The acceptance of a new Key deer habitat paradigm was hindered by the fact that it was not compatible with the values previously held by preservationists, and the concept was hard to experiment with; however, it did have several distinct advantages over the other 2 case studies. First, the new paradigm seemed to be observable. At the time of the research, there were clearly more deer and human developments than had been observed historically. There also was a benefit to the new paradigm itself. It removed the Key deer from their previously contentious role as the reason for halting development in the Lower Florida Keys. By adopting a new paradigm, USFWS could manage the Key deer without the stigma and hindrance of Key deer being caught in the battle over future development of the Keys.

Lastly, the acceptance of Key deer research was greatly aided by a strong and active dissemination strategy used by researchers before, during, and after their research. Most research findings were personally presented to USFWS personnel who were actively engaged in the research. The public also was kept informed through numerous radio programs, newspaper articles, and public presentations. Researchers engaged in constant communication, and although dialogue with management took a considerable amount of time and social maneuvering, it may have proven to be very useful in the implementation of their research.

DISCUSSION

Examining 3 case studies, we found the adoption of new research findings that challenged entrenched management paradigms for endangered species were most likely hindered by small closed groups, bureaucracies, and a lack of expertise in management agencies. Adoption of new management paradigms also appeared to be hindered by an incompatibility of research findings with previously held values and experience, and poor communication strategies to disseminate research findings. Our case studies illustrated the importance of simple, visible, alternative hypotheses and paradigms that can be demonstrated through experimentation. Striving to create simple, understandable, and reproducible research will aid researchers in the acceptance and adoption of their research. Scientists also must be willing to actively communicate their results, make their results accessible and observable to the public, and engage in advisory and decision making roles (Ludwig 2001). Researchers also should abandon the idea of the disinterested expert, since it places them as outsiders, making it difficult for their ideas to become accepted.

Our case studies provided insight for agencies looking to improve their ability to adopt the best management in the quickest possible time. Our examples and literature review showed a need to increase openness and communication with outside experts while increasing the scientific expertise of decision makers. Our case studies and theory on information transfer also suggested that agencies should try to reduce the number of rules, regulations, and paperwork surrounding the adoption of new management paradigms. In addition, it may be beneficial to reduce bureaucracy by making management decisions at a local level.

One method that might aid both researchers and management in the adoption of science is adaptive resource management. Adaptive resource management places an emphasis on decision making based on experience (Organ et al. 2006). By its nature adaptive resource management provides observable results of management alternatives. It also fosters communication between research and management and keeps management decisions at a local level.

MANAGEMENT IMPLICATIONS

We propose there can be a real improvement in the quality of management that our endangered and threatened wildlife receive if researchers and resource mangers take some simple steps to improve the adoption of research results. Researchers should strive to show simple observable results and to improve the way in which they communicate their results. One way to improve their communication and outreach may be to designate a member of the research team to liaise with management, media outlets, and the public. On the other hand, management and agencies also hold the ability to greatly improve the implementation of sound research into management. Before contracting scientists, an agency might consider if they would be willing to change their current practices and what evidence would be necessary for them to consider alternatives. We suggest that government (state and federal) biologists responsible for management of our natural resources be provided literary resources (both current and historical) at their field offices; be allowed to attend local, state, regional, and national workshops, scientific meetings, and conferences; and be provided opportunities for continuing education. We recommend that government biologists seek out and invite outside (those unhindered by current paradigms) authorities to review their management options. Finally, we propose adaptive resource management might be an important strategy for incorporating science into the management of endangered species.

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