Chapter 3

RECONCILIATION ECOLOGY AND THE INDIANA BAT AT INDIANAPOLIS INTERNATIONAL AIRPORT

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Abstract

We provide a case study of conservation efforts at the Indianapolis International Airport near Indianapolis, Indiana, USA that illustrates how small programs aimed at meeting regulatory requirements can develop into projects of regional and national importance, how adaptive management works in the real world, and the potential for reconciliation ecology. Of particular legal and conservation concern is the presence of the endangered Indiana bat (Myotis sodalis), for which the airport agreed to undertake extensive conservation and mitigation efforts including the preservation of existing forest, planting of new forest, installation of experimental roost structures, and intense monitoring of the bats. After 17 years, the site is surrounded by commercial and residential areas, but the Indiana bat is still present. Monitoring has provided detailed information about how this and other bat species respond to a variety of landscape-level challenges and conservation approaches.

Introduction

Traditionally, conservation and economic development have been viewed as competing alternatives for the same piece of land (Rosenzweig 2003). While numerous scientific societies including The Wildlife Society, the American Society of Mammalogists, and the North American Section of the Society for Conservation Biology have each recently passed resolutions in favor of steady-state economic paradigms (Gates et al. 2006, American Society of Mammalogists 2007, Society for Conservation Biology, North American Section 2005), such approaches will take years to implement. During that time, habitat will be lost and biodiversity will continue to decline. In the United States, three federal laws are often used by
conservationists to slow or stop development: National Environmental Policy Act (NEPA), Clean Water Act (CWA), and Endangered Species Act (ESA), but most conservationists view all three as being broadly unsuccessful in reducing loss of biodiversity. Of particular concern has been the inability of ESA to either recover species from near extinction or to prevent species from becoming critically endangered. Similarly, Section 404 of the CWA is aimed at protecting wetlands, but permits issued under section 404 allow replacement of existing wetlands with newly created wetlands. These new wetlands rarely function as well, at least initially, as those lost to development. Finally, NEPA was intended to ensure that a broad array of environmental impacts by activities funded or permitted by the federal government are considered, employing an analysis of alternatives, so that impacts are avoided and minimized to the degree practicable, and that compensatory mitigation is employed for losses that cannot be avoided, including measures undertaken for ESA and the CWA. Unfortunately, such conservation and mitigation efforts are often undertaken in isolation rather than coordinated with one another. The first purpose of this paper is to provide a case study of how a large, long-term, and broadly successful conservation effort grew out of efforts to comply with regulatory requirements.

In addition to efforts aimed at regulatory compliance, this study also describes a substantial number of efforts made with an eye toward providing conservation benefits beyond those normally attained by similar regulatory compliance activities. Particularly unusual at this site was the incorporation of a research and monitoring component in regulatory documents such as incidental take permit under ESA. Unfortunately, success of a mitigation/conservation project too often is legally achieved when the approved work is completed. For example, habitat preserved for an endangered species as part of a construction project is considered a “success” even if the mitigation habitat is not used by the target species. In the present study, a substantial monitoring component was required partly because some conservation measures were experimental. As it has turned out, because of additional academic research undertaken at the site, monitoring at the airport substantially exceeds typical regulatory requirements. This research has demonstrated that efforts undertaken to benefit Indiana bats have benefited the entire community of bats and a variety of other taxa as well. Because this paper demonstrates a system where conservation has succeeded in the presence of development it also demonstrates how reconciliation ecology (Rosenzweig 2003) can be coordinated with regulatory requirements to provide synergistic benefits.

Our experience is that large-scale, real-world conservation efforts rarely proceed on a direct course. Rather, like this project, they boom when funding is available, and essentially shut down when it is not. Thus, we have chosen to provide a review of conservation efforts by describing the study site, providing a review of conservation and regulatory decisions made during this project, and finally examining proposed future activities on the site.

Study Site

This paper details conservation efforts that centered on a large series of properties owned and managed by the Indianapolis International Airport (IND), although many privately owned parcels are interspersed in the landscape. These properties extend south and west along US Highway 40 (US-40) from the Airfield to Indiana Highway 267 (IN-267) in the west and Indiana Highway 67 (IN-67) in the south with Interstate Highway 70 (I-70) bisecting the
study area from east to west. The East Fork of White Lick Creek, a medium-sized permanent stream, bisects the study area north to south. In 1991 the study area included many small, fragmented forest remnants within a matrix of corn/soybean agriculture. Since 1991, most agricultural areas north of I-70 have been developed into residential and commercial properties. Properties south of I-70 remain primarily agricultural although 54.5 ha of wetlands have been created and 323 ha have been reforested as part of the conservation effort.

Airport Expansion

In 1991, the Indianapolis International Airport (IND) began to expand from a regional airfield with 1 runway into a major freight airport with 2 operational runways, and another being planned. As part of this effort, the Indianapolis Airport Authority (a public governing board) began efforts to comply with a variety of regulatory agencies including the Federal Aviation Administration (FAA), Federal Highways Administration (FHWA), US Fish and Wildlife Service (USFWS), US Army Corps of Engineers (USACE), US Environmental Protection Agency (USEPA), Indiana Department of Natural Resources (IDNR), Indiana Department of Environmental Management (IDEM), Indiana Department of Transportation (INDOT), and the Cities of Indianapolis, Mooresville, and Plainfield, Indiana, USA. Early in this effort 3 major compliance issues were identified.

First, expansion of the airport would take air-traffic over a rural area that included some suburban developments. Thus, part of the cost of expansion would include purchasing or noise-proofing these homes to comply with FAA noise pollution regulations. Second, the new runway and its associated developments would remove several jurisdictional wetlands, mostly fragments of seasonally or temporarily flooded deciduous forests. In order to comply with section 404 of the CWA, wetlands destroyed by construction would be replaced at a 4:1 ratio. Third, scattered forest remnants (woodlots hereafter) were considered by USFWS as potential habitat for the US endangered Indiana bat (*Myotis sodalis*). Construction of the additional runway would thus need to minimize impacts to this endangered species. These concerns were intensified when IND was approached by United Airlines which sought to develop a regional service hub at IND.

Impacts of Airport Expansion

Within this document, we most often use mitigation to refer to efforts to replace habitats removed or damaged during development, and conservation indicates efforts to preserve and improve pre-existing habitats. However, the terms that are applied to dealing with adverse impacts vary under NEPA, ESA, and CWA, making the language used when referring to all of them collectively confusing or inaccurate.

Under NEPA, the Council on Environmental Quality (1978) defines mitigation as: “(a) Avoiding the impact altogether by not taking a certain action or parts of an action, (b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation, (c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment, (d) Reducing or eliminating the impact over time by preservation and maintenance
operations during the life of the action, and (e) Compensating for the impact by replacing or providing substitute resources or environments.”

The definition of mitigation for wetlands impacts is taken from that used for NEPA, and follows a path from avoidance and minimization of impacts, to compensatory activities that replace losses that cannot be avoided (USACE 1985). Such mitigation typically revolves around creation of new wetlands or the restoration and enhancement, and preservation of existing wetlands.

In contrast, under ESA (United States Code, 2002.), the term mitigation is essentially replaced with the term conservation and are defined as: “to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to [the] Act are no longer necessary.” Conservation Measures “are actions to benefit or promote the recovery of listed species that are included by the Federal agency as an integral part of the proposed action. These actions will be taken by the Federal agency or applicant, and serve to minimize or compensate for, project effects on the species under review.” As with NEPA and wetlands, the preferred option is to avoid impacting endangered species.

Initially, habitat loss at IND consisted of about 240 ha of woodlands and 40 ha of wetlands. Approximately 90% of the existing wetlands were deciduous forests that were seasonally or temporarily flooded. Mitigation for wetlands was set at a 4:1 ratio and for woodlands (i.e., bat habitat) at 1:1. Wooded wetlands were considered to provide mitigation for both wetlands and bat habitat. At this site, some activities achieved both mitigation of wetlands and conservation of endangered species.


The Airport Authority agreed to mitigation and hired a private consulting firm (3D/Environmental Services, Inc. (3D/ESI), Cincinnati, Ohio) to conduct the work in 1992. Initial conservation and mitigation efforts were composed of three major efforts, all aimed at providing potential bat roosts: (1) preserve existing woodlands, (2) enhance short-term suitability of these woods for bats with artificial roosts, and (3) provide long-term contributions to bat roosting and foraging habitat through creation of both forested wetlands and upland wooded areas.

First, IND purchased a series of existing woodlots (72 ha) that would potentially provide bats with roosting areas. Second, to supplement natural roosts, a series of 9 types of artificial roosts were placed in these woodlots (see Whitaker et al 2006). Several of these artificial roosts were specifically designed to mimic natural roosts of the Indiana bat. There were 2 goals to be attained from these artificial roosts: 1) to experimentally determine if any of the types of artificial roosts could be used as a management tool for the Indiana bat; and 2) provide temporary habitat for the bats until planted forests could mature and begin producing natural roosts (approximately 75 years).

In most managed forests of a suitable size, providing long-term roosting habitat would require managing for standing timber of varying ages, including large and over-mature trees (Kurta and Kennedy 2002). Near the airport, however, little standing timber existed in 1992. Thus a third conservation activity was to plant agricultural land with seedlings of hardwood trees. Land for these plantings was obtained within a noise reduction zone in which the FAA
provided funds to purchase or retrofit existing residential properties to reduce noise impacts of aircraft. Traditionally, these properties are redeveloped as support structures for the airport or industrial facilities. At IND, this area included a substantial amount of agricultural lands that could be modified into conservation areas at low cost. These planted woodlands were placed in and beside areas used to construct new wetlands under the CWA.

Wetland mitigation was designed to meet requirements of the USFWS, USEPA, USACE, IDNR, and IDEM, and also provided the third mitigation effort. Most of these agricultural areas were farmed or prior-converted wetlands that had a high probability of successful wetland mitigation with minimal construction and maintenance requirements. Thus, mitigation was a combination of habitat creation, enhancement, and restoration. Mitigation for wooded wetlands was completed with a minimum of earth-moving, instead relying upon reestablishment of preexisting hydrology by plugging drainage ditches and breaking or plugging drainage tiles (clay pipes that were used to drain surface water from potential farm ground). Mitigation for emergent wetlands was completed using shallow berms and dikes. Mitigation was concurrent with development so that new habitats were built in the same year that existing areas were lost. Wooded wetlands were typically planted with commercial nursery stock (bare root seedlings) and vegetation maintenance activities were aimed at encouraging natural recolonization, by allowing volunteer plants to grow between planted trees. Species composition of planted stock was based upon detailed studies of species native to the area and typical of the desired future habitats resulting from mitigation. Many species of trees were used and planting ratios were stratified by water tolerance (wet, mesic, and dry zones) of each species according to placement in the mitigation area. Thus, plantings in wet zones included dry zone species, and dry zone areas included wet zone species, but at reduced ratios. Monitoring of bat and wetland habitats, and use of bat roost structures was conducted annually for 5 years.

In 1994, conservation efforts were supplemented by the inclusion of regular mist netting of 10 sites along the East Fork of White Lick Creek (Whitaker et al. 2004). Indiana bats captured at these sites were radio-tagged and followed to roosts. In 1994, these efforts led to discovery of a maternity colony of Indiana bats roosting in a tree on private property. This tree proved to be the primary roost for this colony through the 2001 field season (Sparks 2003, Whitaker et al. 2004). This roost was just south of the rapidly-developing commercial area at the junction of I-70 and IN-267, suggesting that these bats would lose much of their foraging habitat to development. Thus, starting in 1996, bats were radio-tracked to not only their diurnal roosts, but also to nocturnal foraging areas and roosts.

Following the 1996 field season, management of the Indianapolis International Airport was privatized and day-to-day operations came under control of BAA International. At that time, implementation of mitigation and conservation efforts was contracted to American Consulting Engineers, Inc. of Indianapolis, who in turn subcontracted bat conservation efforts to Indiana State University (ISU) for the 1997 - 1999 field seasons (Whitaker et al. 2004). ISU instituted regular emergence counts (i.e., numbers of bats exiting diurnal roosts at dusk) on primary and secondary roost trees as they were discovered. The first roost tree, discovered in 1996, was the center of Indiana bat activity until it fell following the 2001 field season (Sparks 2003, Whitaker 2004). Because artificial roosts were rarely used by Indiana bats at that time (Whitaker et al. 2004, 2006), structure monitoring was scaled back following the 1997 field season to check types of structures within woodlots that bats had previously used. Reduced monitoring allowed a focus on telemetry studies of foraging bats. However, 4 of 9
types of structures were used by the northern myotis (Myotis septentrionalis), and that became the subject of studies that began in 1998 (Sparks 2003, Farrell Sparks et al. 2004).

Formal mitigation and conservation associated with airport expansion ended following summer 1999. A greatly reduced monitoring effort was implemented in 2000 and 2001 by ISU students conducting research on northern myotis (Sparks 2003, Farrell Sparks et al. 2004), and the foraging biology of the big brown (Eptesicus fuscus) and evening bat (Nycticeius humeralis) (Duchamp et al. 2004). Study of the Indiana bat was restricted to occasional emergence counts of Primary roosts, telemetry studies on 1 animal each year, and examination of roost structures for northern myotis. These data have proven critical, however, to conservation efforts undertaken under the Habitat Conservation Plan.

Habitat Conservation Plan: 2002 - Present

In 2002, conservation and research targeting the Indiana myotis was reinstated. The reason for this was the addition of a new interchange (Six Points Road) to I-70 and its secondary impacts (Raymond 2006). The interchange is in the center of the study area, and it connects I-70 with private developments near the southern end of the project area. This construction effectively added another multilane highway that bisects the study area from north to south. In many respects, the HCP mitigation plan mirrored that of 1992 - 1999. Mitigation was centered on purchasing land and planting of 147 ha of woodland, and further monitoring and studies of bats. This effort in combination with property protected under other conservation efforts resulted in permanent protection of 860 ha of woodland. Because woodlands near the airport are in an agricultural matrix, many additional hectares of undeveloped land have also been protected, which provide foraging habitat for several species of bats (Duchamp et al. 2004, Sparks et al. 2005a, b, c, Walters et al 2007). Monitoring of the Indiana bat continued to include use of telemetry, emergence counts, and regular mist-net surveys.

Specific Achievements and Results

Artificial Roosts

Artificial roosts are a management tool that could (theoretically) provide an important step in protecting Indiana bats, and artificial roosts may provide research opportunities that are not possible in the loosely-hanging bark of dead trees. However, they also have the potential to be abused. Development of a successful artificial roost could be an important conservation tool that could be used in areas where few suitable roost trees are present such as in stands of pole timber. Because primary roosts (large, dead trees with sloughing bark) cannot be developed on a short-term basis; a successful artificial roost could be combined with planted forests to provide a tool for enhancing habitat, both for general conservation of the species and potentially for mitigating loss of habitat.

The experiment conducted at the airport has offered valuable insight into use of structures (including the widely available bird-house style box) for bats. Artificial roosts at this site were regularly used by northern myotis, but until 2003 received minimal use by Indiana bats (Salyers et al 1996, Ritzi et al. 2005, Whitaker et al 2006). We suspect these structures were
not heavily used by Indiana bats for 3 reasons. First, despite the large number of trees removed during development many suitable roost trees were still present in the woodlots preserved as part of the conservation strategy. Second, structures did not adequately resemble sloughing bark. Third, many structures were placed in shaded areas, because the value of solar exposure was unknown at the time. In 2003, however, Indiana myotis began to make regular use of 2 artificial roosts (Ritzi et al. 2005) and both the rate of use and the number of structures used increased in both 2004 and 2005 (Whitaker et al. 2006), with routine use continuing to present. Success of the artificial roost program is dependent on perspective. Structures were not extensively used until they were in place nearly a decade, and at that time many had fallen. However, a decade is substantially shorter than roughly 75 years required to grow potential roost trees (Whitaker et al. 2006). In addition, this effort was intended as an experiment, and this experiment has provided a wealth of data that has influenced management decisions across the range of the bat. Effective artificial roosts should not be approached or perceived as a panacea, but the potential to aid recovery of Indiana bats and research should not be discounted. Ultimately, long-term management for the species must emphasize trees of sufficient size and number to support a healthy population of bats.

We believe researchers should continue efforts to develop a successful artificial roost for this species. Specifically, we should strive to develop roosts that provide suitable microclimates (Boyles 2007) and that resemble sloughing bark enough to attract bats (Whitaker et al. 2006). Recent use of a variety of man-made roosts by maternity colonies of Indiana myotis include a vacant church and nearby metal batbox in Pennsylvania (Butchkoski and Hassinger 2002), a barn in Iowa (Kurta 2005), and 2 houses in New York (A. C. Hicks personal communication; Brack unpub. data); roost boxes in Illinois (Carter et al. 2001); 3 utility poles in central Indiana (Brack unpub. Data, Hendricks et al. 2005.); and under bridges (Kiser et al. 2002). Given the sudden emergence of these observations across the range of the species, it seems likely that we are seeing a behavioral shift by Indiana bats wherein they are becoming acclimated to anthropogenic structures. As such, this might provide an important model to study this process that must also have occurred as other species such as big brown and little brown bats adapted to buildings following settlement.

The most viable conservation strategies incorporate a combination of preservation, creation, restoration, and enhancement of natural habitats with active management. Use of artificial structures is one management tool appropriate to some, but not all situations. Unfortunately, at times, use of bat boxes at the airport overshadowed other mitigation efforts that have been broadly successful. At the airport, the goal is to provide a mosaic of habitats that include foraging and roosting areas for the Indiana bat. Preservation and planting of woodlots have been successful as these areas are now the most extensively used roosting and foraging habitats on the study area. Use of bat boxes in planted areas (habitat creation) and in young stands (enhancement) or stands that otherwise do not provide a suitable number of sufficient roost sites (restoration) may help support the species until forests mature and natural roosts become available. In addition, artificial roosts may benefit other bats, particularly the northern myotis.
Habitat Conservation and Creation

Since loss of the main roost following the 2001 field season most primary roosts have been in areas purchased for conservation by the airport. Only 1 new primary roost is in the private woodlot that contained the initial primary roost. Together, protected and replanted forests provide the most important foraging habitat for Indiana bats (Sparks et al. 2005 a, b). When purchased, many of these woodlands were surrounded by agricultural lands, which the airport has continued to farm. These open habitats financially benefit the airport, and provide important foraging habitat for at least 5 species of bats (Duchamp et al. 2004, Sparks et al. 2005 a, b, c, Walters et al. 2007), all of which are listed as species of special concern or as endangered in Indiana, including the Indiana bat. This is an important “bonus” because these other bats were not targets of initial conservation efforts. Without this effort, most of the area would have been developed. Instead the conservation area controlled by the airport provides an island of habitat in a sea of suburbia.

Netting Survey

At its inception, netting targeted obtaining Indiana bats for telemetry studies. A second goal was added in 1998—to provide baseline data on composition of the bat community (Sparks et al. 1998, Whitaker et al. 2004) and how that community changes with seasons (Walters et al. 2006) and land-use patterns (Sparks 2003). The netting effort has been successful in meeting these goals. In addition, comparing capture rates of bats in this heavily disturbed landscape to those at more natural sites was enlightening about the response of bats to landscape changes (Sparks et al. 1998, Ulrey et al. 2005). Continuing to monitor changes in this bat community will require long-term data, obtained from continued netting along the East Fork of White Lick Creek.

Telemetry Studies

Radio-tagged bats are being used to develop the first comprehensive overview of nocturnal behavior by an entire community of bats. Important contributions of telemetry studies to conservation efforts at IND have been to: 1) target for acquisition, areas of intensively used habitat; and 2) demonstrate the intensity of use by bats on lands following purchase. Unlike many conservation efforts, those at the airport are long-term and are guided by direct and current information about which parcels are used by target species (i.e. adaptive management). Part of this effort has been a study of foraging habitat at a landscape scale (Duchamp et al. 2004, Sparks et al. 2005 a, b, c, Tuttle et al. 2006, Walters 2007), which aids decision-making for habitat management practices. An unexpected benefit was the opportunity to gain baseline data on movement patterns by migrating bats (Walters et al. 2006). Given the extensive baseline dataset and a rapidly-changing landscape, this site has immense potential to provide insight into how bats respond to development.
Emergence Counts

To obtain information about the population size of Indiana bats at the airport and their movement patterns, we instituted a series of regular emergence counts at known roosts. Most similar information has been obtained from relatively short-term data sets and from a few trees per site (Sparks et al. 2005a). Our data are the most comprehensive to date for the Indiana bat, and thus should supply the best information about long-term population trends at a single site (Whitaker and Sparks in review).

Combining regular emergence counts with telemetry data over many years has provided a unique opportunity to understand how bats respond to environmental change, both natural and anthropomorphic. Following loss of the primary roost in winter 2001/2002, our data provided remarkable insight into the response of bats to such an event (Sparks 2003, Kurta 2005). In addition, we noted a pattern whereby many roosts that earlier studies (e.g., Callahan et al. 1997) would have classified as primary roosts are abandoned at IND, often within a week of discovery, while a few are consistently reused for many years. Studies of emergence counts provided data that put in perspective occasional use of artificial roost structures by Indiana bats (Salyers et al. 1996, Kurta 2005, Ritzi et al. 2005, Whitaker et al. 2006).

Impacts on Nontarget Species

Conservation efforts targeting the Indiana bat and wetlands are providing habitat for many nontarget species. We suspect the state-endangered evening bat would have been extirpated without ever having been detected from this site without conservation activities aimed at Indiana bats. Evening bats were first detected in the netting surveys of 1996, and the first roost was documented in 1997 (Whitaker et al. 2005). The woodlot containing that roost was cleared in winter 1997/1998 and evening bats moved into the woodlot containing the primary Indiana bat roost (Sparks et al. 1998). Evening bats now forage and roost almost exclusively in areas conserved for the Indiana bat (Duchamp et al. 2004).

Local populations of amphibians and reptiles are greatly reduced in developed areas north of I-70 as compared to the IND conservation areas (Foster et al. 2004). Species richness is greatest in the IND mitigation wetlands (Foster et al. 2003, 2004). One species apparently benefiting is Kirtland’s snake (*Clonophis kirtlandii*), a state-endangered species first detected in summer 2004 (B. J. Foster unpublished), although populations are known from nearby areas of Indianapolis (Minton 2001). Similarly, local fish diversity and aquatic habitat quality increases from the northern end of the study site and is greatest in the habitat conservation area (Ritzi et al. 2004). No formal survey of birds has been conducted, but three state-listed species (*Henslow’s sparrow, Annodramos henslowii*; Red-shoulded hawk, *Buteo lineatus*, and least bittern, *Ixobrychus exilis*) have been detected in mitigation wetlands during the summer breeding season with a fourth (upland sandpiper, *Bartramia longicauda*) occasionally observed near the runways. In short, numerous species, some locally rare, are benefiting from the airport conservation effort.
Academic Involvement

Having a university conduct monitoring has provided 3 major benefits. First, it documented project impacts on non-target wildlife that typically would not have been obtained by a private consulting company, because these data were primarily collected as a result of student research projects. Second, results have been published rather than be restricted to technical reports. Third, it has improved public perception of the project. These benefits led the airport to contract Purdue University to conduct monitoring of the tree plantations.

Public Perception and Reception

Initially, airport developments were viewed as positive by the general public, in large part because of anticipated economic benefits. As with most developments, the views of adjacent landowners were typically less favorable. Coincident with a positive view of the development was a similarly positive view of the concern for natural resources, including bats and wetlands. Conservation for bats at the airport was reported on ABC network news as a win-win situation for the airport and for the bats. However, with time, there was a growing perception by the public that mitigation was not as effective as anticipated (i.e. bats were not using the bat boxes), that the financial cost of mitigation was too high, and that concerns for bats were given preference over concerns for humans. These negative views, like the positive ones before, reached the public via television through a segment on a local station. In recent years, involvement of 2 public universities has helped improve perception of the project, including several positive stories in the local media. In retrospect, at least some negative perceptions could have been avoided had not the initial positive perception set unattainable goals. Education of the public is now a major goal of conservation efforts.

Economic Aspects

A detailed analysis of economic features of habitat conservation and scientific research associated with the project is beyond the scope of this paper. However, it is instructive to provide a cursory description of the economic context of this project. This is particularly true given the tendency by some members of the local community to treat the airport expansion and subsequent economic developments as separate from the cost of conservation efforts. In reality, the conservation efforts were an essential component of obtaining federal funding and permits that allowed the project to move forward. These conservation efforts would not have happened without the airport expansion and resulting building boom, which itself would have proceeded very differently without the conservation efforts.

Expansion of the Indianapolis airport and related transportation infrastructure was a large construction project that will continue to provide substantial benefits to the local economy in future decades. Construction of the new terminal alone required a budget of $974 million (Nunn 2004), while the new highway interchange that will serve as access for both passengers and airfreight cost around $170 million (INDOT 2004). From 1990 to 2001 airfreight grew by 661%, averaging 25.6 million tons annually (Nunn 2004). By 1999 the Indianapolis airport was ranked as the eleventh largest in the U.S. for cargo shipments (Schoettle 1999). From
1990-2001 3.3 million people annually embarked from the Indianapolis Airport while airmail loadings (not included in airfreight) averaged 26.8 million tons annually (Nunn 2004). Expansion of freight capacity directly led to a boom in local construction, which has now resulted in an area of large warehouses that now occupies 800 ha and provides jobs for thousands of people. The airport and associated structures are clearly an important capital asset for the local economy, which is based on services and agriculture as well as manufacturing.

Although airports impose a large spatial footprint, significant parts of the required land also can be used for other activities, including habitat conservation. In this case, presence of the Indiana bat resulted in these lands being used for conservation. Typically one of the largest costs of species protection is the withdrawal of required habitat from economic uses that are incompatible with conservation. In the present case, the airport and the bats can and do co-exist. The collective decision to protect the Indiana bat affirms its social value as a public good, and in this particular case the benefit is attained at low cost.

In addition to providing habitat for Indiana bats, conservation lands can be used for a variety of purposes. Outdoor recreation activities might provide a social benefit from a multiple-use management policy. The conservation area is a large portion of the undeveloped habitat within metropolitan Indianapolis, and thus is particularly valuable for outdoor recreation. Negotiations are underway to designate 132 ha of it as a nature park. It may be necessary to restrict activities to meet the primary goal of protecting the Indiana bat, but even limited recreation would offset some costs of withdrawing the land from commercial development. The presence of natural areas, and even individual trees, is an important, economically demonstrable, contribution to urban and suburban settings. In addition to protecting Indiana bats, the properties provide conservation benefits for numerous species. Finally, this property provides general ecosystem services for the local and regional economies such as carbon sequestration and water filtration.

While limiting uses of land is a key cost of conservation efforts, there is also a financial cost for the research. Again, the work is required by environmental permits and is thus directly tied to airport and highway expansion. This research requires a highly skilled labor pool and minor capital resources. Assessing economic benefits of this research is more difficult than calculating the cost. Monitoring provides essential information about the success or failure of conservation efforts, allows use of adaptive management when unforeseen conservation challenges or opportunities arise. Second, because ISU and Purdue students seek research experience, the airport and regulatory agencies have benefited from a substantial body of research beyond the original mitigation requirements at a relatively low cost. Third, research findings are widely disseminated among the scientific, management, and conservation communities in part by the eventual employment of the students within these professions.

A final benefit of research involves an interaction with the basic cost of habitat conservation. As noted, withdrawal of land from commercial uses is the central cost, and arguably the largest one. A detailed knowledge of bat behavior and the local ecosystem obtained from the research allows a more measured and specific response to competing uses. For example, a local developer sought to acquire parcels of the conservation area for projects incompatible with maintaining habitat for the Indiana bat. However, the developer was willing to exchange other parcels he owned for those he was seeking to acquire. The alternate parcels could improve overall conservation efforts, and so an agreement was reached that
benefited both the developer and the bats. Without detailed knowledge of bat use of the project area, this mutually beneficial determination would not have been possible.

**The Big Picture**

The size, shape, and composition of ecological preserves is a common theme for theoretical discussions of conservation (Andleman and Willig 2002, Groom et al. 2006). These efforts have and will continue to play an important role in helping conservationist efforts maximize the potential of reservation areas—particularly new reservations in the developing world. Within the past 5 years several scientific organizations dedicated to natural resource management have produced publications or resolutions that support development of steady-state economies (Gates et al. 2006, American Society of Mammalogists 2007, Society for Conservation Biology, North American Section 2005). While these goals are important, conservation biologists must work within the existing economic structure on properties that often were not designed with the aid of modern conservation science.

Most conservation opportunities within developed nations must fit within confines of pre-existing constraints, such as urbanization (this study), reclamation of coal mines (DeVault et al. 2002), or abandoned military bases (Jones and Preston 2000, Everette et al. 2001) which each have their own management problems and constraints. As such, some scientists advocate an alliance between environmental conservation and economic development (Rosenzweig 2003).

At IND we dealt with a situation rarely discussed in conservation texts, but which is far from unique. We had to develop a plan to protect a single endangered species on a rapidly developing landscape. Scientists are often asked to provide habitat to protect poorly known species or replace poorly documented wetlands, including functions and values. In many cases, this combination is a recipe for disaster (Minkin and Ladd 2003; NRC 2001). We faced a similar mission at IND, but at this site an emphasis was placed on studying the impact of conservation efforts on the target species. The greatest success of the airport project has been the incorporation of traditional approaches like habitat preservation with approaches, such as foraging and artificial roost studies, that clearly document the use or value of measures implemented.

Management of Indiana bats at this site continues to be an interaction among regulatory agencies, private enterprise and academic researchers who rely on site-specific field data. Many challenges remain. That the Indiana bat continues to survive on these conservation lands is a testament to both the success of this effort and the hardiness of the species.

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