-- Comments Welcome – Do Not Cite or Distribute Without Permission --

A Multi-Method Framework for Evaluating Habitat Conservation Plans Using Remote Sensing Analysis

Craig W. Thomas
Assistant Professor
Department of Political Science
Center for Public Policy & Administration
University of Massachusetts, Amherst
Amherst, MA 01003
cthomas@polsci.umass.edu
413/577-0688

&

Charles Schweik
Research Assistant Professor
Center for Public Policy & Administration
Department of Resource Economics
University of Massachusetts, Amherst
Amherst, MA 01003
cschweik@pubpol.umass.edu
413/545-2494

Prepared for presentation at the 8th Biennial Conference of the International Association for the Study of Common Property (IASCP), Bloomington, Indiana, May 31-June 4, 2000.

A Multi-Method Framework for Evaluating Habitat Conservation Plans Using Remote Sensing Analysis

ABSTRACT

The U.S. Endangered Species Act requires individuals and organizations (other than federal agencies) to prepare and implement a habitat conservation plan (HCP) before they develop any part of an endangered species' habitat. Over the last decade, the number and size of HCPs have grown exponentially. Yet no systematic evaluations of HCP implementation have been completed. As a first step in filling this gap, we develop and apply a multi-method framework for evaluating HCP implementation at several geographic scales. One such method is remote sensing, which allows analysts to track changes in land cover within planning areas. We test the utility of this framework by evaluating the implementation of the Coachella Valley Fringe-Toed Lizard HCP in southern California. We conclude with observations about the crucial role that implementation evaluations and remote sensing analysis should play in adaptive management of environmental problems.

KEYWORDS

Habitat conservation plan
Remote sensing
Adaptive management

ACKNOWLEDGEMENTS

We would first like to thank everyone in the Coachella Valley who gave us their invaluable time, particularly Cameron Barrows, Ingrid Eleck, and Mark Fisher. We would also like to thank the Coachella Valley Association of Governments for sharing GIS datasets; the University of Massachusetts at Amherst for funding this study; and the Center for Public Policy and Administration at UMass, and the Center for the Study of Institutions, Population, and Environmental Change (CIPEC) at Indiana University, for providing in-kind support. Last, but not least, we thank Lori Schwarz and Jennifer Balkcom for research assistance; and Bradley Karkainen, Alan Krupnick, and John Stranlund for helpful comments on an earlier draft of this paper, which was presented at the 1999 Association for Public Policy Analysis and Management Annual Research Conference.

Introduction

The U.S. Endangered Species Act (ESA) requires individuals and organizations (other than federal agencies) to prepare and implement a habitat conservation plan (HCP) before they develop any part of an endangered species' habitat. Over the last decade, the number and size of HCPs have grown exponentially. Yet no systematic evaluations of HCP implementation have been completed. As a first step in filling this gap, we develop and apply a multi-method framework for evaluating HCP implementation at several geographic scales. Within this framework, we also explore the utility of remote sensing analysis, using Landsat Thematic Mapper (TM) data to track changes in land cover within HCP planning areas. Though we focus on HCPs, our analysis suggests that remote sensing can be used similarly to evaluate other types of land management plans.

In this paper, we test the utility of this framework by evaluating the implementation of a single HCP – the Coachella Valley Fringe-Toed Lizard Habitat Conservation Plan (CVFTL HCP), which covers 70,000 acres in southern California. The following section provides general background on habitat conservation planning. We then present our framework for evaluating HCP implementation, and apply the framework by evaluating the CVFTL HCP. We close the paper with observations about the crucial role that implementation evaluations and remote sensing analysis should play in adaptive management of environmental problems, and implications for evaluating other HCPs.

Habitat Conservation Planning under the Endangered Species Act

HCP Characteristics

HCPs are shaped by law, ecology, and political considerations about economic development. Therefore, HCPs should be evaluated from legal, ecological, and political-economy perspectives. From a legal perspective, all non-federal actors who want to develop part of an endangered species' habitat must first prepare an HCP and submit it for approval to the U.S. Fish and Wildlife Service (FWS). If the FWS accepts the HCP, then the agency issues an "incidental take permit," which allows permittees to "take" an endangered species "if such taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity."[1] The permit is required prior to developing any part of an endangered species' habitat because FWS regulations equate habitat modification with taking an endangered species, which is prohibited under the ESA.[2] Because implementation is a condition of the permit, the FWS can revoke a permit if an HCP is not completely implemented. Although this is a motivating threat, it has never actually been carried out – in part because HCP implementation is not systematically monitored, and because FWS officials work with permittees to bring them into compliance when problems are discovered.[3]

From an ecological perspective, HCPs should be designed to ensure the survival of species. The FWS issues a permit only if the proposed "taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild…"[4] This means that an HCP should be credible to academic and professional ecologists who study species-habitat relationships. Within the field of applied ecology, there is an entire discipline known as conservation biology that is devoted to studying the causal mechanisms of extinction; and conservation biologists have developed planning principles for designing preserve systems to maintain viable populations of species in the wild.[5] If an HCP is not credible to conservation biologists and other applied ecologists, then we should question whether the HCP ensures the survival of its focal species.

---

[1] Section 10(a)(1)(B), Endangered Species Act of 1973, as amended in 1982. For marine species, the National Marine Fisheries Service (NMFS) reviews HCPs and issues permits. Given that most HCPs target non-marine species, we do not refer to NMFS or marine species in this paper. Additional federal agencies may participate in HCPs as partners or advisers, but federal agencies do not apply for incidental take permits because they face different requirements under the ESA.

[2] The term "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct (ESA, Section 3). FWS regulations further define "harm" to include habitat modification. Substantial controversy has long existed over the meaning of "harm" and whether it should be interpreted to include habitat modification on private property [Rohlf, 1989, pp. 62-70]. In 1995, the U.S. Supreme Court upheld the FWS definition of "harm" in *Sweet Home Chapter of Communities for a Great Oregon v. Babbitt*.

[3] Marjorie Nelson, Division of Endangered Species, U.S. Fish and Wildlife Service, personal communication, October 1, 1999.

[4] 50 CFR 17.22(b)(2)(iv).

[5] For an introduction to this extensive literature, see Noss, et al. [1997]. Also see *Conservation Biology*, the journal of the Society for Conservation Biology.

From a political-economy perspective, HCPs are essentially agreements reached between those who want to develop habitat for economic use and those who want to preserve habitat for species protection. The planning process is not likely to produce outcomes that environmental activists, professional ecologists, or resource users (such as land developers or timber companies) would consider "best." Environmental activists generally believe it is necessary to preserve most, if not all, of a species' habitat; but that is neither legally required nor politically feasible. Ecologists generally want more and better science injected into the planning process, but that takes time. Resource users, meanwhile, are impatient because they seek to reap economic value from the land; they do not want to wait for more studies to be completed. Thus, HCPs are inherently controversial.

The "No Surprises" Policy and Adaptive Management

HCPs have become even more controversial since 1994, when the Clinton Administration established the "no surprises" policy, which provides economic assurances to permit holders, and an incentive for potential applicants to participate. The "no surprises" policy assures permit holders that no additional land use restrictions or financial compensation will be required of them with respect to species covered by an incidental take permit if unforeseen circumstances arise indicating that additional mitigation is needed.[6] Under this policy, the federal government assumes responsibility for implementing additional conservation measures that may become necessary as new ecological knowledge and information arise. This means that the general public bears the risk associated with ineffective HCPs.

The "no surprises" policy is popular among permit applicants because it increases certainty about future land uses; but it is ecologically unsound because surprises occur all

[6] At least 74 HCPs completed between 1994 and 1997 are thought to contain "no surprises" assurances [Yaffee, et al., 1998, pp. 2-5]. In 1998, the "no surprises" policy was codified (50 CFR Parts 17 and 222) when the FWS and NMFS published the final "Habitat Conservation Plan Assurances Rule" in the *Federal Register* (Vol. 63, No. 35, February 23, pp. 8859-8873). All HCPs must now be consistent with this rule. The FWS has recently developed similar assurances through "safe harbor" and "candidate conservation" agreements. See the final rule on "Safe Harbor Agreements and Candidate Conservation Agreements with Assurances," *Federal Register*, Vol. 16, No. 116, June 17, 1999, pp. 32705-32716.

the time. Adaptive management is more sensible from an ecological perspective because knowledge and information are fluid. As we learn more about species and their habitat requirements, HCPs should be revisited and redesigned [Noss, et al., 1997]. After all, the fundamental purpose of the ESA is to prevent extinctions. If new knowledge and information suggest that an HCP does not ensure the survival of targeted species, then the HCP should be adapted to the new circumstances or the permit withdrawn.

More than anything else, applicants want to know what kinds of human uses will be allowed within a planning area. Because incidental take permits increase this certainty, they are willing to spend years and large sums of money to develop and implement HCPs. With a permit, applicants know they can pursue all activities covered in the plan. Without a permit, the ESA's regulatory hammer looms, poised to foreclose any or all activities. Yet these permits vary in the certainty they provide to applicants. Some permits last only one year; others, 100 years. Some permits have a "no surprises" guarantee; others do not. Although most permits since 1994 are covered by the "no surprises" policy, this may soon change because the FWS recently issued a proposed addendum to HCP guidelines.[7] This addendum lays out an adaptive management strategy, which could be required of HCPs if significant biological data gaps exist when the HCP is approved and the permit is issued. For HCPs that incorporate this adaptive management strategy, the implementing agreement would likely state the range of possible adjustments and the circumstances under which they would be triggered. This proposed adaptive management strategy would increase the effectiveness of an HCP by enhancing the probability of survival for its targeted species. If adaptive management becomes the rule or norm, then implementation evaluations and remote sensing analysis will play much greater roles in the policy process.

Existing HCP Research

Very little is known about the actual effectiveness of HCPs, in part because they are a relatively new phenomenon. The first incidental take permit was issued in 1983,

---

[7] "Notice of Availability of a Draft Addendum to the Final Handbook for Habitat Conservation Planning and Incidental Take Permitting Process," *Federal Register*, Volume 64, Number 45, pp. 11485-11490, March 9, 1999. For the handbook itself, see FWS & NMFS [1996].

shortly after Congress amended the ESA in 1982 to authorize the FWS to issue such permits. Yet the FWS issued only 14 incidental take permits during the first ten years (1983-1992). After 1992, the pace rapidly quickened. By June 1999, the number of permitted HCPs climbed to 255, covering 11.7 acres, with approximately 200 additional HCPs in various stages of development.[8] In light of this growth, an increasing number of observers have begun to wonder whether HCPs adequately protect targeted species.

Several studies of HCPs were completed in the 1990s, but they focused on the planning process, not implementation. The first wave of such studies were primarily descriptive cases [Bean, et al., 1991; Beatley, 1994, 1992]. The second wave evaluated HCP effectiveness according to idealized planning processes [Noss, et al., 1997; NRDC, 1997; Thornton, 1991]. Recently, two systematic studies of HCP planning have been completed, both of which evaluated a large sample of HCPs. One study analyzed variation in public participation during the planning process [Yaffee, et al., 1998]; the other analyzed the use of scientific data and methods in developing and justifying the plans [Kareiva, et al., 1999].

Although these studies have been very useful in suggesting how HCPs vary in terms of real and ideal planning processes, they tell us little about actual HCP effectiveness because they focus on planning, not implementation. Implicitly, they assume that preferred outcomes will result if planners follow appropriate processes. This is a big assumption, particularly now that HCPs number in the hundreds and cover millions of acres. It is possible that HCP implementation studies have not yet been conducted because potential evaluators believe it is more difficult to evaluate the implementation of a plan than the process by which a plan was completed. For large HCPs, implementation evaluations might require intensive case studies, with researchers, for example, conducting parcel-by-parcel appraisals of land-use activities spread across thousands of acres. This would be a daunting task – for even a moderately-sized HCP. Fortunately, there may be a more expeditious method in many cases. Rather than survey

---

[8] U.S. Fish and Wildlife Service, "Habitat Conservation Plans/Incidental Take Permits," http://www.fws.gov/r9endspp/hcp/hcptable.pdf, June 3, 1999. This summary table is no longer updated by the FWS. For the most current data, visit the agency's Environmental Conservation Online System (ECOS), at http://ecos.fws.gov, and click on "HCP."

habitat change on the ground, it may be possible to do so from space, using a time series of remote sensing images from Landsat satellites to track changes in land cover within planning areas.

A General Framework for Evaluating HCP Implementation

HCPs exhibit great variation in size, complexity, and institutional form.[9] In size, HCPs vary from less than an acre to more than a million acres. In complexity, they may cover a single species or multiple species. HCP applicants may also be a single organization (such as a timber company desiring to log some of its property) or a consortium of organizations (such as a council of local governments seeking a joint permit covering several local zoning ordinances). In institutional form, HCPs are limited only by the creativity of the applicants. Most HCPs establish a core preserve surrounded by buffer zones, but there are numerous ways to acquire, regulate, monitor, enforce, or otherwise manage these areas. To a large extent, this is determined by the applicants, subject to FWS approval.

Although each HCP is unique in how it is planned and implemented, HCPs do have common attributes that we can use for methodological purposes in developing an evaluation framework. HCP implementation evaluations require focused attention to three institutional components: (1) the rules designed to protect the functional integrity of the habitat preserve system, (2) the monitoring system, and (3) the enforcement system. In addition, as previously noted, HCPs should be evaluated from the perspectives of law, ecology, and political economy. Therefore, a thorough evaluation requires that each of the three institutional systems (rules, monitoring, and enforcement) are viewed through the three analytic lenses. Consequently, we argue that nine evaluation questions are sufficient, as identified in Table 1. Together, these questions address the legal and ecological strengths and weaknesses of an HCP, along with the political feasibility of

---

[9] For data on HCP variation, visit the FWS Environmental Conservation Online System (ECOS), at http://ecos.fws.gov. Additional data, compiled by Kareiva, et al. [1999], can be found on a web site managed by the National Center for Ecological Analysis and Synthesis (NCEAS), at: http://www.nceas.ucsb.edu. For other evidence of HCP variation, including case studies, see Yaffee, et al. [1998], Beatley [1994], and Bean, et al. [1991].

adaptive management, which depends in large part on the economic incentives built into each permit.

[insert Table 1 about here]

Appropriate research methods must then be selected for addressing each of the nine questions. In addition, the appropriate spatial and temporal scales of analysis must be considered because HCPs may perform very well at one scale of observation and poorly at another. In selecting methodologies to pursue for specific questions, researchers should carefully consider: (1) the spatial and temporal “scale” of available datasets and the data collection mechanisms used to study the phenomena of interest, and (2) the "grain" of the *phenomena* in both geographic space and time. The scale of a dataset is defined by two attributes: "extent" and "resolution." Extent describes the geographic area covered (spatial extent) and the length of time captured (temporal extent). Resolution describes the measurement precision of the data used to study the phenomena of interest [Gibson, Ostrom, and Ahn, in press]. We use the term "grain" – as do landscape ecologists [Forman and Godron, 1986] – to describe the appropriate scale at which a phenomenon is observable. For example, in the case study that follows, a lizard foraging in a sand dune is a relatively fine grain phenomenon; it occurs over a small geographic area and during a short period of time. Alternatively, the gradual movement of sand dunes across a valley floor is a more coarse grain phenomenon; it is a gradual process that occurs at a broader spatial and temporal grain.

In sum, HCP evaluators must consider the grain of the phenomena and the spatial and temporal scales of datasets when selecting appropriate methods to answer each question in Table 1. In many instances, a multi-method, multi-scale approach to answer a specific question is required. Moreover, great variation exists among HCPs in planning and implementation, which means that researchers should tailor the questions in Table 1 as they evaluate specific HCPs.

The Framework in Action: Evaluating Implementation of the Coachella Valley Fringe-Toed Lizard HCP

In this section, we apply the evaluation framework to the Coachella Valley Fringe-Toed Lizard HCP.[10] Before reporting the results of the evaluation, we first explain why we selected this HCP for our pilot case study, provide a short history of the CVFTL HCP, discuss its institutional characteristics, and highlight the methods we used to evaluate its implementation. The final subsection reports the results by answering each of the nine evaluation questions in Table 1.

Justification of Case Selection

We selected the Coachella Valley Fringe-Toed Lizard HCP for our pilot study because it was the second HCP, and because it provides more interesting opportunities for remote sensing analysis than the first HCP. Selecting an early HCP allows more time for resource users to transform habitat, and for natural changes in land cover to occur. Therefore, an important selection criterion is the number of years since a permit was issued. The CVFTL HCP fits this criterion well because it was completed in 1985, with the permit issued in 1986. The first HCP was on San Bruno Mountain, just south of San Francisco. Although this permit was issued three years earlier, we opted to focus our initial study on the latter, for two reasons.

First, the CVFTL HCP covers a much larger area; at 70,000 acres, it provides a better opportunity to demonstrate the utility of remote sensing analysis than the 3000-acre San Bruno Mountain HCP. Second, the topography in the Coachella Valley is relatively flat, while San Bruno Mountain is relatively steep. Hilly topography causes shadowing, which complicates Landsat image analysis. Although image analysis can certainly be done for hilly terrain, we purposely selected a relatively easy case for our initial application of the methodology.

---

[10] Despite its length, scope, and impact, the *Coachella Valley Fringe-Toed Lizard Habitat Conservation Plan* is a difficult document to find and cite because there is no central repository of HCPs and this particular HCP has no identifiable publisher. It was written by the HCP Coachella Valley Fringe-Toed Lizard Habitat Conservation Plan Steering Committee, which included representatives from local governments, state and federal agencies, the Agua Caliente Tribe, legal and technical consultants, and The Nature Conservancy. It was released in June 1985.

History of the CVFTL HCP[11]

This HCP focuses on the habitat of one species, the Coachella Valley Fringe-Toed Lizard (*Uma inornata*). The lizard lives in sand dunes that have been whittled away by rapid (sub)urban development in the Coachella Valley, home to several resort cities, including Palm Springs and Palm Desert. The 300 square-mile Coachella Valley was once considered a largely inhospitable desert, with just a few inches of rainfall each year and some of the highest temperatures in North America. Yet air conditioning and water projects transformed the valley into a desirable destination because of its clean air, year-round sun, and mountain vistas. By the 1970s, much of the lizard's habitat was already depleted by development.

In 1978, the FWS proposed to list the lizard as a threatened species under the ESA, and to designate roughly 170 square miles of land – more than half the valley – as critical habitat. Developers fought the proposal because a listed species with so much critical habitat would have seriously impeded (sub)urban growth. Incidental take permits did not then exist, so there was no legal means for developing critical habitat. The FWS formally listed the CVFTL in 1980. Two years later, Congress amended the ESA to authorize the FWS to issue incidental take permits for HCPs. During this period, a working group known as "the lizard club" began meeting to develop an HCP. Developers participated because environmentalists threatened legal action to halt development in the valley. Meanwhile, nine cities and Riverside County came together through the Coachella Valley Association of Governments (CVAG) to support and draft the HCP. The Nature Conservancy (TNC) offered to acquire and manage most of the land needed for the preserve system.

Local politicians initially balked at the idea of preserving even a small percentage of the dune system. After all, the inland dunes contained no charismatic species, such as eagles or bighorn sheep. Yet political positions changed quickly, for several reasons. First, the plan's main preserve area was pitched as a "central park" for the Coachella Valley. The planners argued that it would become the only large remaining open space

[11] This history is drawn in part from on-site interviews we conducted in June 1999. For additional background, see Beatley [1992, 1994], Barrows [1996], Thompson [1994], Bean, et al. [1991], and Holing [1987].

left in the valley, and was therefore worthy of preservation for that reason alone. The dune system targeted by ecologists also contained native palm oases, which added esthetic appeal. Second, parallel freeway and railroad systems (with windbreaks) split the valley down the middle (see Figure 1). This infrastructure was partly responsible for diminishing the wind-blown dune system on the west side of the valley, but it made the east side of the valley less accessible to development, which is where the main preserve would be located. Third, the preserve system would be sited outside city jurisdictions, with the costs of foregone development borne largely by Riverside County, which had much more open space available elsewhere for development than did the cities.

[insert Figure 1 about here]

When the HCP was completed in 1985, environmentalists quickly criticized the plan because it protected only 5-10 percent of the lizard's remaining habitat (roughly 2 percent of its original range), leaving most of the Coachella Valley open to development. Yet ecologists familiar with the lizard's blow-sand habitat believed that most of the ostensible habitat that remained was not viable over the long run due to human alterations that had already occurred. As TNC ecologist Cameron Barrows subsequently argued, "the vast majority of the lizard's range was no longer suitable for long-term protection" because sand sources and wind corridors had already been blocked by human development [Barrows, 1996, p. 888]. Therefore, most of the extant habitat could be developed without long-term risk to the lizard if a preserve system were established that protected the remaining viable dune systems – including sand sources and wind corridors.

It was not sufficient simply to preserve the dunes because they would blow away over time if not replenished by active sand sources. Therefore, to be ecologically sound, an HCP for the fringe-toed lizard had to encompass the dunes, the sand sources, and everything in between. Figure 2 is a diagram of the dune system at the HCP's main preserve (Thousand Palms). The figure demonstrates the fluvial (water) and eolian (wind) characteristics typical of Coachella Valley dune systems. For this preserve, the sand is: (1) flushed out of hills to the north by major storm events, which rarely occur in the desert; (2) sorted by water and wind on alluvial fans; and (3) transported by a southeasterly wind regime to the dunes. The lizard prefers dunes in which the sand grains are small enough for it to burrow into quickly with its fringed toes to escape predators and the sun, but not so small that the grains enter the lizard's ears and respiratory system. Thus, not all sand provides appropriate habitat, which means that evaluation methods must be able to discern different types of sand habitat.

[insert Figure 2 about here]

A major source of uncertainty for the HCP designers was locating the actual sand sources (and hence wind corridors) for the dunes they sought to protect. In the early 1980s, ecologists were unsure whether most of the sand in the main preserve came from the southwestern slopes of the Indio Hills or through Thousand Palms Canyon (Figure 2). Assuming the latter, and knowing there would be fewer owners of private parcels with whom to negotiate purchases, they drew the boundaries of the main preserve around the canyon, while excluding most of the Indio Hills and associated alluvial fans. This assumption about the primary sand source proved to be erroneous.

Institutional Design of the CVFTL HCP

The HCP has a relatively simple institutional design, composed of: (1) preserve areas, (2) managed areas, (3) zoned and regulated areas, and (4) fee areas. Many HCPs include preserve areas, which provide core habitat for targeted species. The CVFTL HCP has three preserves – a main preserve of 13,030 acres (Thousand Palms), and two smaller, back-up preserves of 2469 acres (Willow Hole-Edom Hill) and 1230 acres (Whitewater). Most of the land in the main preserve was to be acquired through developer fees and federal and state funds, and managed by TNC. The smaller preserves would be managed separately. The Willow Hole-Edom Hill preserve had a smaller acquisition component, and would be managed primarily by the U.S. Bureau of Land Management (BLM), which already leased part of the preserve to energy companies for windmills, which was determined to be a compatible use. The Whitewater preserve area was already managed by the BLM and Coachella Valley Water District, so these agencies simply agreed to set it aside for 30 years, the life span of the permit.

The CVFTL HCP also includes managed areas, which are public lands on which uses compatible with habitat maintenance would be allowed. Unlike the preserve areas, the managed areas were designated for multiple uses, while the preserve areas would be off-limits to most human uses. This was sensible because the preserve areas contained the dunes (occupiable habitat for the lizard), while the managed areas primarily contained the sand sources and wind corridors. In managed areas, what matters most is unimpeded movement of sand. In this regard, some uses are actually beneficial, such as off-road vehicle use, which loosens sand, thereby allowing the wind to blow it into the preserve.

The third type of area is private land that would be zoned or regulated. As with the managed public lands, the primary criterion was sand transport. Much of this private land lies in unincorporated areas of Riverside County, where it was assumed that county planners would revise zoning ordinances for compatible uses. This was a big assumption, particularly given that HCP designers were not sure of the actual sand sources and wind corridors. Most of the Indio Hills and their westward flowing alluvial fans lie outside and upwind from the main preserve (see Figures 1 and 2).

The fourth type of designated area in the HCP was the fee area, which comprised more than half of the HCP's 70,000 acres. Unlike the preserve areas and managed areas, all land in the fee areas could be developed without restrictions, provided that the developer paid a $600/acre mitigation fee, which would be used to acquire and manage the preserve areas. The cities and Riverside County would collect these fees from developers, along with other assessed development fees, before issuing building or grading permits. The cities and county would then forward the fees to TNC, which would administer the fund for purchasing and managing the preserve lands.

<u>Methods</u>

In this subsection, we devote particular attention to remote sensing analysis because it is likely new to many readers. For that reason, the other methods – field research, interviews, and observation – are described in brief.

<u>Field research</u>

In June 1999, we spent two weeks in the Coachella Valley conducting field research. In addition to the interviews and observation techniques described below, we gathered several types of documentation, including: (1) news articles, and (2) several aerial photographs from 1/4/85 and 9/17/98, which we purchased from a local map store and the Coachella Valley Water District. We used the news clippings as background to develop the case history. The aerial photos helped us interpret what the land cover looked like in previous years. We also took photographs of the sites we visited. We used these photos to check the validity of our Landsat data analyses.

Interviews

We interviewed thirteen people who had either developed the HCP, implemented it, or observed its implementation. The interviews were loosely structured, relying on open-ended questions tailored to each person's position and knowledge. Some interviews were conducted in offices; others were conducted outside, as interviewees escorted us to specific sites in and around the preserve system. We tape recorded all of the interviews for subsequent analysis. These interviews helped us answer all nine evaluation questions, and provided the only evidence for answering the questions in Column C of Table 1.

In addition to asking questions, we spent 30-60 minutes during office interviews presenting posters of our Landsat images. These presentations helped us in two ways. First, they helped us learn whether and how remote sensing analysis could aid habitat conservation planning, implementation evaluation, and adaptive management. Second, the interviewees helped us to interpret the images, thereby guiding us to specific sites in the field and helping us to determine appropriate Landsat data analysis techniques to apply. The images were also of great interest to those we interviewed – so much so that we asked our questions first because the remote sensing discussions could easily consume the allotted time.

Field observation

Because the HCP covers 70,000 acres of hot, dry desert, field observation primarily involved driving throughout the area on paved and unpaved roads. We covered most of the area without escorts, stopping to take photographs and global positioning system (GPS) readings at sites containing uniform or mixed types of habitat cover. At some sites, we needed escorts for legal or informational purposes. Parts of the preserve system, for example, are closed to human uses other than research. In order to walk in and around the dunes, we were escorted by Mark Fisher, a biologist who studies species in the dune fields. Fisher guided us to specific spots to show us different types of habitat, and provide a history of human uses in the vicinity. Cameron Barrows, the preserve manager, escorted us to other sites in the 13,000-acre main preserve to identify examples of land cover types; and BLM Ranger John Blachley provided a tour of enforcement challenges he confronts in and around the main preserve. These field observation methods were particularly useful for answering the evaluation questions in Columns A and B of Table 1.

Remote sensing

We used remote sensing data provided by the U.S. Landsat Thematic Mapper (TM) satellite system. One Landsat TM image is really seven distinct digital photographs from seven sensors, each recording light reflectance at different portions of the light wavelength: three visible (blue, green, and red), two infrared, one mid-infrared, and one thermal [Campbell, 1996]. It is the data these seven sensors provide, along with Landsat TM's broad "footprint" (185 by 185 km), frequent temporal sampling (once every 16 days), and relatively fine spatial resolution (30 by 30 meter pixel) that makes it such a promising tool for land cover change research in general and for HCP evaluation in particular. However, utilizing Landsat TM images for policy analysis is not a trivial task, especially when comparisons across time are required.

We obtained "raw" Landsat TM data from the U.S. Geological Survey (USGS).[12] We selected two time points: 6/6/86 and 7/9/98. We chose the 1986 image because it coincides with initial implementation of the HCP. We chose the 1998 image to maximize the temporal extent and to control for seasonal and weather effects. We then conducted several technical procedures (georeferencing, radiometric calibration and atmospheric correction) to make the two time points comparable and to permit the use of image analysis techniques. (For more information on these processes, see Schweik and Green, 1999.) Figures 3 and 4 display the data from one sensor – visible blue light reflectance – for the northeast portion of the 1986 and 1998 images, with two of three preserve boundaries (Thousand Palms and Willow Hole/Edom Hill) overlaid. Darker areas reflect

[12] For more information, visit the Global Land Information System (http://edcwww.cr.usgs.gov/glis).

lower percentages of visible blue light, while whiter areas reflect higher percentages of visible blue light.[13]

[insert Figures 3 and 4 about here]

There are a variety of image analysis techniques one can apply to analyze land cover change [Campbell, 1996; Schweik and Green, 1999]. The choice of appropriate method depends on the research question and the particular habitat the analyst is studying. Traditional classification, probably the most common technique, is best utilized when the landscape exhibits discrete qualities because each 30 by 30 meter pixel is assigned to one category (e.g., forest, desert, or agriculture). In the CVFTL HCP case, there are some discrete components to this landscape (e.g., desert areas versus golf course fairways), but it is the more subtle and continuous change in amounts of active sand across the landscape, across time, and within pixels that are crucial to understanding the sand transport system and the performance of this particular HCP. The critical question in cell 1B of Table 1 requires remote sensing analysis that is sensitive to this transport system.

For this reason, we turned to an image analysis technique called "Matched Filtering" (MF)[14]. With MF, the analyst can estimate the amounts of important "pure" land cover types contained within each pixel [ENVI, 1997a, 1997b]. The challenge for the analyst is to locate a set of important "pure land cover pixels" or "endmembers" that can, in various combinations, accurately describe all of the other pixels in the landscape of interest. One way to reduce the number of endmembers required is by "clipping" the digital images so they only contain the geographic areas important for the research questions at hand. For instance, to understand the sand source and dune dynamics for the main preserve, we only need to analyze the valley floor from the wash areas of the Indio Hills to the south-east edge of the Thousand Palms Preserve. Therefore, we clipped out

[13] Color images or "composites" displaying combinations of sensor images can be viewed at our web site (http://[to be inserted after review]). Color composites are beneficial because they map the information of three spectral bands to the primary colors of red, green, and blue. By mapping various combinations of Landsat TM bands in color composites, more information is provided visually for analysis.

[14] MF is a module available in the software "Environment for Visualizing Images" (ENVI™).

this subregion (the dotted rectangles in Figures 3 and 4) using geographic information systems (GIS) procedures.

We then selected endmembers through a series of GIS steps using the ENVI™ software, along with field information supplied by local scientists (Barrows and Fisher) and our knowledge and observation of the region. We concluded that the landscape defined by the dotted area of Figures 3 and 4 is comprised of five important types of land cover related to the lizard's habitat and human uses. These are:

EM1: Active blow sand/sand dunes (primary habitat for the fringe-toed lizard)

EM2: Packed silt (very fine sand and silt that is stabilized like dry clay), with scattered creosote bushes

EM3: Unsorted/poorly sorted alluvial sands, gravel and rock, with scattered creosote bushes

EM4: Development (within the town of Thousand Palms)

EM5: Bright live vegetation (primarily golf course fairways)[15]

The locations of these endmember pixels for each time point are identified in Figures 3 and 4. The sensor values for these pixels were then used as input for MF modeling.

MF generates abundance estimates for endmember spectra for every pixel within the image.[16] Output can be viewed as a series of gray-scale images, one representing the abundance of each endmember. Each pixel in these gray-scale images is assigned a number between zero and one, where one is a perfect spectral match [ENVI, 1997a]. However, some pixel areas not modeled particularly well can exhibit numbers below zero or above one. We generated MF models for the two images, shown in Figures 4 and 5, respectively.

---

[15] The locations for EM2 (packed silt) and EM5 (bright live vegetation) differ between the 1986 and 1998 images. In the case of EM5, it is because the golf fairway most spectrally extreme in 1998 did not exist in 1986. In the case of EM3, it is because the spectra of the location used in the 1998 image looks different in the 1986 image. We cannot be sure that this location represents packed silt in 1986. Therefore, we chose a region more likely to exhibit packed silt in 1986 based on the spectral qualities for the 1986 MF process.

[16] Further discussion of how this is accomplished technically can be found in the ENVI™ users guide [ENVI, 1997a] and in Boardman et al. [1995].

[insert Figures 5 and 6 about here]

We validated the MF results at two spatial scales. First, we reviewed MF output at a broad spatial scale to see if patterns in endmembers made sense based on what was previously published, what we witnessed in the field, and what we heard during our interviews. Each endmember output matched our general expectations. The only noticeable problem was some slight discrepancies in development areas, where higher than expected levels of EM1 (active sand) and EM3 (unsorted sand, gravel and rocks) were identified. In many instances this could be correct because the soil in developed areas is probably made up of EM1 and EM3 material. In other instances, it could be a modeling artifact. Development pixels can be made up of many different and spectrally distinct materials, and finding one endmember location that models all other development well is difficult. While ENVI™ provides procedures to deal with these kinds of problems, we believe we identified development areas effectively with current model output by analyzing combinations of EM1, EM3, and EM4 results.

Second, we reviewed MF output at a fine spatial scale (one or more pixels) using detailed field inventory sites gathered during June 1999. For each of these sites, we documented the percentage of various land cover components and used GPS and map products to identify our location accurately. In each of the thirteen sites tested, the relative EM values matched what we documented in the field. Consequently, from both the broad and fine scale validation, we are satisfied that the MF results can be used to answer the evaluation questions in cells 1A, 1B, and 3B of Table 1.[17] We did not use remote sensing analysis to answer any other questions.

<u>Evaluation of the CVFTL HCP</u>

This section evaluates implementation of the CVFTL HCP in light of the nine questions in Table 1 and the methods specified above. Due to space limitations, we do not address each question equally; instead, we focus on the more intriguing findings.

---

[17] We provide more detail on endmember selection, validation procedures, and outcomes on our web site (http://[to be inserted after review]).

Question 1A: Are actors complying with HCP rules?

The crucial compliance issues for the CVFTL HCP have to do with whether land was acquired and protected, as specified in the HCP. Land acquisition depended, in part, on per-acre fees paid by developers. The interviews produced little evidence of developer noncompliance with fee payments. If the interviews had indicated that fee payment compliance was a problem, then we could have investigated the extent of noncompliance by gathering fee receipts for the 1986-1998 time frame and estimating, by jurisdiction, how many acres should have been developed. Comparisons could then be made to actual development based on land cover change maps generated from Landsat data.[18]

This same type of remote sensing analysis can be used to investigate how well the main preserve protected habitat from development pressures. Interviews with the preserve manager and others clearly indicated this was not a problem in the CVFTL case. Comparing the MF results from 1986 (Figure 5) and 1998 (Figure 6) for bright live vegetation (EM5) confirm this. They reveal more agriculture within the preserve boundaries in 1986 than in 1998, and a new golf course near the southern boundary. The preserve, as a set of institutions, effectively ceased new development within its boundaries. Moreover, previously disturbed desert ecosystems within the preserve boundaries are now regenerating.

Some of the designated preserve land, however, had not yet been acquired. Although these parcels were not developed, the threat nevertheless remains. These parcels had not been acquired for two reasons. First, the rate of development in the fee area slumped in the late 1980s, which meant that fewer fees flowed into the acquisition fund when land was relatively cheap. Second, the flat mitigation fee of $600/acre did not account for inflation or changes in market demand; thus, the acquisition fund proved insufficient when the pace of development quickened in the 1990s. Moreover, the HCP stated that the fee would drop to $100/acre once $7 million had been acquired, because that was the estimated value of the lands targeted for acquisition through fee payments. This plateau was reached in 1999, which means that less money is now flowing into the fund to acquire the remaining preserve lands. Unless the local governments (the permit

[18] See Macauley and Brennan [1998] on the use of remote sensing for regulatory enforcement.

holders) agree to raise the per-acre fee, the remaining lands will have to be purchased with public or nonprofit funds.

Question 1B: Do the rules sufficiently protect species and habitat?

This question should be addressed at fine, mid-range, and broad geographic scales. Measuring populations requires both a fine and mid-range scale. Given that the fringe-toed lizard is 6-9 inches long, field biologists monitor its population size at a fine scale by kneeling or walking along transects; and by capturing, marking, and releasing lizards. Mid-range scale analysis involves geographic sampling, because biologists can not count lizards at every conceivable site. Field studies indicate that fringe-toed lizards are more prevalent at sites with looser, less compact sand [Barrows, 1997].

Unfortunately, existing time-series data on lizard population counts at all three preserves are indeterminate with respect to the adequacy of the institutional rules surrounding the preserves. From 1986-1991, lizard populations declined at all three preserves (see Figure 1), particularly at the smallest preserve (Whitewater); but this period coincided with a severe drought. To what extent the rules affected lizard populations rather than the drought is unknown, particularly because lizard populations rebounded quickly after the drought Barrows, et al., 1995]. Nevertheless, the Whitewater Preserve suffered the largest population decline during the drought, which suggests that preserve size matters, and that the two small preserves may not be functionally viable for maintaining independent lizard populations in the long run. This is problematic because few lizards exist outside the preserve boundaries [Barrows, et al., 1995].

Remote sensing can not be used to monitor lizard populations, but it is very helpful for tracking changes in the lizard's habitat over broad spatial and temporal scales. In this regard, we used Matched Filtering to analyze whether the main preserve sufficiently protects the dune system and the sand transport system maintaining the dunes. (We did not address this question for the smaller preserves.) Recall that the CVFTL HCP designers were unsure of the extent to which the Indio Hills provided an important sand source for the Thousand Palms dune field (identified in Figure 2). As preserve manager Barrows [1996, p. 889] later explained:

> Experts in aeolian sediment transport estimated that the two identified sand sources each contributed about 50% of the total sand delivered to the Thousand Palms dune field. The Thousand Palms Canyon sand source was largely in a single ownership and would be a relatively simple acquisition. The western Indio Hills sand source and transport corridor was made up of hundreds of small parcels, each with separate ownership. The acquisition of this sand source would be difficult and extremely costly. This situation posed a dilemma to the architects of the HCP and the preserve system. Without quantitative data there was no way to determine whether protecting just one of the sand sources would be sufficient. Nevertheless, a decision was required; the architects of the HCP decided to protect just the Thousand Palms Canyon sand source through direct acquisition.

As time passed, Barrows and others questioned this model of dune maintenance, and accordingly commissioned geological field studies in the early 1990s, which indicated that the western Indio Hills provides as much as 95 percent of the dune field sand source [Barrows, 1996].[19]

Our multispectral data and the MF results support these conclusions.[20] Figure 7 compares the MF results for 1986 and 1998 for EM1 (active blow sand/sand dunes). In both time points, significant levels of active sand spectra appear in the alluvial areas fed by Indio Hills runoff (circles designated by "A"). The area fed by Thousand Palms Canyon (circles designated by "B") reveals much lower levels of active sand spectra in both time points.[21] This provides more evidence that the current rule system, including preserve boundaries, is insufficient to protect the main preserve's primary sand source.

[insert Figure 7 about here]

The CVFTL HCP assumed that Riverside County would protect much of the Indio Hills and its alluvial fans (see Figure 2) through zoning (see Figure 1); but it is an open question as to whether county planners will actually protect this sand source area.

---

[19] One geological study analyzed trace elements in sand grains [Meek and Wasklewicz, 1993; Wasklewicz and Meek, 1995]. A second study used aerial photographs from 1939 to 1992 to analyze active sand movement [Lancaster, et al., 1993].

[20] TM images of the Coachella Valley existed when the preserve design was chosen. The additional information provided by Landsat TM might have led the designers to a different conclusion, had these images been available to them. Availability is largely constrained by budget costs and technical capacity.

Through interviews we learned of misunderstandings or breakdowns in communication between the local officials with the Town of Thousand Palms and Riverside County who participated in designing the HCP and their counterparts who would be involved in zoning decisions. Consequently, development has occurred in blow-sand areas north and west of the existing preserve, which can be seen in the time-series comparison of EM4 (development) and EM5 (bright live vegetation) in Figures 5 and 6. It is unclear whether this development will radically alter the sand transport system, but it remains a threat because houses, buildings, and tree rows impede the movement of windblown sand into the main preserve.[22]

Question 1C: Are actors willing to redesign the rule system?

This is an intriguing question for the CVFTL HCP, and it has important implications for other HCPs. As discussed above, individuals who developed and implemented the plan are aware – and readily admit – that the Indio Hills sand source for the main preserve was not adequately protected. The preliminary images we showed them during our visit to the Coachella Valley simply confirmed what they already suspected. Yet none of these actors want to revisit and redesign the HCP itself. Instead, they hope to fix this ecological shortcoming through changes in local zoning or new acquisitions by land conservancies. These are feasible solutions because several public and private organizations in the Coachella Valley are currently developing a new HCP covering multiple species. Yet it is uncertain whether this new multispecies HCP will incorporate the "missing" sand source, or whether the HCP will even be implemented.

FWS officials have given the current permit holders an incentive to fix design problems with the CVFTL HCP by hinting that they might revoke the permit if these problems are not addressed. This may be an empty threat, however, given that the FWS

---

[21] Notice there is significant change between 1986 and 1998, with more active sand in 1998. This is consistent with a major storm event that occurred between these time points.

[22] Multispectral analysis using hyperspectral data, such as the airborne visible/infrared imaging spectrometer (AVIRIS), could help to answer this question. Landsat's bands limit the number of endmembers to five, whereas AVIRIS's 224 spectral channels significantly increase the number of endmembers one can use. This would likely improve active sand estimates near and around development.

has never revoked a permit. Nevertheless, participants in the CVFTL HCP generated a great deal of social capital that has carried over into the planning process for the new HCP, which may provide the basis for incorporating the “missing” sand source into the multispecies HCP.

The Coachella Valley experience tells us something intriguing about HCP implementation. The planning process is challenging, expensive, and time-consuming, particularly when it involves multiple actors. Hence, there is great inertia against redesigning HCPs once permits have been issued, regardless of applicant sincerity about implementation. In the Coachella Valley, actors made a good-faith effort to implement the plan, building trust through this endeavor. Now that the plan appears to be inadequate, and trust has been established, they are attempting to address the plan’s shortcomings through other means. This suggests that we should not expect to see HCPs revised if monitoring reveals ecological shortcomings in the rule system. Instead, permit holders may opt to fix HCP weaknesses through other planning processes because the HCP planning process is cumbersome and creates uncertainty for permit holders. Their legal incentive to do so depends heavily upon the willingness of FWS to revoke incidental take permits. Their economic incentive depends upon the amount of uncertainty about future land uses created by opening the rule system to redesign.

<u>Question 2A: Are actors monitoring compliance with HCP rules?</u>

Compliance monitoring was not systematic, but it did occur. With regard to fee payments, no one whom we interviewed reported examples in which developers failed to pay the per-acre fee prior to development. Compliance in this case was probably due to institutional design, because the fee was bundled with several other fees developers paid to local governments prior to receiving building or grading permits, and the $600/acre fee was relatively cheap compared to other assessed fees. The institutional mechanism for transferring the fees from developers to local governments proved effective. Yet local governments did not immediately pass the fees along to TNC. Instead, some cities held the fees for months, either to accrue interest or because controllers simply had not set up procedures to manage the transfers. Nevertheless, some actors monitored the flow of money. Preserve manager Cameron Barrows, for example, observed several large construction projects in the Coachella Valley that were not followed by new acquisition funds. He accordingly asked federal officials to investigate, and discovered that certain local governments were slow in moving the fees to TNC. In this case, monitoring subsequently led to full compliance on fee transfers.

Question 2B: Are actors monitoring habitat change in light of HCP assumptions?

As noted earlier, several actors monitored habitat change indirectly via population counts. This first-hand experience led them to wonder about the actual sand sources for the main preserve, and to commission geological field studies to identify their location. Moreover, to improve monitoring and data management for the preserve, and to support the new multi-species HCP, several actors (e.g., the preserve manager, CVAG, and the Coachella Valley Mountains Conservancy) have been actively developing a sand transport and "natural community" GIS by interpreting aerial photos and the field-based knowledge of various actors working within and around the preserves.

Given these on-going efforts, they were very interested in the remote sensing images we could provide. After returning from the field, we accordingly mailed to them several georeferenced and processed images, compatible with their GIS datasets. Our products thus provided an additional monitoring component. In short, local actors are actively monitoring whether habitat change conforms with HCP assumptions at several spatial scales.

Question 2C: Are actors willing to redesign the monitoring system?

Local actors were willing to redesign the monitoring system. In fact, everyone we interviewed expressed enthusiasm about adding Landsat data as an additional means for monitoring land cover change – for both the CVFTL HCP and the new multi-species plan. This may seem odd, given their reluctance to redesign the CVFTL preserve system, until one considers the context. In this case, everybody sought good data because good data provides certainty, and the desire for certainty is what motivates applicants to design and implement HCPs. Thus, they are very receptive to new types of monitoring, such as remote sensing analysis, because they believe it will provide better data. Redesigning the rule system, however, entails revising the HCP itself, and no one advocates revising the

HCP because they believe the cumbersome planning process creates uncertainty regarding future land uses.

Two caveats about monitoring in this particular case are in order. First, local actors in the Coachella Valley had a viable alternative to reopening the CVFTL HCP, in that they were developing a new multi-species HCP, within which they could potentially fix problems with the CVFTL HCP. Because they had this out, they were likely more willing to rethink the monitoring system for the CVFTL HCP than would be the case if monitoring threatened to expose problems that would necessitate reopening the HCP itself. Second, legal compliance was not an issue in this case. If it had been an issue, then local actors may have been much less open to a new monitoring system, because it would expose lurking compliance problems.

<u>Question 3A: Are actors enforcing HCP rules?</u>

The current enforcement system meets the general specifications laid out in the HCP and accompanying documents. The HCP specifies a bare bones enforcement system. It simply notes that each jurisdiction covered by the incidental take permit is responsible for monitoring and reporting violations to the FWS, at which point the FWS "may suspend or revoke that portion of the permit which allows actions under that jurisdiction" [CVFTL HCP Steering Committee, 1986, p. VIII-5]. The Implementation Agreement that accompanied the subsequent permit similarly specifies general enforcement responsibilities. What is intriguing in this case is that the actual enforcement system is more expansive than specified in the HCP, because the BLM agreed to enforce trespass violations – such as dumping, hunting, and off-road vehicle use – in and around the preserve. This commitment was not delineated in the HCP or Implementation Agreement. BLM support was crucial in this regard because trespass was a severe problem in the early phases of implementation, particularly until TNC and the FWS erected fences around the main preserve, and various actors educated local resource users about appropriate uses. Hunting, off-road vehicle use, and criminal practices (such as drug dealing, rape, and even murder) were once common in this area. Because the BLM did not own all of this land, BLM rangers enforced trespass violations through cooperative agreements with other jurisdictions.

Question 3B: Does the enforcement system sufficiently protect species and habitat?

The enforcement system effectively protected species and habitat in the preserve system through the late 1990s. Recently, however, the BLM reorganized ranger responsibilities in the Coachella Valley, leaving only one ranger to patrol the preserve and neighboring jurisdictions. The remaining ranger expressed great misgivings about the new situation, believing he was unable by himself to provide adequate protection for the preserve from off-road vehicle use, hunting, and other types of illegal trespass.[23] To demonstrate this point, he showed us numerous sites at which large amounts of construction material, yard waste, and household items had been dumped on the fringes of the main preserve. Although esthetically displeasing, the dumping did not suggest an immediate threat to the lizard or its habitat. Nevertheless, the possibility of exotic seeds or toxics migrating into the preserve is a possibility, and dumpers may accidentally kill (or “take”) lizards when they drop the materials.

Remote sensing products can also help to analyze enforcement effectiveness at a broad spatial and temporal scale, by monitoring compliance with rules. If there is evidence that rules are repeatedly broken, then the enforcement system is presumably inadequate. Outcomes from development and agricultural expansion and retraction are fairly easy to detect in deserts given that development usually involves planting live vegetation, for which reflectance spectra are fairly easy to distinguish. Therefore, a simple visual comparison of individual spectral bands from 1986 (Figure 3) and 1998 (Figure 4) reveal conversion from agriculture back to desert at the area identified with an "A" in both figures. Similar conclusions are reached when one compares the endmember results for 1986 and 1998 in Figures 5 and 6, respectively.

Flood control structures also manifest themselves at a variety of spatial scales. At the broad scale, we easily located known large-scale flood control structures in the Landsat TM images in various locations throughout Coachella Valley. None of these appear in these figures because there are no such structures within or near the preserves.

---

[23] Interview with John Blachley, Chief Area Ranger, Palm Springs South Coast Resource Area, Bureau of Land Management, June 13, 1999.

Nevertheless, our interviews indicated that the Army Corps of Engineers is considering new structures that might affect sand transport to the preserve, and thereby compromise the integrity of the preserve.

Evidence of prohibited off-road vehicle action is harder to detect given that the grain of off-road vehicle tracks are typically thinner than one Landsat TM pixel (30 by 30 meters). They also likely exhibit light spectra similar to flood patterns. For these reasons, evidence of off-road vehicle use and associated activities are better detected through on-site interviews and field observations, both of which have a finer degree of resolution. Interviews and field observations indicated that off-road vehicle use is now effectively excluded from the preserve. Off-road vehicle use occurs frequently in the managed areas, but this does not impede sand transport to the preserve, and may actually enhance sand transport by sorting sand from other alluvial deposits. In sum, the current enforcement system appears adequate when evaluated at several spatial scales; however, the recent reorganization of BLM ranger responsibilities raises questions for the future.

3C: Are actors willing to redesign the enforcement system?

This is a relatively innocuous question for the CVFTL HCP, because the enforcement system has not been problematic, at least not until recently. In the early years of implementation, enforcement was a severe problem, requiring intense labor input by BLM rangers and other local officials, who sought to change traditional human uses of the undeveloped lands that became part of the main preserve. Over time, intense enforcement and perimeter fencing greatly reduced unwanted behaviors, at which point the enforcement system was considered to be effective and a relatively minor issue. The recent BLM decision to reduce the number of rangers patrolling the preserves and surrounding areas suggests that actors are willing to redesign the enforcement system based upon current needs. Whether this redesign will have negative effects in the future is an open question.

Implications for Other HCPs and Other Planning Processes

An implementation evaluation such as this is a retrospective judgment of institutional performance. Yet it should be more than that. HCPs, like other planning processes, are experiments designed and implemented with incomplete knowledge and information. Hence, they are likely to be fallible even under the best intentions. There is no shame in that; but we should be willing to redesign these experiments as new knowledge and information become available. Shame and blame, if they are used at all, should be distributed only when actors are unwilling to redesign and reimplement these experiments, or when they fail to comply with explicit rules. In this regard, implementation evaluations are not simply academic exercises. Their purpose should be to inject new information and knowledge into an adaptive management process.

Adaptive management is emerging in a variety of environmental policy arenas.[24] HCPs have thus far been a notable exception. Indeed, the HCP experience is remarkable for the relative absence of adaptive management [Kareiva, et al., 1999]. The fact that this first HCP implementation evaluation was conducted sixteen years after the FWS issued the first incidental take permit suggests the magnitude of the research agenda ahead. As previously noted, at least 255 HCPs – covering 11.7 million acres – are now in some stage of implementation, with approximately 200 more HCPs under development. Other than the CVFTL HCP, we simply do not know to what extent these HCPs have been implemented, and whether they were designed effectively.

Fortunately, this study shows that implementation evaluations are feasible, that learning from new information and knowledge is possible, and that actors may be willing to redesign an HCP or fix problematic components through a variety of other institutional mechanisms. This study also suggests that remote sensing analysis is a feasible method for linking changes in land cover to specific public policies, such as the ESA. Unfortunately, the "no surprises" policy impedes adaptive management by removing a fundamental incentive for permittees to fix HCP design flaws. The CVFTL HCP is not covered by a "no surprises" guarantee because the FWS issued the permit eight years before the new policy appeared. Therefore, the FWS can revoke this permit if local governments in the Coachella Valley do not fix the design flaws, either by redesigning the HCP or through the new multi-species HCP they are currently developing. For HCPs covered by the "no surprises" guarantee, implementation evaluations can inform federal officials because they now bear the burden of fixing HCP design flaws when new knowledge and information arise.

New knowledge and information can come from many sources. Implementation evaluations, for example, should contribute to the knowledge and information stream. If those receiving a permit are not complying with the terms of an HCP, then the FWS and environmental watchdogs should know this to be the case, so they can decide whether and how to enforce the law. If the institutional design of an HCP proves to be less than ecologically sound, then it should be redesigned to ensure the survival of the targeted species. If the applicants are unwilling to redesign an ecologically unsound HCP, then federal officials and the public should know this is occurring. In sum, we need to evaluate all aspects of HCP implementation to understand how well an HCP is performing, and then incorporate these findings into an adaptive management framework. This requires acknowledging resource users' desire for certainty regarding future land uses, but without granting them the long-term guarantees embedded in the "no surprises" policy and permits lasting several decades.

Remote sensing data provides current and retrospective information for adaptive management. The available time series of Landsat images increases every month, providing an immense opportunity to inject new information into planning processes and implementation evaluations – not just for HCPs, but for other types of environmental management activities as well. Landsat data has been publicly available during all HCP planning processes, but planners may not have considered it due to budgetary constraints or limited technical capacity. It can, however, be used retrospectively to evaluate the adequacy of the plans themselves. We do not want to give the impression that remote sensing analysis is cheap, because it is not.[25] Yet the social cost of ignoring remote

---

[24] See, for example, Lee [1993] and Noss, et al. [1997]. Others use similar language, but do not use the term "adaptive management." Ostrom [1990], for example, argues that an important institutional design principle is the ability for actors to revise rules when it is deemed necessary.

sensing data may be greater, particularly when compared to the costs associated with flawed HCP designs – such as potential lawsuits, damaged habitat that may need to be restored, or even species extinction. The relative value of remote sensing analysis over other techniques may be particularly great for HCPs – and other planning processes – that cover a substantial geographic area by creating economies of scale.

We should also note that remote sensing data can be used to analyze changes in all types of land cover. As stated earlier, we chose the CVFTL HCP for this pilot study in part because the Coachella Valley has relatively flat topography. Although terrain issues (such as hill shadowing) can make remote sensing analysis more challenging, it can be applied in almost any setting, from flat deserts to hilly forests. Indeed, several scholars have applied remote sensing analysis to forested environments in non-HCP settings.[26] Regardless of the setting, the primary questions a researcher needs to ask are: (1) What types of habitat am I trying to monitor? (2) What types of human actions and land cover disturbances am I trying to detect? (3) Is it likely that satellite images and analytic techniques will provide adequate information related to these phenomena? Combined with other research methods, such as field observation and interviews, remote sensing analysis is a powerful tool for linking public policies to the environmental impacts of human activities.

---

[25] In this study, we purchased two Landsat TM images for approximately $900, but these costs can vary (up to $4840 for one image), depending on the organization purchasing them and other factors. (See http://edcwww.cr.usgs.gov/glis/hyper/order_info/prices.) There is also the cost of image processing software and a higher-end NT workstation for image processing with hard disk space and hardware for backup storage (e.g., a CD writer or Iomega Jaz drive). Field work took us about two full weeks, including interviews. Global positioning equipment has a one-time cost from $300 to $1500 depending on the quality of the receiver. Finally, the remote sensing processing, particularly the image processing techniques, took us about a month of full-time work by a person already skilled in remote sensing analytic techniques.

[26] See, for example, research conducted at the Center for the Study of Institutions, Population and Environmental Change (http://www.indiana.edu/~cipec/publications).

References

Barrows, C. (1996). "An Ecological Model for the Protection of a Dune System." *Conservation Biology* 10, pp. 888-891.

Barrows, C. (1997). “Habitat Relationships of the Coachella Valley Fringe-Toed Lizard.” *The Southwestern Naturalist* 42, pp. 218-223.

Barrows, C., Muth, A., Fisher, M., & Lovich J. (1995). “Coachella Valley Fringe-Toed Lizards.” In *Our Living Resources: A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems*, edited by E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, & M.J. Mac. Washington, D.C.: U.S. Department of the Interior, National Biological Service.

Bean, M.J., Fitzgerald, S.G., & O’Connell, M.A. (1991). *Reconciling Conflicts Under the Endangered Species Act: The Habitat Conservation Planning Experience*. Washington, DC: World Wildlife Fund.

Beatley, T. (1992). “Balancing Urban Development and Endangered Species: The Coachella Valley Habitat Conservation Plan.” *Environmental Management* 16, pp. 7-19.

Beatley, T. (1994). *Habitat Conservation Planning: Endangered Species and Urban Growth*. Austin, TX: University of Texas Press.

Boardman, J.W., Kruse, F.A., & Green, R.O. (1995). "Mapping Target Signatures Via Partial Unmixing of AVIRIS Data," in *Summaries, Fifth JPL Airborne Earth Science Workshop*, JPL Publication 95-1 (1), pp. 23-26.

Campbell, J.B. (1996). *Introduction to Remote Sensing*, Second Edition. New York: The Guilford Press.

Coachella Valley Fringe-Toed Lizard Habitat Conservation Plan (CVFTL HCP) Steering Committee (1985). *Coachella Valley Fringe-Toed Lizard Habitat Conservation Plan*. Palm Desert, CA: Coachella Valley Association of Governments.

ENVI (1997a). ENVI Users Guide, Version 3.0. Better Solutions Consulting, Lafayette, Colorado.

ENVI (1997b). ENVI Tutorials, Version 3.0. Better Solutions Consulting, Lafayette, Colorado.

Fish and Wildlife Service & National Marine Fisheries Service (FWS & NMFS) (1996). *Endangered Species Habitat Conservation Planning Handbook*. Washington, DC: U.S. Fish and Wildlife Service and National Marine Fisheries Service.

Forman, R.T.T., & Godron, M. (1986). *Landscape Ecology*. New York, NY: John Wiley & Sons.

Gibson, C., Ostrom, E., & Ahn, T.K. (in press). "Scaling Issues in the Social Sciences: A Report for the International Human Dimensions Program." *Ecological Economics*.

Holing, D. (1987). "Lizard and the Links." *Audubon* 89, pp. 39-49.

Kareiva, P., et al. (1999). *Using Science in Habitat Conservation Plans*. Washington, DC: American Institute of Biological Sciences.

Lancaster, N., Miller, J. R., & Zonge, L. (1993). *Geomorphic Evolution and Sediment Transport Dynamics of Eolian Terrains in the Coachella Valley Preserve System, South-Central California*. Reno, NV: Quaternary Sciences Center, Desert Research Institute.

Lee, K. N. (1993). *Compass and Gyroscope: Integrating Science and Politics for the Environment*. Washington, DC: Island Press.

Macauley, M.K., and Brennan, T.J. (1998). "Enforcing Environmental Regulation: Implications of Remote Sensing Technology." RFF Discussion Paper 98-33. Washington, D.C.: Resources for the Future.

Meek, N., & Wasklewicz, T. (1993). *Final Report on the Sand Sources of the Coachella Valley Fringe-Toed Lizard Habitat*. Thousand Palms, CA: Coachella Valley Preserve System, The Nature Conservancy.

Natural Resources Defense Council (NRDC) (1997). *Leap of Faith: Southern California's Experiment in Natural Community Conservation Planning*. Washington, DC: Natural Resources Defense Council.

Noss, R.F., O'Connell, M.A., & Murphy, D.D. (1997). *The Science of Conservation Planning: Habitat Conservation Under the Endangered Species Act*. Washington, DC: Island Press.

Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. New York, NY: Cambridge University Press.

Rohlf, D.J. (1989). *The Endangered Species Act: A Guide to Its Protections and Implementation*. Stanford, CA: Stanford Environmental Law Society.

Schweik, C.M., & Green, G.M. (1999). "The Use of Spectral Mixture Analysis to Study Human Incentives, Actions and Environmental Outcomes." *Social Science Computer Review* 17, pp. 40-63.

Thompson, R. (1994). "Coachella Valley Habitat Conservation Plan." In *Coordinating Growth and Environmental Management Through Consensus Building*, edited by J.

Innes, J. Gruber, M. Neuman, & R. Thompson. Berkeley, CA: California Policy Seminar, University of California.

Thornton, R.D. (1991). “Searching for Consensus and Predictability: Habitat Conservation Planning Under the Endangered Species Act.” *Environmental Law* 21, pp. 605-656.

Wasklewicz, T.A., & Meek, N. (1995). “Provenance of Aeolian Sediment: The Upper Coachella Valley, California.” *Physical Geography* 16, pp. 539-556.

Yaffee, S., et al. (1998). *Balancing Public Trust and Private Interest: Public Participation in Habitat Conservation Planning*. Ann Arbor, MI: School of Natural Resources and Environment, University of Michigan.

Tables and Figures

Table 1

<u>Questions for Evaluating HCP Implementation</u>

<u>Institutional Component</u> **<u>Analytic Lense</u>**

	(A) *Law*	*(B)* *Ecology*	*(C)* *Political Economy*
(1) *Rule System*	Are actors complying with HCP rules?	Do the rules sufficiently protect species and habitat?	Are actors willing to redesign the rule system?
(2) *Monitoring System*	Are actors monitoring compliance with HCP rules?	Are actors monitoring habitat change in light of HCP assumptions?	Are actors willing to redesign the monitoring system?
(3) *Enforcement System*	Are actors enforcing HCP rules?	Does the enforcement system sufficiently protect species and habitat?	Are actors willing to redesign the enforcement system?

Figure 1: Institutional Design of CVFTL HCP

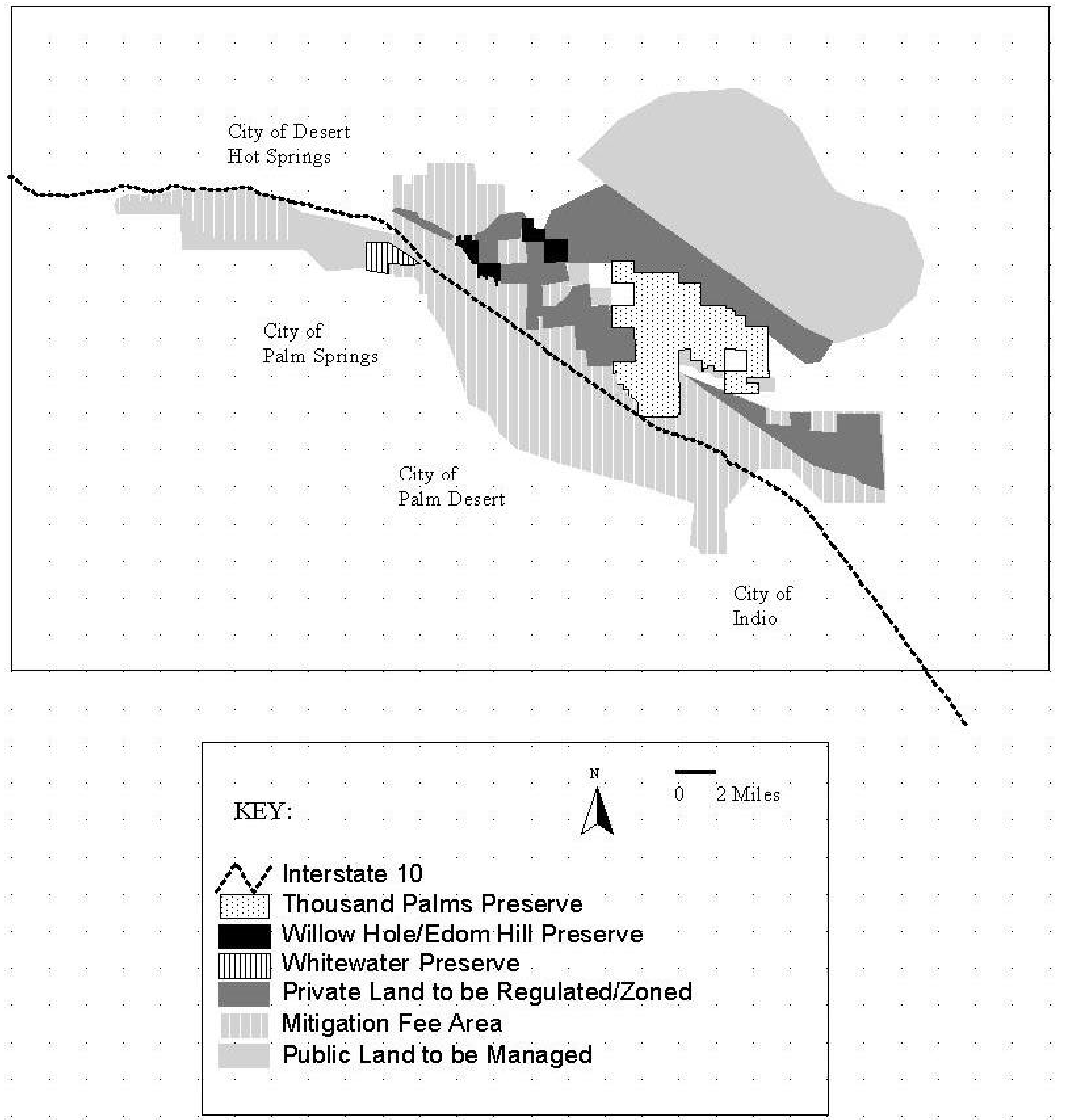


Figure 2: Depiction of the Ecological Model of Sand Transport for the CVFTL Thousand Palms Preserve (Overlaid on the 6/6/86 Landsat TM Image, Band 1 (Visible Blue); Model Adapted from Barrows, 1996)

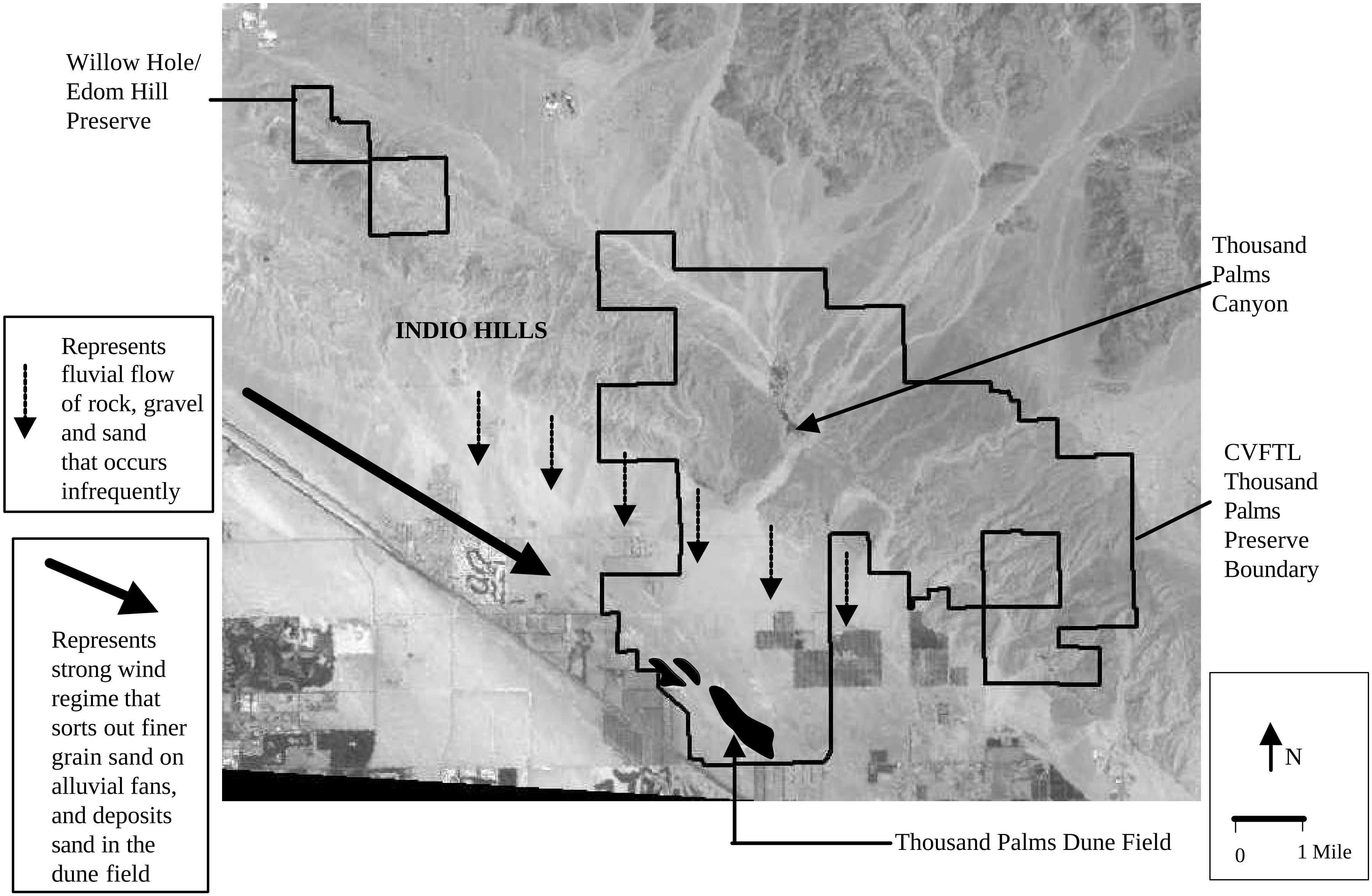
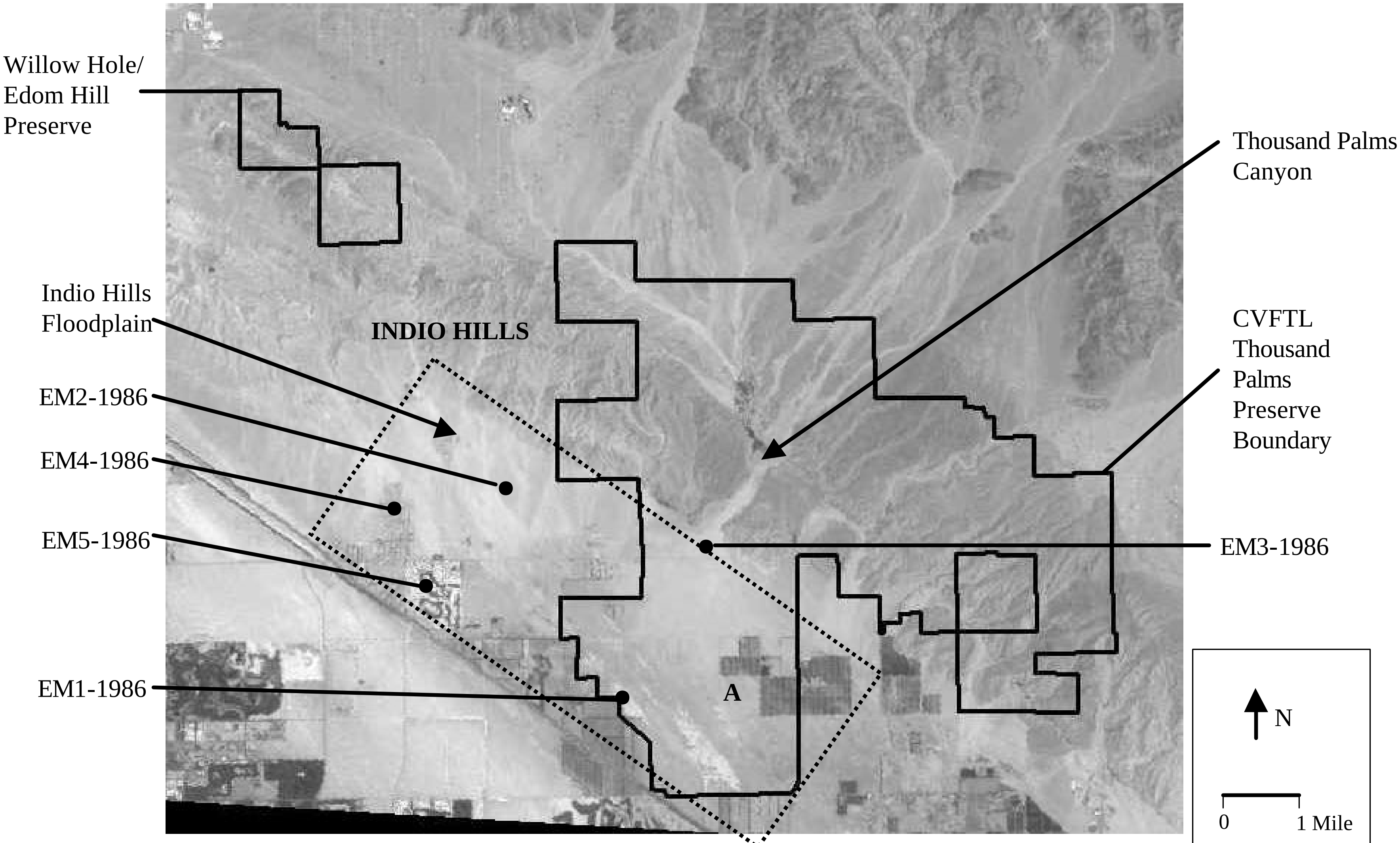
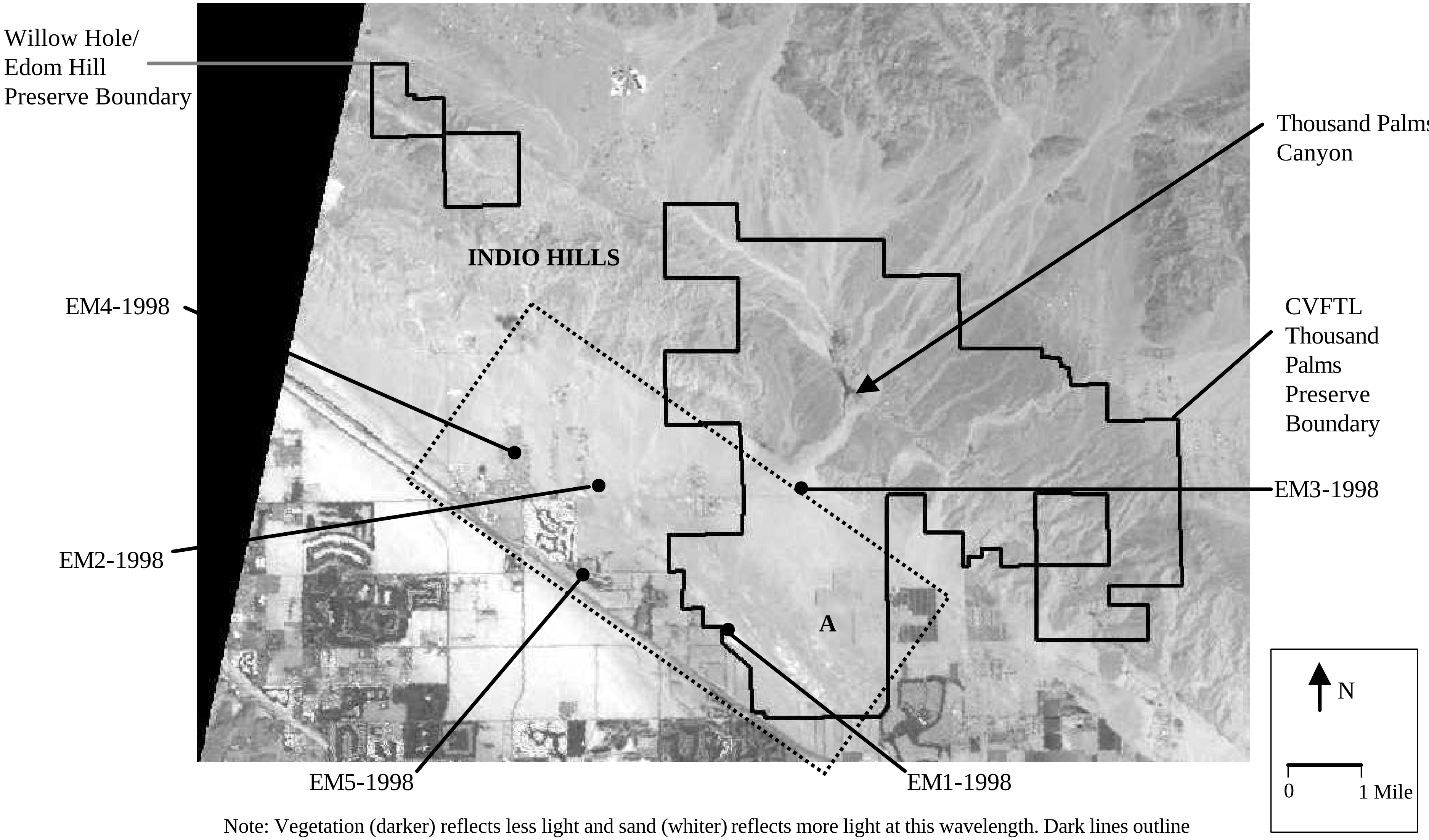


Figure 3: The CVFTL Preserve Boundary and 1986 Endmember Locations Overlaid on the 6/6/86 Landsat TM Image, Band 1 (Visible Blue)



Note: Vegetation (darker) reflects less light and sand (whiter) reflects more light at this wavelength. Dark lines outline main preserve area (large boundary in eastern portion of image) and smaller Willow Hole/Edom Hill preserve to the northwest. EM#s represent 1986 image endmember locations for input to Matched Filtering analysis. Dashed box indicates approximate subset area for Matched Filtering analysis. Location "A" indicates area of agriculture conversion to desert between 1986 and 1998.

Figure 4: The CVFTL Preserve Boundary and 1998 Endmember Locations
Overlaid on the 7/9/98 Landsat TM Image, Band 1 (Visible Blue)

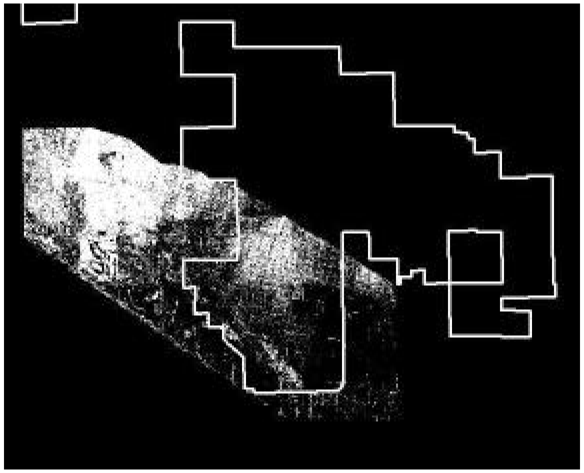


Note: Vegetation (darker) reflects less light and sand (whiter) reflects more light at this wavelength. Dark lines outline main preserve area (large boundary in eastern portion of image) and smaller Willow Hole/Edom Hill preserve to the northwest. EM#s represent 1998 image endmember locations for input to Matched Filtering analysis. Dashed box indicates approximate subset area for Matched Filtering analysis. Location "A" indicates area of agriculture conversion to desert between 1986 and 1998. The reader may also note that the western edge of the 1998 image is different from the 1986 image.

Figure 5: Landsat TM 06/06/86 Matched Filtering Results With
The CVFTL Thousand Palms Preserve Boundary Overlaid

EM1 1986 - Active blow sand/Sand dunes

EM2 1986 - Packed silt with scattered creosote bushes



EM3 1986 - Unsorted or poorly sorted alluvial sands, gravel and rock

EM4 1986 - Development

EM5 1986 - Bright live vegetation

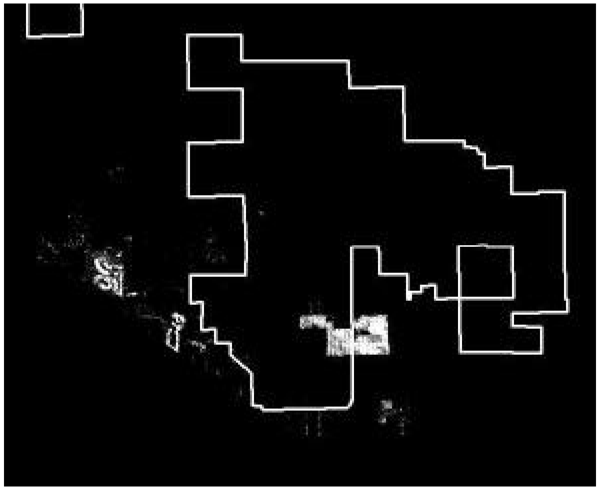
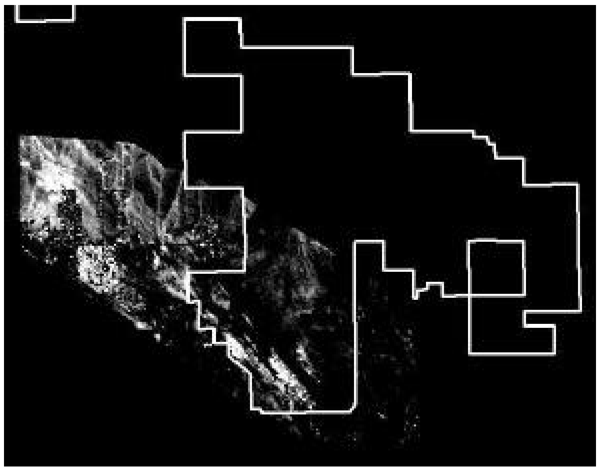
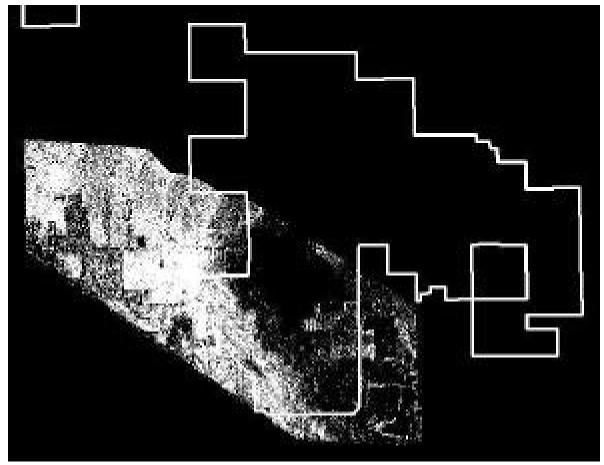


Figure 6: Landsat TM 07/09/98 Matched Filtering Results With
The CVFTL Thousand Palms Preserve Boundary Overlaid

EM1 1998 - Active blow sand/Sand dunes



EM2 1998 - Packed silt with scattered creosote bushes



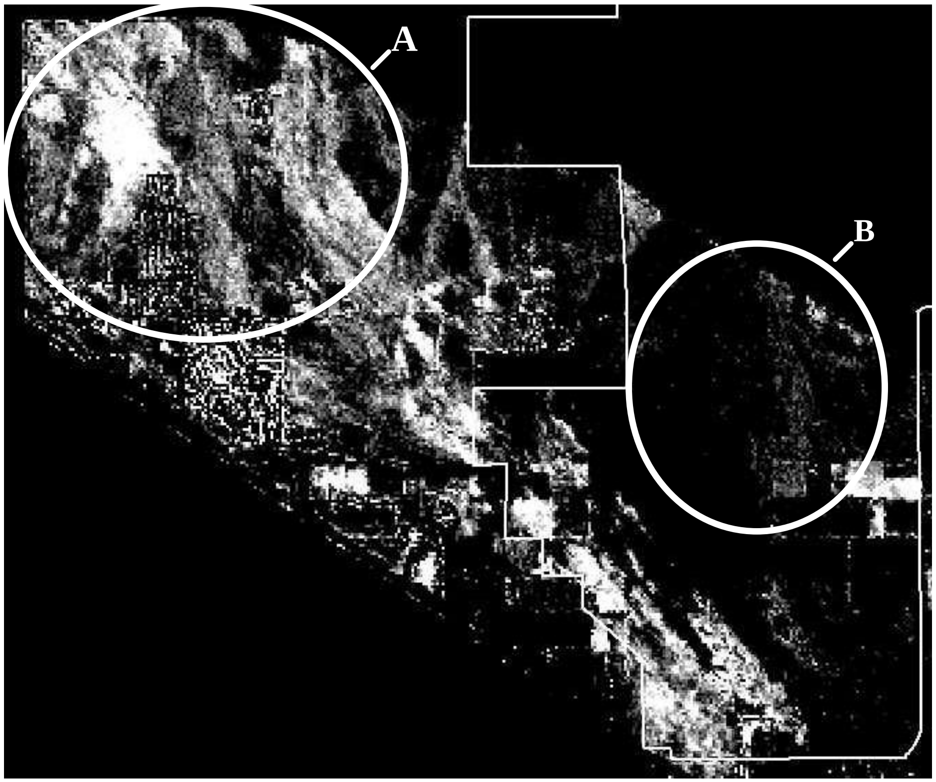
EM3 1998 - Unsorted or poorly sorted alluvial sands, gravel and rock

EM4 1998 - Development

EM5 1998 - Bright live vegetation

Figure 7: Time-Series Comparison of Active Sand (EM1) MF Results

6/6/86 EM1 MF Results



7/9/98 EM1 MF Results