EXECUTIVE SUMMARY

Assessing Ecosystem Service Benefits from Military Installations

SERDP Project RC18-1604

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ACRONYMS AND ABBREVIATIONS

BRI	benefit relevant indicator
DOD	Department of Defense
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
MoTIVES	Model-based Tracking and Integrated Valuation of Ecosystem Services
SERDP	Strategic Environmental Research and Development Program
STSM	state-and-transition simulation model

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ACKNOWLEDGEMENTS

Our team would like to acknowledge the major assistance we received from many people critical to the successful completion of our project. In particular, Brett Williams, the Eglin Wildland Support Module Lead, provided access to data and information; he gave us valuable time and expertise, assuring that we understood as much as possible about the how Eglin is managed. Brett and Bruce Hagedorn both willingly addressed all of our questions.

Equally important to the project success was the help provided by Dan Hipes and Jon Otting at the Florida Natural Areas Inventory of Florida State University, who provided us with data, helped with the analysis linking forest states to Eglin threatened and endangered species, and, because of their expertise and experience with Eglin species, were able to help us solve many of the complex questions that arise in a project involving multiple models.

At Fort Hood, we received data and guidance from Amber Dankert, Virginia Sanders, and David Preston from the base, and Charlotte Reemts of The Nature Conservancy, provided time and information from her work at the base to help understand the relationship between habitats, endangered birds, and management at the base.

KEYWORDS

Bayesian modeling, Benefit-relevant indicators, Ecosystem services, Eglin Air Force Base, Integrated modeling.

1.0 OBJECTIVES

This project addresses the following three objectives from the Strategic Environmental Research and Development Program (SERDP) Statement of Need:

1. Define and delineate the biological, physical, and chemical services provided, including natural and nature-based features that provide benefit.
2. Understand cumulative effects, feedbacks, and compensatory behavior of complex systems related to management of natural ecosystems and biological diversity.
3. Examine models that incorporate economic concepts and that may improve decision-making to evaluate trade-offs.

To meet these objectives, we are developing an integrated ecosystem services model called **MoTIVES (Model-based Tracking and Integrated Valuation of Ecosystem Services)** that can be applied to any military base or Department of Defense (DOD) facility to estimate the impact of base management on the provision of ecosystem services, while accounting for interactions, offsets, and co-benefits among services.

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2.0 APPROACH

Ecosystem services are the benefits that nature provides to people. Often, the existence of healthy natural systems and species is of sufficient importance to decision makers that no further information is needed, but in many cases, it can be more impactful and informative to quantify the specific benefits that nature is providing. To this end, we are developing the integrated ecosystem services model MoTIVES so that it can be applied to any military base or DOD facility at which natural resource management is being undertaken or considered. The model encompasses a wide range of habitats and management activities and will produce an assessment of a wide range of ecosystem services while accounting for interactions among habitats and services. To date, we have developed methods for evaluating **two scenarios relative to a baseline of current management**: (1) a no management scenario to assess how ecosystem services would differ if the base did not conduct any natural resource management, and (2) a no base scenario to assess how ecosystem service provision would differ if the base did not exist.

We developed and piloted our conceptual models at four bases: Eglin Air Force Base in Florida, Fort Hood Army Base in Texas, Camp Lejeune Marine Base in North Carolina, and Joint Base Lewis–McChord in Washington. We then applied this approach using more specific data and relevant ecosystem services to **Eglin Air Force Base**, as an example of how it could be applied elsewhere.

The development of our integrated ecosystem services modeling approach involved:

1. Creating a set of generalized ecosystem service **conceptual models** as the foundation for a modeling framework that links management actions to ecosystem services while identifying potential interactions.
2. Selecting and applying biophysical ecological models (terrestrial, aquatic, and flood models) that characterize ecological state, condition, and function under the various scenarios of interest.
3. Translating ecological state, condition, and function to benefit relevant indicators (BRIs) of ecosystem service provision.
4. Estimating the economic value of the BRI levels whenever appropriate using approaches including benefits transfer and direct estimation.
5. Joining the components above into the integrated ecosystem services model (MoTIVES) to quantitatively and holistically account for cumulative effects, co-benefits, feedbacks, and compensatory behavior.

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3.0 CONCEPTUAL MODELS

Ecosystem service conceptual models visually display how a base management action can cause changes to biophysical aspects of an ecosystem and how these changes translate to BRIs and, when applicable, their economic values (Figure 1). Such conceptual models form the basis of our subsequent quantitative modeling. Because there are common habitat types that occur across DOD lands and there are often a defined set of management actions being taken within these habitats, we determined that we could formulate a limited set of **generalized habitat conceptual models** to be adapted and applied to any military base to then create a **base-specific model**. These base-specific models are then used as the framework for quantitative estimates of ecosystem services under specific base-relevant scenarios. Thus the conceptual framework creates consistency in ecosystem service assessment across bases, displaying how different elements of the system interact and providing a visual summary of the relevant ecosystem services being quantified at each base.

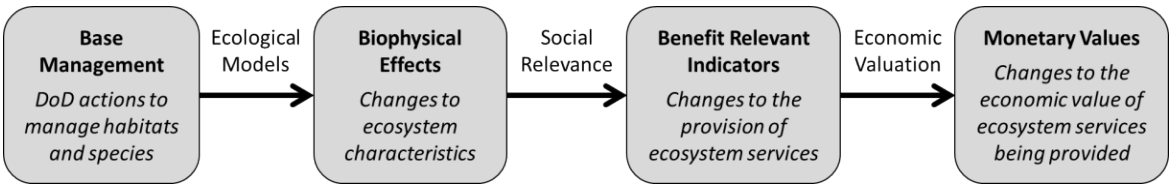

Figure 1. General Structure of an Ecosystem Services Conceptual Model.

The actual conceptual models include a detailed representation of each of the four stages shown here.

Generalized habitat conceptual models: Eight generalized habitat conceptual models have been created to reflect common ecosystem service flows on military bases. These models illustrate how management actions on bases result in changes to ecosystem services being provided by specific terrestrial and aquatic habitat types that occur on bases all over the U.S., including: 1) fire-maintained forests, 2) forests not maintained by fire, 3) fire-maintained grasslands, 4) grasslands not maintained by fire, 5) deserts, 6) rivers, streams, and riparian areas, 7) lakes, ponds, and wetlands, and 8) estuaries, saltmarsh, bays, and shorelines.

Base-specific conceptual models: Generalized habitat models are adapted and combined to create base-specific conceptual models that reflect the ecosystem service changes resulting from management at a particular base. Since the generalized models include *potential* ecosystem service outcomes, some outcomes may not be applicable to a particular base of interest. Therefore, to build a base-specific model, the user selects only the habitat models relevant for the base and removes irrelevant components. Once each relevant habitat model has been adapted to reflect the base-specific context, the resulting connected habitat models represent the integrative conceptual modeling framework to be used to quantify the base total ecosystem service flows.

Quantitative predictive model MoTIVES builds on the conceptual models by integrating ecological models to represent the biophysical connections between management actions and changes to ecosystem type, condition, function or extent. Following are the two classes of ecological models being used:

Terrestrial Vegetation Condition Models: State-and-transition simulation models (STSMs) describe the primary states of vegetation composition and structure, and how individual states change over time under various disturbances (e.g., wildfire) or with management. We used STSMs to estimate the effects of management actions such as prescribed burning and timber harvest, disturbances such as wildfire and floods, and other processes on future vegetation condition using the open source ST-Sim software. STSMs provide outputs describing the amount of area occupied by each vegetation condition on a base under a set of management actions. These area estimates can then be tied to certain ecosystem services that are dependent on vegetation condition.

Aquatic Models: A series of models are available to model how management, wetlands, riparian vegetation, streams and other water bodies, soils, and other factors influence the type and amount of aquatic ecosystem services provided by a base. These include flood risk and flood amelioration, provision of water for drinking, livestock, irrigation or industrial use, reduction of sedimentation and nutrients, and habitat for valuable aquatic species. For this project, we included a flood risk model (HAZUS) to calculate the flood hazard, or the annual chance of inundation at specific flood depths associated with inland flood risk as a function of local elevation and land use characteristics. Flood events are valued economically within HAZUS using data from the U.S. Census. In some cases, high resolution aquatic data sources specific to military installations can be used to parameterize models or provide economic valuation for services provided on the base.

Services were quantified using metrics referred to as **benefit relevant indicators (BRIs)**. BRIs are the hand-off between ecological function and social impact, connecting the supply of benefits and the reception of those benefits by people. For example, water storage capacity of a wetland is an ecological indicator, but the reduction in flooding risk to the downstream community resulting from that wetland is a BRI. In some cases, these BRIs can be extended to a monetary value, but in others monetary valuation is not possible or appropriate. When possible, we assign **economic valuation** to these BRIs using literature or base-specific data.

For final evaluation, the various steps and components described above were joined into the **MoTIVES** model. This has the advantage over parallel assessment of individual ecosystem services in that it allows for quantitative and holistic consideration of interactions, including co-benefits and offsets. This is especially important when accounting for uncertainty or potential site-to-site variability in assessment results. Changes in individual habitats and ecosystem services may be positively or negatively related to one another at any particular base. These relations may counterbalance one another, resulting in a smaller-than-expected change, or may reinforce one another, resulting in a larger-than-expected change. Representing such relations and interactions in an integrated model provides a more robust and realistic comparison of ecosystem service differences between evaluated scenarios.

4.0 PROOF OF CONCEPT: EGLIN AIR FORCE BASE

Eglin Air Force Base is the largest forested military base in the United States, supporting the largest remaining mature longleaf pine (*Pinus palustris*) forest in the world, habitat for 24 listed threatened or endangered species, and extensive freshwater and estuarine wetlands, ponds, and riparian meadows. The base has a number of coastal streams and bays that support at-risk fish, along with desirable fishing locals. The base allows access for fishing and boating in all appropriate areas. Much of the eastern portions of Santa Rosa Island, a Gulf of Mexico barrier island, is part of Eglin, supporting turtle nesting, habitat for endangered shorebirds and a sand adapted threatened lichen, along with providing protection from storm surges and coastal flooding to the communities of Fort Walton Beach and Navarre. The base supports recreation, hunting, and fishing, while providing the necessary infrastructure for its primary training mission.

We used the MoTIVES model to evaluate three scenarios for Eglin Air Force Base:

- **Current management scenario:** The baseline scenario of current management assumes that current natural resource management on the base would continue at current rates, primarily consisting of widespread use of prescribed burning to create the open conditions favorable to longleaf pine and associated wildlife species.
- **No-management scenario:** In this scenario, we assumed that the base continued all military operations but did not (currently or historically) manage for natural resources, with no prescribed fire or other management activity specific to natural resources.
- **No-base scenario**: To assess the total ecosystem services being provided by the base, we created a counterfactual scenario in which the base does not exist, and based projections on land use and land cover consistent with surrounding areas.

Annualized results from these scenarios were calculated for the future time period of 2020-2035. Results for these analyses were reported for 1) vegetation condition, 2) flood exposure and protection, 3) summarized for all monetized ecosystem services and 4) habitat for at-risk species.

1: Vegetation condition. Currently, late open conditions cover roughly half of the forested area at Eglin (roughly 77,000 ha). Under the current management scenario (consisting of continuing large-scale prescribed burning), the area of late open forest is expected to increase to roughly 115,000 hectares, covering the majority of the base (Figure 2). Conversely, under the no management scenario (without any prescribed burning either currently or historically), the base would likely contain very little (<5%) older, open longleaf pine and largely consist of older, closed forest. Closed canopy forests burn rarely, tend to become invaded by sand pine, and provide low quality wildlife habitat. Under the no base scenario, we expect ~50,000 hectares of conversion from forest to other land use types, and of the remaining forest, very little is projected to remain in late open conditions due to frequent clear-cutting and dense replanting on private timberlands.

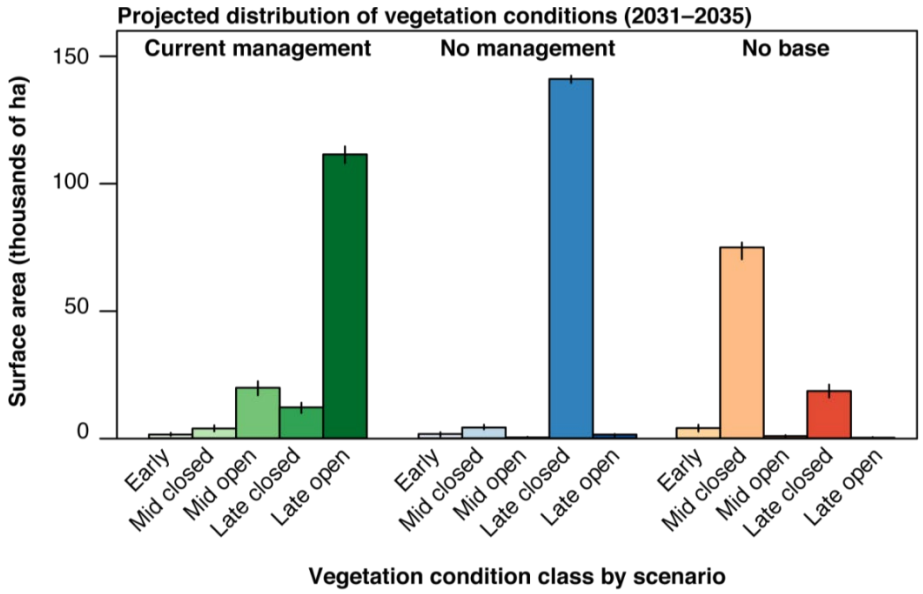

Figure 2. Projected Longleaf Pine Forest Condition Classes at Eglin Air Force Base across the Current Management, No Management and No Base Scenarios in Years 2031-2035.

Without active management of longleaf pine through prescribed fire under the current management scenario, condition degrades from open (desirable) to closed (undesirable) canopy conditions.

2: Flood exposure and protection. Under current management, expected losses from flood events over the period 2020–2035 average $610.4 million per year for the three counties surrounding Eglin Air Force Base. Under no-management and no-base scenarios, these losses are expected to be $579.8 million per year and $637.3 million per year respectively. However, increased density of all trees under the no-management scenario means that this counterfactual scenario would be associated with flood risks roughly $31 million per year lower than with current management conditions.

Table 1. Modeled Valuations of Future Flood Risks (damages) by Scenario over Period 2020–2035.

Values displayed are means (95% CI).

Units	Current management	No management	No base
M$/yr [(b)]	610.4 (251.7–1,689.2)	579.8 (239.1–1,604.7)	637.3 (262.8–1,763.6)

3: Monetized ecosystem services. Current management practices generate ecosystem service benefits that are most often greater than the benefits associated with counterfactual no-base and no-management scenarios. However, there are trade-offs: flood risk may be lower with no base; timber harvest would likely be greater with no base; and above-ground carbon storage is greatest with a base that is not managed for natural resources.

Annualized results from these scenarios are presented for the future time period of 2020-2035. They include very high flood hazard reduction values, with no management preventing ~ $31 million in flood damage than current management, and ~$57 million more than a no base scenario. Because these represent risk probabilities, they were treated separately. All other services that could be valued in dollars were compared, with the results shown in Figure 2.

Table 2. Modeled Ecosystem Service Values Under Three Scenarios.

Values displayed are means (95% confidence interval in parentheses where modeled probabilistically).

	Current management	No management	No base
	Monetized services in millions of dollars/year[a]		
Timber harvest	1.0	0	39 (24–48)
Recreational hunting	36	0	0
Recreational fishing	11	0	0
Carbon storage	1.6 (0.7–3.5)	3.1 (1.4–6.7)	1.2 (0.6–2.6)
Red-cockaded woodpecker value	56 (35–70)	30 (18–36)	11 (6.8–14)
Total monetized services[b]	**109 (87–123)**	**33 (20–40)**	**51.2 (32–63)**

[a] Annualized net present value over period 2020–2035 assuming a 5% discount rate.

[b] Total adjusts for correlated uncertainties and may not equal arithmetic sum of individual services.

4: Habitat of at-risk species. Eglin Air Force Base is home to a number of threatened, endangered, and endemic species, many of which rely almost entirely on the base for their survival. Thirteen of these species were modeled under the three scenarios as part of this study. Current management practices produce the greatest area of suitable habitat for most of these species, including sufficient amounts to preclude federal listing for a number of them. The exceptions were the Gulf Coast redflower pitcherplant and smallflowered meadowbeauty. For these two species, the no-management scenario provides slightly more area of suitable habitat. The no-base scenario severely reduces available habitat for all species. Figure 3 shows the comparison between the predicted species habitat areas.

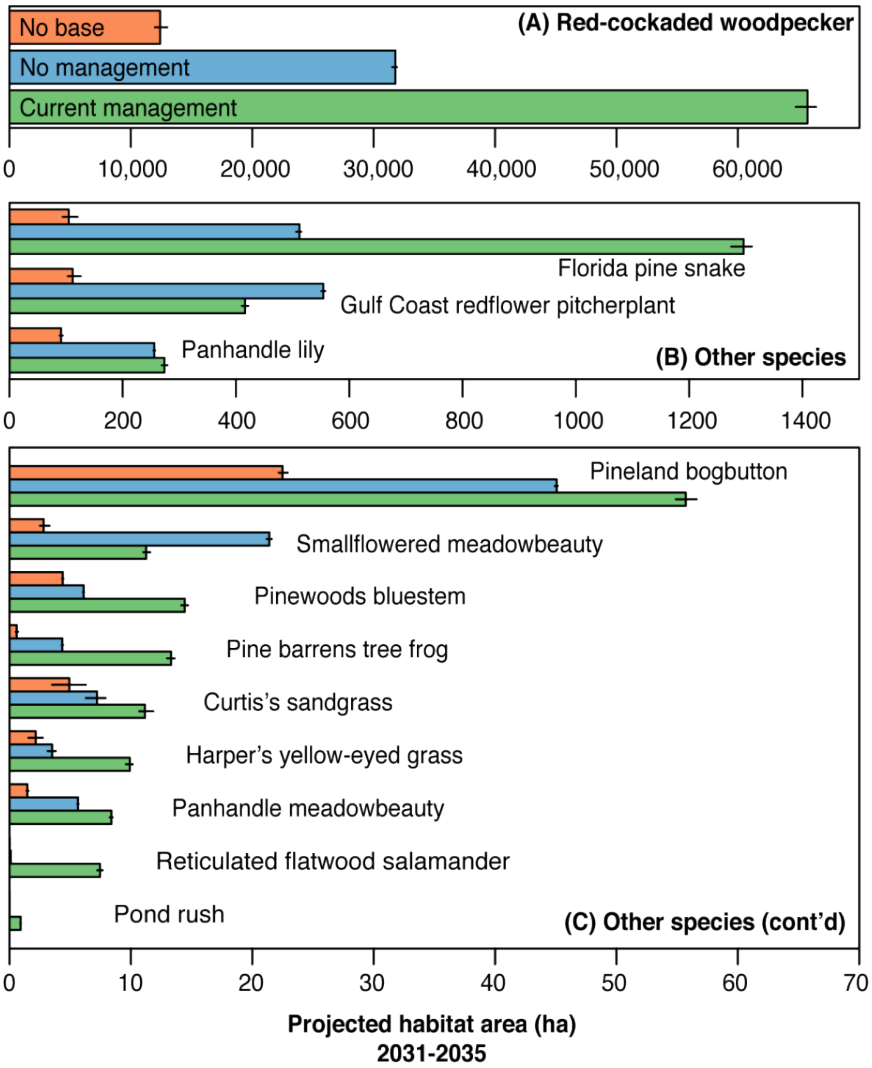

Figure 3. Habitat Area Available for Key Species Under the Three Scenarios.

Values plotted are based on projected distribution of vegetation in the period 2031–2035. Error bars are the 95% confidence interval.

5. Comparison of scenarios. Current management practices are associated with higher ecosystem service generation and lower value of flood risks than the no-base counterfactual. Conversely, the no-management counterfactual is associated with lower ecosystem service generation but also lower flood risks than current management. Taking account of these expected costs and benefits across scenarios, we find that the current management practices scenario produces significantly higher net benefits than either of the two counterfactuals (mean of $90.8 million and $40.5 million per year relative to no-management and no-base respectively) (Table 3).

Table 3. Modeled Net Benefits of Current Management Compared to Counterfactual No-management and No-base Scenarios.

Values displayed are means (95% CI).

Current management service provision improvement over		
Units	**No management**	**No base**
M$/yr [(a)]	90.8 (66.5–127.1)	40.5 (9.2–69.6)

[(a)] Annualized net present value over period 2020–2035 assuming a 5% discount rate and accounting for correlated uncertainties across individual services

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5.0 RECOMMENDATIONS FOR ADDITIONAL RESEARCH NEEDS

Aquatic ecosystem services. Because the most important services provided by Eglin Air Force Base were linked to the management of terrestrial ecosystems, in our pilot study we were not able to take advantage of some of the models and tools related to aquatic ecosystem services. At other bases, where aquatic systems and services are important, other models should be incorporated. The Integrated Valuation of Ecoystem Services and Tradeoffs (InVEST) models have been tested and are simple to apply in many areas.

Water quality improvements. Similarly, research into water quality improvement related to both the ecosystem processes of nutrient removal, and the value of removed nitrogen and phosphorus for anything but waste water treatment would improve our model outputs.

Research into valuing species existence. Tradeoffs are most easily evaluated if different services can be measured in similar units, which is why economic valuation is so useful. Yet many base management activities on the pilot bases are focused on management of threatened, endangered or endemic species, as they provide critical habitat for them. The conservation or expansion of populations of at-risk species represent important management outcomes.

More comprehensive assessment of economic values. We estimated economic values for many BRIs, but future research is needed to provide a more comprehensive assessment. Economic values for market goods are readily estimated because these goods have observable prices. For example, we computed economic values for timber and flood damage using market data on stumpage and real estate prices. Valuation of non-market goods is also possible using techniques such as the contingent valuation method. Non-market benefits quantified for Eglin include species preservation and carbon storage.

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6.0 CONCLUSION

Since ecosystem services have become widely recognized as a useful tool for assessing the success of natural resource management actions, quantifying and reporting on these services is becoming part of good resource management practice. Our approach can help DOD natural resource managers show how they are enhancing the production of services, and how the existence of the base itself provides substantial ecosystem services benefits to people.

Our approach is unique in a number of ways. First, we use conceptual models as an intuitive transferable foundation for building base specific models across habitat types and management strategies. Second, we develop an assemblage of multiple models in an interactive probabilistic platform that can address trade-offs and interactions. Third, we explicitly use BRIs as an alternative or additional measure to economic valuation.

Due to its modular framework, we have been able to take advantage of previous ecological assessment work available at many bases, but also have methods that apply where previous ecological modeling has not occurred. We have identified national models and datasets available for the contiguous 48 states. To use the approach in other regions, additional data and models would need to be identified. The methodology can be readily transferred to any large base anticipated to generate ecosystem services.

Ecosystem service outputs in the model are estimated in dollar values when possible, and also in valued benefits (BRIs). Often BRIs are more meaningful for stakeholders and are useful to communicate in addition to dollar values when both are available. Because most bases provide a diverse array of ecosystem services, and because some management decisions can reduce some services while increasing others, our methods combine this complex assemblage into a single, Bayesian model (MoTIVES) to integrate outputs and allow an evaluation of alternative management scenarios. This makes it possible for natural resource managers to evaluate how management for a particular habitat condition to support species or training will impact values for other services. Additionally, these management scenarios allow a comparison of different management choices as well as providing essential baseline comparisons needed to measure some ecosystem services such as flooding prevention.

The MoTIVES structure also allows it to take advantage of a broad array of available ecosystem assessment tools, broadening the ability to use the best data or model available for a particular base. A distinguishing feature of MoTIVES is the fact that it explicitly considers uncertainty in all aspects of the model and translates this uncertainty to model endpoints using Monte Carlo simulation. By using simulation to explore the range of possible consequences of management on ecosystem service values, we decrease the likelihood of later surprises or missed opportunities. This approach makes conclusions robust to questions about confidence in numerical answers. For example, despite wide confidence intervals, we are able to say with >95% confidence that net benefits of current management practices at Eglin Air Force Base are greater under current management than under plausible alternative scenarios considered.

The results from Eglin Air Force base show that current management provides very significant ecosystem service values, estimated at approximately $110 million dollars a year, much more than the same base not managed, or the same area if it had not become a base. It appears likely that similar results would result from this analysis at Fort Hood and most of the other large military installations.