**An Essay:**

# CONSIDERATIONS IN

# INVENTORY AND MONITORING

# FOR THE

# KAHO‘OLAWE RESTROATION PLAN

**by:**

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# I. INTRODUCTION

*Aloha e pa‘a ‘oia ma ka pono.* After decades of struggle against destruction, the native peoples of Hawai‘i have reclaimed their rights to their ancestral Island of Kaho‘olawe and embarked on a mission of restoration. This remarkable undertaking is unprecedented: to bring back to life an island that has served as a bombing range for over fifty years. As foresters, farmers, and stewards of our own lands, the authors of this essay wish to extend to the Kaho‘olawe ‘ohana our heartfelt appreciation and respect for your perseverance, our joy in your accomplishments, and our sincere best wishes for the success of your restoration endeavors. *Mahalo.*

This essay examines natural resource information considerations in order to assist the Kaho‘olawe Island Reserve Commission in their development of the Kaho‘olawe Restoration Plan. Conceptual Outline Goal 8, Establish a Long-Term Monitoring Plan, is consistent with the Vision of the Kaho‘olawe Island Reserve Commission: *to restore the long-term future condition of the environment and ecosystems of the Kaho‘olawe Island Reserve, to involve the people of Hawai‘i in caring for the Island, and to help perpetuate the indigenous Hawaiian culture for future generations*, (Kaho‘olawe Use Plan, 1995).

This essay includes discussion of important inventory and monitoring considerations, together with specific recommendations for the Kaho‘olawe Restoration Plan, organized into five themes: comprehensiveness, cost-effectiveness, analytical integrity, spatial scales, and presentation.

Inventory is the process of collecting and analyzing *static* information about natural resources: baseline measurements of the current environment. Monitoring is the collection and analysis of *dynamic* information: the changes in conditions, factors, and characteristics over time. Together they encompass the task of knowledge acquisition, or learning, about natural systems.

Valid and comprehensive information about natural resources has multiple values. Management decisions affecting Kaho‘olawe Island restoration efforts will be made with respect for the land and the Hawaiian peoples, and must therefore be based upon, and justified by, acceptable information. Good stewardship and fulfillment of environmental responsibilities require many forms of data gathering and analysis, about many resources. Information must be trustworthy, and the inferences drawn through analysis must be valid and robust. Managers and decision-makers need to know what is true, what is probably true, and what is neither, when making management decisions.

Direction of inventory and monitoring is best kept in the hands of those individuals who bear the greatest accountability and authority. Responsibility for the numerous and diverse restoration efforts under consideration, for proper training of restoration workers, and for appropriate application of treatments, require that ‘ohana leaders be knowledgeable in all aspects of the program. Inventory and monitoring provide the means to ensure that all restoration efforts lead to fulfillment of the Kaho‘olawe Vision as wahi pana, linking Hawaiians to their past and future.

# II. CONSIDERATIONS

## A. Comprehensiveness: "Asking the Right Questions"

Comprehensive inventory and monitoring means systematic assessment of present and anticipated future conditions and characteristics of all archaeological, historical, and environmental resources found on Kahoʻolawe and surrounding waters, and of the many cultural, social, and economic factors which influence, and are affected by, those resources.

Planning for comprehensive inventory and monitoring systems should begin with an intensive examination of goals. Goal formation should include input gathered from managers, decision makers, researchers, biometricians, concerned groups, and affected communities, with clear descriptions of the information desired. The key point is to ask the right questions: those with answers that can be acceptably and efficiently estimated, and that yield the information necessary for management decision-making.

The primary purpose of inventory is to quantify existing resources. The condition and potential productivity of the resources are among the attributes that are desirable to measure. Descriptions of the locations of ecosystem characteristics of the Island must accompany quantification of those attributes.

Managers often expect inventory systems to identify special conditions or situations, including potential hazards to various resources. Some of these have already been extensively inventoried on Kahoʻolawe, such as damaged soil and remnant military ordinance. Other special ecological conditions that require inventory efforts, such as the presence and abundance of alien plant and animal species, may be identified in the planning process.

A monitoring system is an inventory system that can detect change. Detecting trends in resource attributes often requires more effort and expense than one-time inventories. Ideally, monitoring systems should also predict change. Both detection and prediction require a base from which to measure transitions, but the necessary accuracy of measurements may be different. Prediction error always exceeds detection error. Predictive inference is always weaker. However, reasonable expectations of predictive accuracy may be estimated prior to data collection through preliminary investigations, helping to build cost efficiencies into the monitoring program.

Two types of monitoring are generally required by decision-makers: *effectiveness* monitoring and *compliance* monitoring. Effectiveness monitoring investigates the extent to which restoration projects are achieving natural resource goals. Compliance monitoring investigates whether programs and personnel are following the rules and conditions established by restoration managers. Together they form the feedback mechanism necessary for integrating restoration efforts with restoration goals.

Decision makers sometimes desire monitoring to ascribe causes to change. Causation is very difficult to infer from non-experimental data, (some would say impossible). Planning for inventory and monitoring should consider *designed experiments* as powerful tools to include in the program. Designed experiments are the best means of detecting and measuring cause-and-effect relationships. Decision makers must be aware that some questions cannot be answered without controlled experimentation. Expending scarce funds on retrospective, observational studies, which promise little inferential utility, is wasteful and may impede useful knowledge acquisition.

Each restoration project requires unique monitoring protocols designed to yield the maximum information and the broadest inferences, within the available funding constraints. Monitoring systems should include explicit testable hypotheses in order to differentiate between natural environmental fluctuations and ecological responses to restoration treatments.

Timeliness is an important consideration in planning inventory and monitoring systems. Data analyses completed long after decisions must be made are less valuable than analyses prior to decision making.

Coordination of inventory and monitoring efforts, between each other and among resources, is also important. Vegetation, wildlife, cultural, and other resources should be inventoried together when possible to avoid repetition of effort. Standardized methods are needed for long-term studies. Capricious changes in monitoring protocols hamper the ability to make strong inferences about resource trends.

## B. Cost-Effectiveness: "Getting the Most Value from Inventory and Monitoring Expenditures"

Inventory and monitoring systems must be efficient and effective at answering questions of interest. Our present knowledge about natural systems is greater than ever, but proportionally more information is needed now, as well. At the same time the cost of knowledge acquisition is significant and increasing.

Inventory and monitoring can convey direct benefits. If ‘ohana members are active participants in data collection and analysis, then inventory and monitoring dollars will remain in the ‘ohana community. In addition, participants will learn about the resources of Kaho‘olawe, and they will build personal cultural, emotional, and spiritual bonds with the Island and their heritage.

> *Restoring the Island will provide a place and a purpose for a new generation of Hawaiians to be trained in both the rights and responsibilities of "kahu o ka ‘aina" (stewards of the land). This involves learning to care for the natural resources. ... The Island will provide a place for Hawaiians and other kama ‘aina who see Hawai‘i as their homeland to experience the intimate connection to land, the sea, the kupuna (ancestors), and the akua (gods).* Kaho‘olawe Use Plan, 1995.

The indirect benefits of inventory and monitoring are more difficult to measure, but they are significant nonetheless. New knowledge influences management decisions, aiding in achievement of management goals. Conservation and enhancement of resources are improved and validated by inventory and monitoring. With good information, management is more efficient, effective, and justifiable. The desired legacy, which the Vision of the Kahoʻolawe Island Reserve Commission calls for, will be more easily attained, and will become a verifiable reality for future Hawaiians.

The Kahoʻolawe Island Restoration Commission should own all data collected, and enforce this ownership through responsible contracting when utilizing outside research providers. Data sets themselves often have monetary value, and gain in value as they age. Corporate-owned data has been valued in the millions of dollars in forest ownership mergers and buyouts. Kahoʻolawe is not the only Pacific island in need of restoration. Lessons learned on Kahoʻolawe will have many applications in other places.

The Kahoʻolawe Island Restoration Commission should archive their data, together with the attendant sampling designs, protocols, and analyses, in their own library and computer data bank. Direct possession of the products of inventory and monitoring will provide the Commission with accessibility, propriety, security against careless loss, and control over future data uses. Monitoring efforts may extend over many decades, or even centuries. If data are misplaced, future monitoring inferences will be weakened. Given the dangers inherent in restoring a bombing range, data loss might actually compromise restoration worker safety. Desired future uses may include provision of data to interested parties for free, but control should be retained.

Pre-monitoring evaluations should be made by experienced statisticians and biometricians before contractual commitments are made to undertake specific inventory, monitoring, or restoration projects. Inferential strength and cost/benefit analyses of proposed sampling protocols and sampling intensities must be made to insure dollars are well-spent. Population frames, stratifications, parameter identification, expected population variances, as well as field collection costs, are only a few of the technical considerations in sampling design.

The amount of funding available for inventory and monitoring influences choices about the expected accuracy of results and the probable usefulness of the data in answering questions of interest. Data accuracy expectations are refined through cost/benefit and risk analyses. Inferential goals must be balanced against the cost of knowledge acquisition to produce an efficient set of desired accuracy levels. There are always questions too expensive to answer with great exactitude. Inventory and monitoring planners should face the problem of weak inference before undertaking low-utility data collection efforts.

The potential cost of not gathering information may also be analyzed through cost-loss function minimization. In addition, efficiency in sampling may be augmented by cost minimization algorithms. All these issues require that statistical and biometrical expertise be applied prior to data collection.

Monitoring of operational treatments is a cost-efficient opportunity to gain considerable information benefits. Operational treatments include vegetation planting, introduction of wildlife species, construction of educational and cultural centers, and all other manipulations of the environment. Experimental design techniques, such as replication, randomization, and use of control plots in treatment areas, produce valuable information already integrated with management practices. New practices and adaptive treatments are prime candidates for project level, operational monitoring. Project monitoring should include aspects of both compliance and effectiveness monitoring, (is the project carried out as planned, and does it achieve restoration goals?).

## C. Analytical Integrity: "Accuracy, Precision, Significance, and Validity"

The usefulness of inventory and monitoring depends on the strength of the revealed **i**nferences about natural resources. The new knowledge acquired is often in the form of estimations of resource attributes and characteristics. The strength of these inferences and estimations must be measured, for accuracy, precision, significance, and validity, to determine whether the data satisfactorily answer the key questions. Data analyses must include these measures of inferential strength, and the meaning of those measures must be effectively communicated to the users of the analyses.

Accuracy is the degree to which sample measurements approximate the sample average. This "spread" of the data is measured by variances and standard deviations. Variation within forest and reef populations is a natural feature, but variation in sample averages may be controlled by increasing or decreasing the number of sample points and plots. Accuracy is reported by calculating confidence intervals around averages.

Precision is the degree to which a sample average approximates the actual (true) population average. The lack of precision is known as statistical bias. Precision is difficult to measure, but may be controlled by using statistically sound methodologies, together with meticulous training and oversight of data collectors.

Statistical significance is the probability that the actual (true) population average is within the calculated confidence interval. A 95% significance means there is a 19 out of 20 chance that the reported interval contains the true average. Statistical significance is often used to test comparisons, such as differences between groups.

Such tests are complex; application of the proper statistical tests should be made in consultation with experienced statisticians.

Most data analyses are based on models, mathematical descriptions of resource attributes and interactions.  Models do not equal Truth; "All models are wrong but some are useful," (Bunnell, 1989).  There are two separate, and usually mutually exclusive, purposes of models: *prediction* and *understanding*.  Predictive models quantify probable changes in a response variable from a set of explanatory variables. Predictive horizons are short, and variables are chosen using statistical principles. Models for understanding are based on theoretical statements about system interactions.  They yield insight into processes, but may be poor predictive tools.  Both types of models are useful, but for different applications.  Distinguishing between these two model types is crucial to inference.

Models cannot be verified, but may be validated.  Verification implies establishing the truth or reality of a model, which cannot be done.  Models are mathematical descriptions many magnitudes simpler than the complex natural systems they symbolize.  But models may be validated.  Predictive models, in particular, may be shown to have precision and accuracy through testing.

The systematic use of inductive inference is the key measure of scientific performance, (Platt, 1964).  If hypotheses cannot be tested, they do not lead to strong inference. Only testable models lead to knowledge acquisition.  Only models that have been tested and found to have some quantified level of validity should be used for decision making.

Perhaps the most important inferential proviso is that no causal conclusions may be made from observational data.  Analysis of observational data cannot distinguish between antecedent and proximal causes. Confounding causal factors include genotype differences, segregation of types following pre-survey events, causes whose effects are masked, misunderstood mechanisms, and observer bias. Attempts to infer cause-and-effect without experimental controls are futile. Expanding inferences beyond the range of the data, or to other populations, is also unscientific and leads to insupportable, (and often erroneous), conclusions.

Most data analyses involve complex statistical procedures. These include time trend analysis, ANOVA, linear and non-linear regression, survival analysis, simultaneous equation systems, measurement error models, and many other technically difficult methodologies. While most such procedures are made easier through modern computer software packages, their proper use and application still requires statistical expertise. For this reason, the Kaho‘olawe Island Restoration Commission should consider utilizing statisticians and biometricians for data analysis oversight, as well as for inventory and monitoring planning.

Information providers should expect feedback on their analyses. Peer reviews, lay reviews, Commission reviews, and public reviews are necessary for the success of knowledge acquisition efforts. Feedback allows decision makers to adjust their inventory and monitoring program for maximum effectiveness.

## D. Spatial Scales: "From Microsite to Landscape"

Natural resources occur across various scales of time and space. For example, an Achatinelline snail occupies a much smaller home range than a Crested Honeycreeper, and insect populations fluctuate seasonally more than do bird populations. Inventory and monitoring programs must specify measurement of resources at scales appropriate to the questions of interest about those resources.

Scale may be thought of as the range between grain, the smallest unit of measurement in an inventory, and extent, the overall area encompassed by the inventory, (Wiens, 1989). Fine grain inventories are generally restricted to small areas. Broad-scale (regional) inventories must often use large grain measurements, and sacrifice detail to cost constraints. The kinds of management decisions that will be based on inventory and monitoring should predetermine the grain and extent of the data collection.

The recognition of hierarchical pattern across scales is a necessary element of inventory and monitoring. Ecosystems are often viewed as mosaics of "patches" formed by interaction of physical, biological, and human factors, (Turner et al., 1990). A "patch" may be as small as a single tree, or as large as a watershed, depending on the focus of inquiry. Some resource questions involve individual trees or beaches; others involve larger regions, such as streamsheds or ‘ili.

The scale of interest changes as the scale of application changes. Evaluations of natural resources at the patch level may aid in project management, and evaluations at the island level may aid overall Island management.

## E. Presentation: "Meaningful Reports, Charts, Tables, and Maps"

Reports, charts, tables, and maps are the immediate products of inventory and monitoring. Practitioners must be able to effectively communicate their findings. There is little utility in deriving inferences unless the intended audience understands them.

Reports should be carefully planned, clearly written, and thoroughly checked. Charts and graphs should have self-explanatory titles, labeled axes, and stated units of measure. Extraneous cluttering should be avoided. Tables should be formatted for readability, with clear headings and the appropriate number of significant digits. Computer output is usually unsuitable for direct inclusion in reports due to poor formatting. Smaller summary tables may be included in reports, and larger tables annexed as accompanying documentation.

All maps are a kind of graphical display of quantitative and qualitative information. The data are generally represented as lines and other symbols. Like other data, geographic information has qualities of accuracy, precision, significance, and validity, but these inferential strength measures are often missing from maps commonly in use today. Lines on maps are only as accurate as the underlying quantitative data set. As the basis upon which all resource analysis is placed, new maps must meet high standards of information quality.

Many ecosystems and habitats cannot be accurately mapped at all. Ecosystems usually change gradually across ecotones, rarely at distinct limits. The definitions of specific ecosystems and habitats change over time, as well. We are often not sure where the line is, or just what is inside the line. The inability to locate zonal boundaries impedes management and adds uncertainty to inventory and monitoring results.

A better option is to map for efficient inventory, monitoring, planning, and management, with acceptance of ecological heterogeneity within units of interest. Indeterminate ecosystem edges need not be the criteria for mapping. Instead, roads, streams, ridge tops, ahupuaʻa, ʻili, and other easily specified topographic features should be used.

Hannah Kihalani Springer reminds us that *"The ahupuaʻa [is an] interpretive and management tool. We can learn of the history of cultures, natural resources, economies, and management through study of our ahupuaʻa."* (Hawaiʻi Tropical Forest Recovery Action Plan, 1994). The Kahoʻolawe Island Reserve Commission wisely states, *"The ʻili concept is a valuable planning tool because it recognizes integral relationships ... [and] helps to define appropriate uses and activities."* (Kahoʻolawe Use Plan, 1995).

Today maps are relatively easy to make with geographic information systems. While this new technology holds great promise, managers and decision makers must demand that maps be made from data of measurable validity and utilize functional mapping units.

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## III. RECOMMENDATIONS

1. The Kaho‘olawe Island Restoration Commission should use inventory and monitoring as tools to help control and direct restoration efforts. p. 2

2. Inventory and monitoring should be comprehensive, timely, and coordinated. pp. 3 & 5

3. The right questions should be asked: those with answers that can be acceptably and efficiently estimated, and that yield the information necessary for management decision-making. p. 3

4. Inventory systems should measure baseline (current) conditions. Monitoring systems should detect and predict change. pp. 3 & 4

5. Both effectiveness monitoring and compliance monitoring should be undertaken. p. 4

6. Designed experiments should be incorporated into inventory and monitoring efforts. p. 4

7. Monitoring systems should include explicit testable hypotheses to differentiate between natural environmental fluctuations and ecological responses to restoration treatments. p. 5

8. Kaho‘olawe ‘ohana members should be active participants in data collection and analysis. p. 6

9. The Kahoʻolawe Island Restoration Commission should own all data collected, and enforce this ownership through responsible contracting when utilizing outside research providers. p. 7

10. The Kahoʻolawe Island Restoration Commission should archive their data and analyses in their own library and computer data bank. p. 7

11. Pre-monitoring evaluations should be made by experienced statisticians and biometricians prior to undertaking specific projects. pp. 7 & 8

12. Planning for inventory and monitoring should include appropriate cost/benefit and other economic analyses. p. 8

13. Project level, operational monitoring should be undertaken. p. 8

14. Data analyses should include measures of accuracy, precision, significance, and validity. p. 9

15. Mathematical models for prediction and understanding should be validated through scientific testing. p. 10

16. Inferences about cause-and-effect relationships should be based only upon the results of designed experiments. p. 11

17. The Kahoʻolawe Island Restoration Commission should consider utilizing statisticians and biometricians for data analysis oversight, as well as for inventory and monitoring planning. p. 11

18. Data analyses should be thoroughly reviewed by a broad spectrum of interested parties. p. 11

19. Measurement of resources should be made at temporal and spatial scales appropriate to the questions of interest. p. 12

20. Research findings should be clearly communicated through understandable reports, charts, and graphs. p. 13

21. Maps should have analytical integrity, and utilize distinctive ‘ili boundaries. p. 14

## IV. CONCLUSIONS

The Kahoʻolawe ʻohana has achieved admirable successes in reaffirming the rights of native Hawaiians and returning Kahoʻolawe to the people of Hawaiʻi. Now the Kahoʻolawe Island Restoration Commission is ready to "*re-establish the life and spirit of Kahoʻolawe and its surrounding waters*", (Kahoʻolawe Use Plan, 1995).

This bold undertaking will involve numerous planning, research, and treatment efforts. All these will require appropriate information to guide decision-makers and managers. Inventory and monitoring are the means by which information is acquired, and the need for inventory and monitoring is recognized by the Kahoʻolawe Island Restoration Commission.

Inventory and monitoring of the Kahoʻolawe Island Reserve should be comprehensive, cost-effective, done with analytical integrity and across spatial scales, and presented to users through meaningful reports, charts, tables, and maps.

Consideration and application of these factors will improve the efficiency and effectiveness of knowledge acquisition systems, and will help managers, planners, regulators, and citizens become aware of and responsive to natural resource issues. Conscientious planning and implementation of inventory and monitoring programs is a necessary prerequisite to good stewardship.

The addition, to the Kahoʻolawe Restoration Plan, of the carefully considered inventory and monitoring recommendations presented in this essay will aid in the fulfillment of the Kahoʻolawe Vision.

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