

# Long Term Ecological Monitoring Program on the Kenai National Wildlife Refuge, Alaska: An FIA Adjunct Inventory

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**ABSTRACT:** *Kenai National Wildlife Refuge (KENWR) has a legislative mandate “to conserve fish and wildlife populations and habitats in their natural diversity”. To improve our understanding of spatial and temporal variation at the landscape level, we are developing the Long Term Ecological Monitoring Program (LTEMP) to assess change in biota on the sample frame used by the USDA Forest Inventory and Analysis program (FIA). Through a formal agreement with the FIA, we completed our baseline inventory of 259 permanent terrestrial plots systematically distributed at 5-km intervals across the 805,000-ha KENWR in 2004 and 2006. In addition to the forested vegetation sampled by the FIA, we sampled vascular and nonvascular plants on non-forested plots, and breeding landbirds, arthropods, and noise on all plots. All sampling methods are passive, nondestructive (to habitat), relatively inexpensive, and require  $\leq 2$  visits to a plot in a given sampling year. To date, we have recorded 647 species including one insect family and five insect species new to Alaska, two new sedges for KENWR, and a range expansion for Hammond’s flycatcher. In collaboration with the FIA, we plan to resample 20% of plots every other year over a 10-year monitoring window. However, implementation of the monitoring phase was delayed as we complete species identification, develop novel ways of estimating species-specific detection probabilities, evaluate statistical power to detect change, and consider modifications to the proposed rotating panel design. Our approach provides a statistically-rigorous framework for landscape monitoring and modeling, yet maintains a great deal of design flexibility. Integration with the FIA ensures that LTEMP is cost effective, and the collocation of floral and faunal sampling permits additional species-habitat modeling and other explanatory spatial modeling. We believe LTEMP can serve as a template for agencies that are developing long-term monitoring programs of biodiversity at the landscape level.*

**KEYWORDS:** Kenai, National Wildlife Refuge System, Forest Inventory and Analysis, inventory, monitoring, occupancy modeling, Long Term Ecological Monitoring Program, diversity, arthropod, bird, plant

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## Introduction

The National Wildlife Refuge System (NWRS), part of the U.S. Fish and Wildlife Service (USFWS), is composed of 38 million ha contained in more than 520 units in all 50 states and U.S. territories. The NWRS helps sustain more than 700 bird, 220 mammal, 250 reptile and amphibian, and 200 fish species including habitats for at least 250 species of threatened and endangered plants and animals (West et al. 2003). Although the NWRS is over a century old, its mission, *to administer a national network of lands and waters for the conservation, management and where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans*, was only recently established under the Refuge System Improvement Act of 1997 (Public Law 105-57). This federal legislation mandated that the “biological integrity, diversity, and environmental health of the system” be maintained; USFWS policy was subsequently codified as 601 FW 3 in 2001. Not only is this the first organic legislation to be enacted since the 1970s, Meretsky et al. (2006) point out that this is one of the most emphatic conservation directives ever written by Congress.

By policy (701 FW 2), most units in the NWRS have some sort of inventory and monitoring program for wildlife and habitats. Monitoring on refuge units has traditionally been focused on the species or taxon identified in their establishing legislation, usually the Migratory Bird Treaty Act or Endangered Species Act. However, given the spatial and taxonomic scope of the Refuge System Improvement Act, future monitoring of biological resources will be more complex and likely require new approaches. Indeed, Meretsky et al. (2006) cautioned that existing refuge monitoring programs should not automatically be “grandfathered”. They recommended several ways that traditional monitoring programs could be modified to respond to this new legislation including the detection of biological changes even before the causes of those changes are recognized; use of ecological indicators to justify management actions; expand the scope of conservation monitoring, assessment, and management beyond refuge boundaries to encompass surrounding landscapes; consider the use of composite or multi-metric indexes and other methods to assess ecosystem condition; and, consider an NWRS-wide approach to developing ecosystem monitoring tools.

Additionally, it is recognized that new data will be needed to respond to the impacts of accelerated climate change. An *ad hoc* group of concerned USFWS biologists noted that “the fundamental impact of climate change...is the re-distribution of flora and fauna in response to changes in disturbance regimes and climatic envelopes. Because extirpation and extinction, colonization and invasion, and novel species assemblages are expected but unpredictable future outcomes, we need a more holistic approach to inventorying and monitoring biota. The USFWS cannot be expected to adapt strategically to climate change impacts without a better sense of *in situ* biodiversity. We speak almost cavalierly about the impacts of climate change and invasive species on biodiversity without any

knowledge of the full extent of species richness for the lands we manage. We strongly recommend developing a national program to inventory and monitor changes in the biological integrity, diversity, and environmental health of the NWRS consistent with the 1997 Refuge Improvement Act”. More specifically, “objectives of this program would be scaled to detect changes in flora, fauna, and other metrics at the regional and/or national level. This program would consist of permanent sampling sites, ideally integrated and cost-shared with existing national monitoring programs such as the USDA Forest Inventory & Analysis (FIA) program” (Johnson et al. 2008).

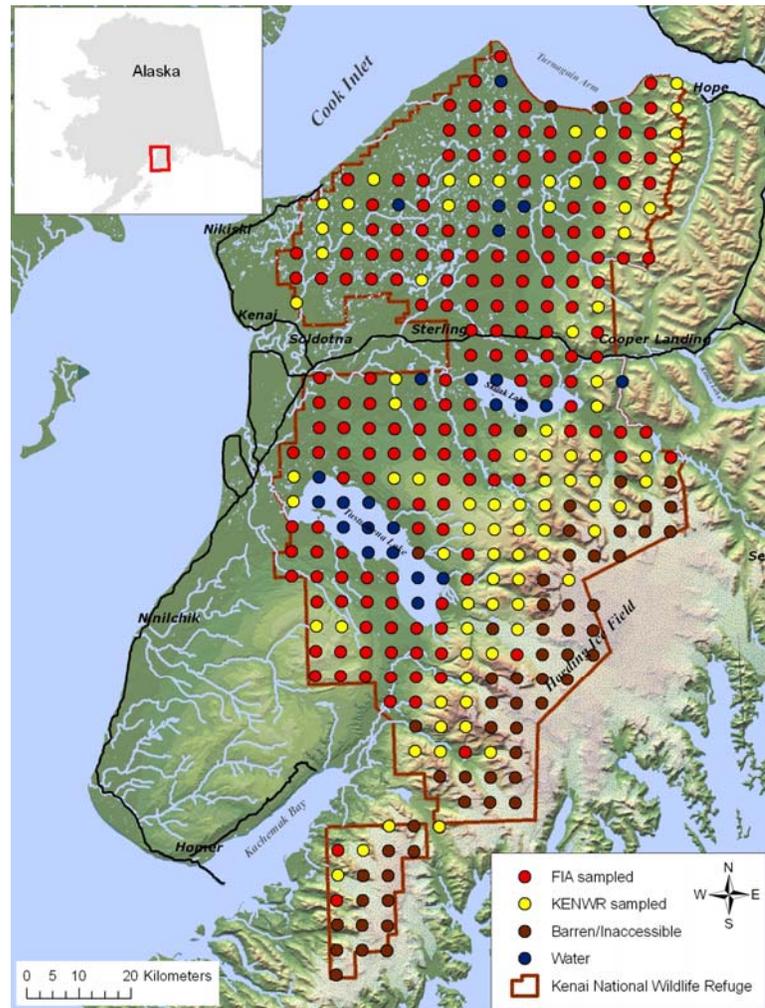
Here we show how a formally-designated adjunct inventory to the FIA, the Long Term Ecological Monitoring Program (LTEMP) on the Kenai National Wildlife Refuge (KENWR), can be a viable approach for inventorying biodiversity at hierarchical scales. The programmatic goals of the LTEMP are to determine the occurrence and distribution of selected floral and faunal assemblages on KENWR and within selected habitats; develop explanatory statistical models to assess the effects of geological, biological, and anthropogenic factors on floral and faunal distributions; and assess trends in the occurrence and distribution of selected floral and faunal assemblages on KENWR. In this paper, we present preliminary results from our initial inventory of species richness on the KENWR.

## Study area

The 805,000-ha KENWR is in south-central Alaska on the Kenai Peninsula, which is formed by the Cook Inlet and Prince William Sound (Fig.1). The KENWR shares boundaries with Chugach National Forest and Kenai Fjords National Park. The KENWR was established in 1941 as the Kenai National Moose Range but was renamed under the Alaska National Interest Lands Conservation Act (ANILCA) in 1980. This act also gave KENWR its mandates, of which the primary purpose is *to conserve fish and wildlife populations and habitats in their natural diversity*. Furthermore, ANILCA also defined fish and wildlife as *any member of the animal kingdom including without limitation any mammal, fish, bird, amphibian, reptile, mollusk, crustacean, arthropod or other invertebrate*.

Biodiversity is unusually high for this latitude (59°25' - 61°) because of the juxtaposition of two biomes on the Kenai Peninsula: the northern fringe of the Sitka spruce-dominated (*Picea sitchensis*) coastal rainforest on the eastern flank of the Kenai Mountains, and the western-most reach of boreal forest in North America on the western side of the Kenai Mountains. Forests on KENWR are dominated by white (*P. glauca*), Lutz's (*P. x lutzii*), and black spruce (*P. mariana*) with an admixture of aspen (*Populus tremuloides*) and birch (*Betula neoalaskana*). Extensive peatlands are interspersed among spruce in the Kenai Lowlands. Lichen-dominated tundra replaces mountain hemlock (*Tsuga mertensiana*) and sub-alpine shrub (primarily *Alnus* spp.) above treeline in the

Kenai Mountains and Caribou Hills. Topographic relief varies from sea level at Chickaloon Flats, a tidal estuary extending into the Cook Inlet, to 1800 m above sea level in the Kenai Mountains. The 1800-km<sup>2</sup> Harding Icefield straddles the Kenai Mountains along the boundary that separates Kenai Fjords National Park and KENWR.



**Figure 1:** Distribution of 342 systematically distributed at 4.8 km intervals on the 805,000 ha Kenai National Wildlife Refuge.

The impacts of a warming and drying climate are well documented on the KENWR. The Kenai Peninsula was the epicenter of a spruce bark beetle (*Dendroctonus rufipennis*) outbreak that lasted over a decade and caused high mortality of Sitka, Lutz, and white spruce on 1.6 million ha in south-central Alaska. A run of warm summers since 1987 set the stage for this outbreak of unprecedented scale, suggesting that with a future warmer climate, fire and beetle kill may be more closely associated than in the past (Berg et al. 2006). Closed-basin lake levels have declined by as much as 1 m and many ponds shown on 1950 maps and aerial photos are now grassy pans with various degrees of black spruce

and hardwood invasion (Klein et al. 2005). The Harding Icefield has lost 21 m in elevation (Adageirdottir et al. 1998) and 5% in surface area (Rice 1987) during 1950 - 1990s. Over this same period, treeline in the Kenai Mountains has risen, on average, 1 m per year (Dial et al. 2007).

## Methods

### Forest Inventory and Analysis Program (FIA)

The FIA consists of a nationally-consistent core program to “make and keep current a comprehensive inventory and analysis of the present and prospective conditions and requirements of the renewable resources of the forest and rangelands of the United States”. The FIA can be enhanced at the regional, state or local level to address special interests (<http://www.fia.fs.fed.us/>). Vegetation data are stored in a well-defined database (Miles et al. 2001) and are available for public dissemination from the National FIA Database Retrieval System (<http://www.srsfia.usfs.msstate.edu/scripts/ew.htm>). However, coordinates for FIA plot locations are not available and are protected from Freedom of Information Act requests under the Agriculture Research, Extension, and Education Reform Act of 1998 (16 USC 1642(e)). The national FIA core consists of three phases:

Phase 1 uses remote-sensing data to classify land into forest and non-forest, and take spatial measurements such as fragmentation, urbanization, and distance variables. This phase has historically been done using aerial photography, but is changing to a system based on satellite imagery.

Phase 2 consists of a set of field sample points distributed across the landscape in a systematic grid of tessellated hexagons, each containing 2,360 ha. One FIA plot is located within each hexagon on which vegetation structure and composition are re-sampled every 10 - 15 years (Roesch and Reams 1999). Non-forest locations may also be visited to quantify rates of land use change.

Phase 3 consists of a small subset (~6%) of the Phase 2 plots which are visited during the growing season in order to collect an extended suite of ecological data including full vegetation inventory, tree and crown condition, soil data, lichen diversity, coarse woody debris, and ozone damage. Prior to 2000, these plots were part of the Forest Health Monitoring program.

As part of the implementation of the Alaska Coastal Inventory in south-central Alaska, the Pacific Northwest Research Station (PNWRS) established 176 FIA plots on KENWR

in 1999 (Fig. 1). Consistent with Phase 2, these plots were distributed across the forested portion of KENWR at a resolution of 1 plot per 2,360 ha. By 2003, the PNWRS had completed the first inventory of these plots following field protocols of the Coastal Alaska Inventory (USFS 2002a).

However, the Coastal Alaska Inventory was implemented before the FIA national protocols were fully developed. Also, under a 2004 Memorandum of Understanding, the PNWRS agreed to reduce the frequency of re-sampling to ensure the integrity of 525,000 ha of Congressionally-designated Wilderness on KENWR. Consequently, there are several significant differences between what has been done on KENWR than in other parts of the U.S including systematically-distributed plots at regular intervals (versus randomly placed within tessellated hexagons); inventory of vascular and nonvascular flora in a 5.64-m radius column on each center subplot; and a monitoring design that specifies re-sampling 20% of plots every other year for 10 years (i.e., rotating panel design).

## Sample Frame

To take advantage of inventorying and monitoring by the FIA, we adopted their sample frame by extending the existing FIA grid over the remaining non-forested portions of KENWR and overlaid additional sampling to inventory selected faunal assemblages on all points regardless of vegetation. This full sample frame, hereafter considered the LTEMP sample frame, is comprised of 342 plots systematically distributed at 4.8-km intervals across the 805,000-ha KENWR (Fig. 1). At this spatial resolution, the distribution of these plots is proportional to the availability of macro-habitat types (Table 1). This is an important attribute as data derived from the LTEMP sample frame are representative of the KENWR.

**Table1:** Comparison of the proportional distributions of LTEMP plots with macro-habitats on the Kenai National Wildlife Refuge.

Habitat	Plots (%)	Hectares (%)
Forest	161 (47)	382,790 (48)
Conifer	105 (31)	222,980 (28)
Deciduous	12 (4)	29,463 (4)
Mixed	44 (13)	130,347 (16)
Shrub/grass	26 (7)	57,392 (7)
Barren/sparsely vegetated	60 (18)	133,260 (17)
Wetlands	20 (6)	49,489 (6)
Snow/ice	51 (15)	117,348 (15)
Water	24 (7)	64,442 (8)
Σ	342 (101)	804,721 (101)

## Vegetation Sampling of Forested Sites by FIA

The PNWRS sampled vegetation on 176 forested plots following field protocols used in the Coastal Alaska Inventory (USFS 2002a). Consistent with national Phase 2 protocols, each FIA site consists of four subplots to measure within-site variance (Fig. 2). Each subplot consists of three nested fixed-radius circular plots: 7.3-m tree plot, 5.64-m horizontal-vertical (HV) vegetation profile, and a 2-m seedling/sapling plot. Three 11.28-m transects intersect the center subplot to estimate downed wood (see USFS 2002a). National and regional FIA field protocols were generally similar except for relatively minor differences in measurement units and location of subplot sampling. The one obvious and significant discrepancy was the exclusive sampling of HV plots as part of the Coastal Alaska Inventory.

### Phase 2/Phase 3 Plot Design

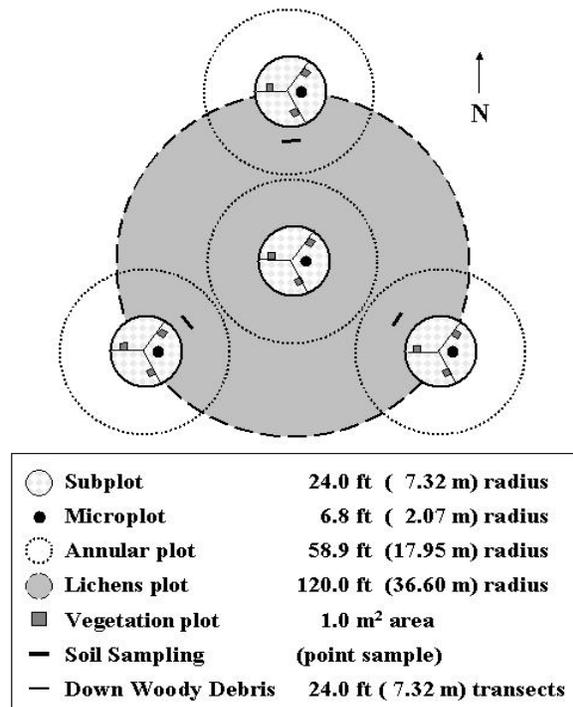


Figure 2: Sampling schematic at FIA grid point.

**Horizontal-Vertical (HV) Plot:** A 5.64-m radius (horizontal distance) circular plot was established at point center. The HV plot was used to determine the horizontal and vertical distribution, density, diversity, and composition of plants and non-living material. Vegetation was classified into strata or layers starting at ground level such that this plot represented a column with a base of 100 m<sup>2</sup>. Vertical dimensions were estimated using the natural layer breaks observed on the plot. One HV profile plot was established for each polygon type that had a point meeting the following criteria: the polygon type at point center is vegetated (i.e., shrub, herbaceous, forest); the HV plot falls entirely within the polygon at point center (i.e., does not straddle polygon types); the polygon type at point center covers  $\geq 90\%$  of the area; and the point center does not fall in an inclusion.

Data collected on HV plots include shrubs, grasses, forbs, lichens, mosses, tree seedlings (trees < 2.5 cm DBH), and in some cases shrub-like trees not recorded on the tree plot. For example, Krummholz and other stands where trees were growing in a twisted/stunted shrub-like form, were treated as shrub land. The HV record also included arboreal lichens, mosses, forbs and shrubs regardless of their substrate.

## Adjunct Inventory Field Methods

**Vegetation Sampling of Non-forested Sites by KENWR:** We did not use the FIA cluster sampling design, where four subplots are surveyed at a site (Fig. 2). Instead, we sampled one plot, centered on the plot center and used sampling methods which better characterize non-forested vegetation (Fig. 3). Our objectives were to quantify the relative frequency of ground cover and species within different height strata at each site. Similar to the HV plot sampled by the FIA, we also recorded all vascular and nonvascular flora on a 100-m<sup>2</sup> circular plot with a 5.64 m radius from plot center. Voucher specimens or unknown plant material were collected at the site, but from locations > 10 m from plot center. We also took two stereo digital photographs on the north-south axis of each plot similar to PNWRS protocols for the HV plot.

Herbaceous and woody vegetative cover within the first 2 m above ground were sampled using a modified point-intercept technique (Dunn 1992). A version of this



**Figure 3:** Sampling alpine tundra using a modified line-intercept method in the Kenai Mountains. Ecologist Ed Berg kneels near the permanent monument that marks the center of a 5.64-m radius circular plot and four 10-m transects that radiate in the cardinal directions from plot center.

sampling approach has been adopted by Denali National Park. Four 10-m long transects were laid out in the cardinal directions from plot center using tightly-woven, braided nylon cord marked at 0.5-m intervals ( $n = 20$  points per transect). A 2-m long, 13-mm diameter steel rod, marked at 1 m to separate the vertical column into two strata, was used as a sampling pin that is held vertically at each sampling point. Each plant taxon that touches the sampling pin  $\geq 1$  time was recorded within stratum at each point. Only one hit per point per stratum per taxon was recorded at each of the 80 sampling points. Consequently, a minimum of 40 tallies were recorded per stratum; the number of tallies recorded can exceed this value considerably depending on species richness.

Substrate categories were BARE GROUND, ROCK, LITTER, DEAD WOOD ( $> 25$  mm diameter), WATER, SNOW/ICE, ASH/CHARCOAL, and LIVE VEGETATION. If a dead wood fragment/stick was  $< 25$  mm in diameter or width, then it was recorded as LITTER. Rock particles  $< 13$  mm in longest dimension were recorded as BARE GROUND;  $\geq 13$  mm were recorded as ROCK. Any live vegetation recorded as a substrate was also recorded by species in the 1-m stratum. The total number of substrates recorded always equaled 20 per transect.

**Arthropods:** We sampled arthropod occurrence and relative abundance within the 5.64-m radius circular plot using a 30 cm (12 inch) diameter sweep net (BioQuip™ model 7112CP with 30 cm extension handle). We swept the entire plot for  $\geq 5$  min, ensuring that all substrates and microhabitats within reach (including overhead) were sampled. All specimens were placed in a single Nalgene® wide-mouth 250 ml bottle containing sufficient 95% denatured ethanol to cover the sample.

**Birds:** We sampled landbird abundance and occurrence using variable circular plot methods during the last three weeks in June. We adopted (with some modifications) the protocols used in the Alaska Landbird Monitoring Survey (Handel et al. 1998), where horizontal distances to each bird were estimated at 1-min increments during a 10-min sampling interval using auditory or visual cues. Surveys were conducted 30 min after sunrise during the first 4 - 5 hrs of the morning, but only under specified conditions of good visibility, little or no precipitation, and light or no winds. We used a laser range finder to help with distance estimation and recorded unknown or questionable songs/calls with a Sony digital Walkman™ MZ-N10 minidisc recorder and a Saul Mineroff Electronics™, Inc., ATR55 mini-microphone boom.

**Weather and noise:** We measured wind speed (m/sec averaged over 30 sec), temperature ( $^{\circ}\text{C}$ ), and relative humidity with a Kestrel 3000 Pocket Weather™ meter at ground level. We used the Beauford wind scale to record wind speed at canopy level. We used the Larson Davis Model 720 sound meter to measure sound levels ( $L_{eq}$ ,  $L_{max}$  and  $L_{peak}$ ) over a 5-min interval while birds were being counted. The sound meter was mounted on a tripod, oriented with the microphone pointed skywards, and placed  $\geq 3$  m from either observer to reduce recording of incidental noise.

**Curation and Species Identification:** In the lab, vascular plants were pressed, and lichens and mosses were stored in paper bags. Plant specimens were dried in a convection oven at 60° C until dry, typically 1 - 3 days. Arthropod specimens were processed and archived using appropriate curation methods. All arthropods present in the samples were sorted into orders and most were sorted to families. Species identifications for both plants and arthropods were made whenever possible but many specimens were shipped to >40 specialists for expert determinations. With the exception of small amounts of material lent to various systematists, all specimens remain in the collection of the KENWR (international collection coden: KNWR).

## Results

### Overview of Field Sampling Approach

Of 342 plots on the LTEMP sample frame, only 259 plots were deemed terrestrial and accessible; 59 plots were considered inaccessible and 24 plots were located on water. Of these 259 terrestrial plots, vegetation was sampled on 176 and 83 by FIA and KENWR staff, respectively. The forest vegetation was sampled as part of the Coastal Alaska Inventory during 1999 – 2002. We sampled the non-forested vegetation, primarily alpine tundra and lowland wetlands, in July - August of 2004 and 2006. A 2-person team typically spent ~ 2 hrs sampling vegetation on plot.

We inventoried breeding landbirds, arthropods, and noise on 255 terrestrial plots during the latter three weeks in June of 2004 (n = 152) and 2006 (n = 103); data from four plots were discarded for various reasons. Our sampling window was optimized to detect most breeding landbird species at this latitude, and arthropod and noise sampling were considered lesser priorities. We used a rapid approach, spending ~ 40 min on each plot. A 2-person team typically divided duties such that the primary bird observer conducted the 10-min bird survey while the other observer measured sound and weather parameters. While one person sampled for arthropods, the other would take plot photographs, record incidental wildlife sign, and take other notes. Because the plot and potential landing site were not at the same location, round-trip travel time between the helicopter and plot was typically 20 min such that a team could complete a plot every hour.

With a few exceptions, plots were accessed by helicopter. We used a Bell 206 Jet Ranger during wildlife surveys, “hop-scotching” two 2-person teams from point to point. We completed 4 – 6 plots per team per day, with hours of operation typically restricted to 0400 – 1000 due to constraints imposed by avian breeding activities. Because we were concerned about potential latitudinal (59°25' - 61°) and elevational (0 – 1800 m above sea

level) bias in breeding phenology over a 3-week sampling interval, we alternated starting points in the morning between the northern and southern part of KENWR and the western and eastern parts of KENWR although this protocol was contingent on weather constraints. We also shared an A-Star jet helicopter with PNWRS staff later in one summer to help complete sampling of non-forested plots.

FIA plots were previously monumented following protocols outlined in the Coastal Alaska Inventory (USFS 2002a). We monumented non-forested plots on the LTEMP sample frame ( $n = 83$ ) with Bernsten® aluminum survey caps on 80-cm long aluminum break-away shafts that were pounded in so as to as flush as possible with the ground surface. Both the cap and shaft have magnets inserted to facilitate re-finding these plots with a metal detector during subsequent visits.

### Data Derived from Adjunct Inventory

To determine species occurrence of vascular and nonvascular flora, and arthropods, we considered only those species detected in the 5.64-m<sup>2</sup> radius circular plot. To determine the occurrence of avifauna, we used only those bird species which were detected within 200 m of plot center.

To date, we have identified 647 species including 86 birds, 333 vascular plants, 78 nonvascular plants, 44 lichens and fungi, and 106 arthropods as part of LTEMP. As many as 54 species were recorded for a single LTEMP plot, but this value will certainly increase as outstanding taxonomic work is completed. The subset of forested HV plots that were sampled by the PNWRS yielded 217 vascular plant species and 33 nonvascular plant species.

We have spatial data (albeit limited for species with low detectability) for 90% of 96 landbirds and 67% of 499 vascular plants previously documented on the KENWR or thought to occur based on range maps. We identified two sedge species new to the KENWR (*Carex tenuiflora*, *C. dioica*) and a range expansion for Hammond's flycatcher (*Empidonax hammondii*). We found four exotic vascular plant species (*Lupinus polyphyllus*, *Poa trivialis*, *Potentilla gracilis*, *Taraxacum officinale*) on 3% of LTEMP plots.

From more than 15,000 arthropod specimens collected, we have identified 220 taxa representing 18 orders. Although the taxonomy of many arthropod and some nonvascular plant specimens are still outstanding, we have identified one insect family new to Alaska (Achilidae: *Epiptera* sp.) and five insect species new to Alaska (*Aphelopus albopictus*, *Aphodius aleutus*, *Delphacodes serrata*, *Gonatopus ashmeadi*, and *Paraliburnia kilmani*).

Lastly, we have established a benchmark for ambient sound during early morning hours in the absence of rain and high winds. Sound levels integrated over 5 minutes on 257 plots averaged 45.1 dBa (SE = 0.68) and ranged from 32 - 95 dBa.

## Discussion

We have designed the LTEMP to be a comprehensive, albeit not exhaustive, spatial and temporal assessment of biodiversity (i.e., species richness) on the KENWR. In just two summers of inventorying, we have amassed a significant volume of spatial data for almost 650 species over 805,000 ha that continues to be processed and analyzed. Taxonomic work on nonvascular plants and insects is still being conducted. Nonetheless, the utility of the LTEMP as an adjunct inventory has already been demonstrated. We have expanded the known distributions of several species as part of this inventory. We have increased the known species richness on the KENWR to > 1,000 species. We have used these data to model bird distributions (Magness et al. 2008) and arthropod diversity (Bowser and Morton 2009).

We are already using the value of 3% to benchmark the occurrence of exotic flora on KENWR at the landscape scale. Although LTEMP plots represented only 10% of the plot data used to develop the first supervised vegetation classification of the Kenai Peninsula from LANDSAT imagery, they were disproportionately critical because of their complete spatial distribution (Lee O'Brien, pers. comm.). For landscape-level wildfire, which is still a major disturbance process on KENWR, we also expect to use vegetation and fuel load data from the FIA as pre-treatment data for wildfire and possibly as experimental controls for large prescribed burns.

The LTEMP will likely continue to expand as funding and field techniques permit. Unlike other similar programs such as the Long-term Ecological Monitoring Program at Denali National Park, the Alberta Biodiversity Monitoring Program, or the Forest Service's MultiSpecies Inventory & Monitoring Program (Manley et al. 2004), we employed a rapid sampling approach to assess species occurrence (primarily) as well as other taxon-specific population metrics. All sampling methods are passive, non-destructive (to habitat), relatively inexpensive, and require  $\leq 2$  visits to a plot in a given sampling year. Sampling efforts greater than this are likely to be too costly to sustain over the long term and may damage permanent plots by trampling or the introduction of exotic biota. Other critical attributes that make the LTEMP successful include

- permanent sampling sites to measure change;
- statistically robust sampling frame (systematic) to survive planned and unplanned habitat changes;
- data that are representative of the refuge unit;

- multi-taxa sampling and co-location of biotic and abiotic sampling to enhance both predictive and explanatory spatial modeling; and
- interagency cost-share.

It is critical to the success of this program, however, that we estimate species detection probabilities as the LTEMP is further developed to monitor spatial and temporal changes in species distributions (Bowser and Morton 2009). Species occupancy (which is essentially occurrence corrected for imperfect detection) will be our primary metric for assessing change in distributions of all taxa found on the LTEMP. Other metrics derived from repeated occupancy estimation include local rates of extinction and colonization, both of which would be desirable for evaluating shifts in species distributions. However, a major limitation in occupancy modeling as currently practiced is that detection is estimated by making multiple revisits within season to a plot (MacKenzie et al. 2006). This estimation procedure is expensive, particularly if helicopters are being used, and results in collateral damage to the plot. Alternatively, we are currently exploring spatial and temporal subsampling within a single plot visit to estimate detection probabilities (Bowser and Morton 2009).

We are also concerned that the PNWRS has abandoned the HV plot. Although the space occupancy concept behind the HV sampling methodology does not provide reproducible estimates of plant cover (van Hees and Mead 2000), the floral inventory generated on the HV plot appears to be fairly comprehensive. We developed the arthropod sampling to be spatially consistent with the floral community within the 100 m<sup>2</sup> plot. However, the PNWRS has chosen to use the Phase 3 sampling in lieu of the HV plot to be consistent with national protocols. We will have to consider changes to sampling design and protocols as we move towards the monitoring phase in LTEMP.

We had originally planned on extending this adjunct inventory into spatial and temporal monitoring by now. However, we have yet to complete the taxonomic identification of both arthropod and nonvascular plant specimens. Also, the synergistic value of co-locating additional inventory data on the LTEMP sample frame has become apparent as we explore spatial modeling approaches (e.g., Magness et al. 2008). Consequently, implementation of the monitoring phase has been postponed as we complete species identification, develop novel ways of estimating species-specific detection probabilities, evaluate statistical power to detect change, and consider modifications to the proposed rotating panel design (Bowser 2009, Bowser and Morton 2009). Assuming we can address these concerns in a timely way, we will re-sample 20% (n = 51) of the LTEMP plots every other year beginning in 2010 in collaboration with the FIA (Table 2).

In the future, the LTEMP sampling frame may also be used to sample the winter distribution of mammals with aerial digital photography, to apply more rigorous insect sampling methods for monitoring selected taxa, to collect soil samples to help develop better soil maps, and to determine baseline levels of ambient contaminants. We hope to

use the sound data as a basis for developing soundscape models. We have yet to analyze the structure and composition of the floral community, and to develop models to explain their relationship to faunal species distributions. In particular, we expect to examine potential silvicultural and fire management prescriptions to improve bird densities as estimated by Program DISTANCE (Laake et al. 1993).

**Table 2:** Proposed rotating panel design for the Long Term Ecological Monitoring Program on the Kenai National Wildlife Refuge in which a panel of 51 plots is jointly re-sampled by both FIA and KENWR every decade.

PANEL	N		SAMPLING YEAR						
	FIA	KENWR	2004/2006		2010	2012	2014	2016	2018
			FLORA	FAUNA	ALL	ALL	ALL	ALL	ALL
1	35			X	X				
2	35			X		X			
3	35			X			X		
4	35			X				X	
5	35			X					X
Σ	175			X					
				X					
1		16	X	X	X				
2		16	X	X		X			
3		16	X	X			X		
4		16	X	X				X	
5		16	X	X					X
Σ		80	X	X					

Our approach provides a statistically-rigorous framework for landscape sampling, yet maintains a great deal of design flexibility. Integration with the FIA ensures that LTEMP is cost effective, and the co-location of floral and faunal sampling permits additional species-habitat modeling. Certainly the LTEMP approach and protocols are applicable to the other 15 refuges in Alaska which have similarly large landscapes; in fact, the 16 Alaskan refuges comprise 87% of the land base within the NWRS. On the other hand, almost 90% of the 540 units in the NWRS are < 50,000 acres (USFWS 2003). These refuge units are too small to benefit from the relatively coarse resolution of Phase 2 sampling by the FIA. However, this disadvantage can be overcome by increasing the sampling density within the FIA sample frame. Indeed, agency staff at Pictured Rocks National Lakeshore in Michigan have used exactly this approach to estimate fuel loads (Woodall and Leutscher 2003) and bird populations (Lieske 2006) for their unit while ensuring a landscape context. Consequently, we believe that LTEMP can serve as a template for agencies that are developing long-term ecological monitoring programs at the landscape level, particularly in the context of accelerated climate change, but still provide useful data at the local scale.

## Acknowledgements

This work would not have been possible without the collaborative efforts of the PNWRS, FIA, particularly Sue Willits and Bill van Hees. LTEMP data management was provided by Mark Laker (KENWR). Several biologists and seasonal interns enthusiastically assisted in the field and lab including Toby Burke, Elizabeth Jozwiak, Charlotte Hockin, Doug Fisher, Susie Grimes, Suzy Medwell and Kimo Rogala. Additional funding was provided through Marathon Oil Corporation.

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