Functional Connectivity of Tongass Old-Growth Reserves: An Assessment Based on Flying-Squirrel Movement Capability

Progress Report

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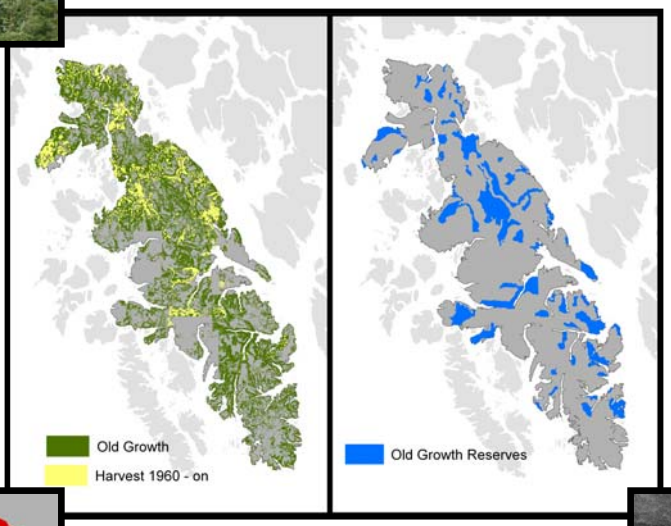
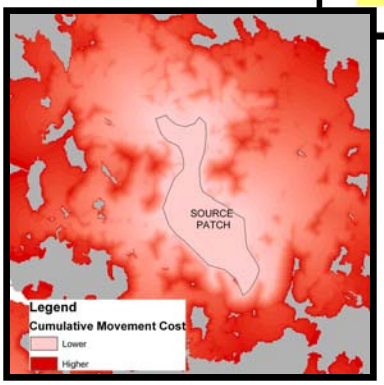
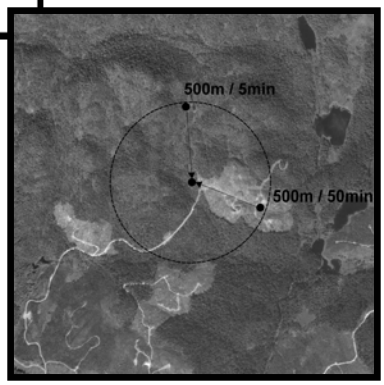




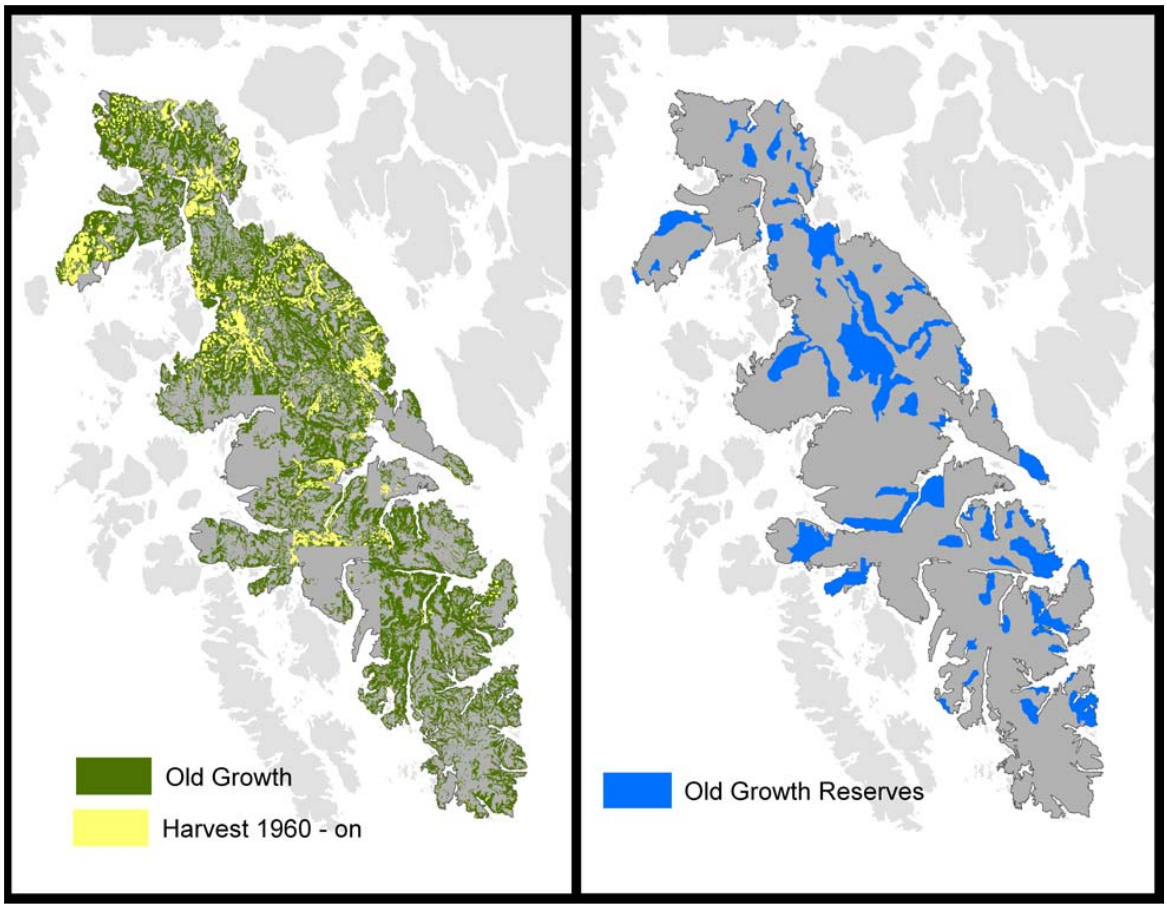


Objectives

To test the assumption that functional connectivity among Old-Growth Reserves and old-growth habitat elements in the matrix surrounding Reserves on Prince of Wales Island is adequate to support dispersal by northern flying squirrels; and to identify Reserves and/or portions of the landscape where this assumption may not be tenable.

Justification

In 1997, the Tongass Land Management Plan (TLMP) established a network of small, medium, and large Old Growth Reserves (OGR) on the Tongass National Forest to provide viable metapopulations of old-growth associated species, such as northern flying squirrels. A key assumption of TLMP is that populations inhabiting OGR should be functionally connected: individual animals should be able to effectively move (disperse) from OGR through the surrounding matrix, perhaps in a stepping stone fashion involving > 1dispersal event, to other OGR; thereby facilitating gene flow and preventing isolation of OGR. However, the assumption of functional connectivity among OGR, and between individual OGR and the surrounding matrix, remains untested. The validity of this assumption has particular relevance for areas of the Tongass, like Prince of Wales Island, that were heavily impacted by clearcutting prior to initiation of TLMP.



Background

The Prince of Wales Island Northern Flying Squirrel (*Glaucomys sabrinus griseifrons*) is an island endemic that was initially designated a Management Indicator Species (MIS) on the Tongass National Forest because the species' close association with several facets of late seral forest structure and ecological processes purportedly render it a good indicator of forest ecosystem health (Carey et al. 1999, Carey 2000a). Elsewhere in the Pacific Northwest, the northern flying squirrel has been recognized as a species whose populations become increasingly abundant with increasing forest complexity (horizontal and vertical heterogeneity in vegetation and structural features) (Carey 2001, Carey et al. 1999), and its life history reputedly is linked to numerous attributes of older forests (Carey 1995, 1989, Carey et al. 1992, Waters and Zabel 1995, Witt 1992). Several small carnivores (e.g., American marten, *Martes americana*) and raptors prey on the northern flying squirrel and, in turn, flying squirrels eat sporocarps and disseminate spores of ectomycorrhizal fungi (Maser et al. 1978, Forsman et al. 1984, Maser and Maser 1988, Carey 1995, Carey et al. 1999, Pyare et al. 2003), which are essential symbionts of dominant conifers (e.g., Douglas-fir, *Pseudotsuga menziesii*) in the Pacific Northwest. Arboreal gliders like the northern flying squirrel are also intuitively attractive for evaluating a critical element of forest management and planning: habitat connectivity. Their unique form of locomotion suggests movement capability may vary with respect to differences in vertical forest structure and the spatial configuration of forest patches, and in recent years, there has been interest in utilizing the movement capability of arboreal gliders to evaluate connectivity in a variety of forested landscapes (Hokkanen et al. 1982, Incoll et al. 2001, Ruenanen 2001, Ruenenen et al. 2002, Selonen et al. 2001, Kurtilla et al. 2002, D'Eon 2003). However, even basic data on the dispersal behavior and movement of the northern flying squirrel is lacking in Southeast Alaska and other parts of its range, and this makes it difficult to evaluate the adequacy of alternative forest plans that may affect the functioning of important metapopulation processes. How well do flying squirrels move across different landscape elements, such as non-forested areas, young regenerating stands, and narrow riparian buffers? How far and to what types of areas will flying squirrel typically disperse? What do movement patterns imply about the location and extent of old-growth elements on the Tongass? Our study was designed to answer such questions using a combination of field experiments, empirical field data and a spatially explicit modeling technique to describe flying squirrel movement capability. More specifically, the study components are:

I. An experimental phase in which flying squirrels have been translocated to different landscape elements and radio-tracked intensively while homing to estimate the relative movement capability, or *effective distance* traveled. We have also conducted a second experiment in which we use a spool-and-line tracking technique to establish the *perceptual range* of flying squirrels.
II. An empirical study of flying squirrel dispersal in fragmented landscapes in 3 instances: (1) among resident adults during 'normal' movement bouts within home ranges; (2) during a short-term fall dispersal phase when juveniles potentially disperse from natal areas; and (3) during a spring period when males move long distances in search of females.
III. Development of a GIS-based landscape model of movement capability that will be parameterized and validated using movement data derived from 1 and 2 above, and application of the model to the OGR system on Prince of Wales Island to assess relative levels of connectivity between each OGR and its surrounding matrix, as well as among OGR.

Methods

Study Area. The study area consists of 3 sites on northwest Prince of Wales Island: Upper and Lower Yatuk Creek, both in the vicinity of the town of Naukati, and Sarkar Lake (Fig. 2). This region has experienced extensive timber harvesting between 1954 and 1995 when 56,950 ha of old-growth forests was removed (U.S. Department of Agriculture 1997). This area is a high-contrast landscape that includes regenerating clearcuts of varying ages (1 to 40 years), small remnant fragments and riparian buffers, and Old-Growth Reserves.

Schedule. Each year during the 3-year study, we collected data during two primary periods March 01- May 30 and Aug 1 – Oct 30 (Fig. 3).

Live-Trapping. One permanent live-trapping grid was established in each of the 3 study sites. Each grid contains ~35 trap stations in a ~ 5x7 array, with 40m inter-trap spacing. One Tomahawk No. 201 (41 X 13 X 13 cm) wire live trap was placed at a height of 1.5 m along the bole of a large tree within 5 m of the grid point. Each trap was covered with a 1-gallon waxed carton box to enhance insulation and reduce exposure to rainfall. A nesting box, consisting of a waxed carton cut in half and polyester batting will be placed in the rear of each trap to provide refuge against exposure to cold and precipitation. Traps were covered with 1/4“ mesh hardware cloth to prevent predation by marten (W.P. Smith, unpublished data). During trapping sessions, traps were baited with a mixture of peanut butter, whole oats, and molasses (Rosenberg and Anthony 1991, 1992; Carey et al. 1991). Trapping sessions were run in facultative fashion for approximately 8-10 days and closed in between sessions for 2-4days. Traps were baited and checked between 0600 and 1100 hrs. Each captured squirrel was removed from a live trap with the aid of a handling cone (Carey et al. 1991) and placed in a cloth bag for weighing. Initial captures were weighed with a 300 g spring scale (graduated at 2-gram intervals) and ear tagged with either uniquely numbered Monel No. 1 tags (Rosenberg and Anthony 1991, 1992) or PIT tags. Body mass, age, and sex were recorded for all initial captures following procedures outlined in Villa et al (1999).

I-a: Estimation of Movement Capability. We used an experimental approach to determine the “effective distance” that different landscape elements represent to dispersing flying squirrels. Effective distance is a relative measure of landscape resistance or movement cost and will be used to parameterize a GIS-based model of movement capability we are developing (below) (Nikolakaki 2003, Verbeylen et al. 2003, Adriaensen et al. 2003). Thus, effective distance is the distance effectively traveled for each unit of Euclidean distance actually traveled in a particular landscape element: a unit of Euclidean distance traveled in a landscape element with high resistance is effectively further than the same Euclidean distance traveled in an element characterized by low resistance.

To establish effective distances of different landscape elements, subadults, adult males and non-reproductively active adult females were fitted with radiocollars (3.0g; Model PD-2C; Holohil Systems), and transferred to canisters until experiments were initiated approximately 0.5hr before the period of peak diel activity. Each squirrel was released $\leq$ 1.0km away from trapping grids into 1of 4 primary landscape elements (Fig. 4a-d). During pilot studies conducted in 2003, this was well within the maximum homing distance ($\geq$4km) recorded for animals originating within our study sites. Two people with radiotelemetry receivers were strategically located on raised roadbed surfaces $\leq$500m from the point of release, and took simultaneous bearings every 5 min until it was estimated the squirrel has entered the forest edge. To help make this determination, a 3rd person may have been positioned along the edge of the old-growth stand and landscape element, and monitor squirrel movements to this edge. We recorded homing time, i.e. total time it took to reach the forest edge, as well as the locations of fixed telemetry stations with a GPS and bearings with a compass. Effective distance for each trial was calculated as the inverse of the effective

movement rate: 1/[(Euclidean distance between point of release and forest edge)/homing time)] (Fig. 5). We calculated mean effective distances for each landscape element and standardized effective distances for landscape elements such that 1m of Euclidean distance traveled in the element characterized with greatest effective movement rates, and therefore with lowest resistance (e.g. old-growth forest), represented an effective distance of 1m. Therefore, 1m of geographic distance traveled in elements characterized with lower effective movement rates and higher resistance (e.g. clearcuts) represent effective distances >>1m.

I-b: Estimation of Perceptual Range. To establish the perceptual range of flying squirrels, subadults, adult males and adult non-breeding females were transferred to canisters and held in cages until experiments were initiated. Animals were fitted with tracking spools (≤250m; Boonstra and Crane 1986), and placed in clear cuts or very young regenerating stands (<5yrs) at 1of 3 distances (100, 150, 175m) from old-growth patches. Canisters were positioned during 2000 to 2300 hours, near the period of peak diel activity (Zollner 2000; Mech and Zollner 2002). Observers were subsequently returned to release locations within 24 hrs, and tracking-spool threads were followed and turning angles and distances (cm) were recorded for all step-lengths with angular divergence >5 degrees and lengths >5cm. Using regression analyses of angular divergence against release distance, we will assess perceptual range of squirrels by determining the ability of squirrels to orient to forest cover across the range of distances (Mech and Zollner 2002). We will utilize this information to estimate maximum distance that flying squirrels might travel between old-growth elements separated by areas that lack old-growth forest structure (young second growth, clearcuts, roads, streams) and incorporate this information into the GIS movement-capability model.

II: Natural Movement Patterns in Fragmented Landscapes. We studied movements in fragmented areas around trapping grids in 3 instances (Table 1): (1) resident adults and subadults were studied opportunistically during spring and fall 2003-2005; (2) juveniles were studied just prior to and during short-term dispersal phases in fall 2003-2005; and (3) resident and transient adult males were studied during a long-distance mate-seeking phase in Spring 2005 (and tentatively in 2006). All animals were fitted with radiotransmitters (2.8 – 4g; Model PD-2C; Holohil Systems) and released near the point of capture. Thereafter, animals were relocated with varying frequency during both night (to establish occurrence in active periods) and during the day (to establish den locations) (Table 1). During night sessions, simultaneous telemetry bearings of squirrels were recorded by 2 observers from established points. To avoid spatial autocorrelation of location data, ≤2 locations were collected for each squirrel per night and min. time intervals between locations were >1/2 hr. GPS units were used to both record observer locations and any den locations that were established during day telemetry sessions.

Although we could not unequivocally assume juveniles were captured in natal patches of forest, we expected that this generally was the case: we were live-trapping just prior to, and then during, the period of juvenile emergence (Villa et al. 1999). Hence we anticipated this temporal phase of emergence was inferable by the unprecedented occurrence of juveniles, as well as repeated captures of young animals that had notably accumulated body mass. After September 31, we assumed juveniles had dispersed to new locations when (1) they have not moved for > 4 weeks and (2) were consistently using the same den site. To establish whether any animals had been preyed upon, we verified that den site characteristics, emergence patterns, and telemetry signals were similar to characteristics of animals we knew were alive. When signals were potentially out of range on the ground, we also conducted aerial telemetry to locate animal dens. We generally monitored animals from March to mid-May in spring and September to early December in Fall; after which transmitter signal faded.

We also estimated radiotelemetry error rates by recording bearings from 10 different pairs of observer points for each of 10 "dummy" radio-transmitters hung in trees at known locations in old-growth stands (< 25m in Oregon old-growth habitats; Martin and Anthony 1997).

III-a: GIS-Based Movement Capability Model. To establish movement capability in our study areas, we are employing a least-cost modeling approach, which assumes that flying squirrels will choose to move through a heterogeneous landscape by minimizing perceived movement-related costs, e.g. along a path of least resistance. Base GIS layers (Table 3) have been assembled and relevant layers are being updated using aerial-photo interpretation. These layers will be combined into a composite layer and structure types (e.g. old-growth, regenerating) will be converted into a raster (grid) layer of 20m x 20m cells. A movement-cost surface will be created by coding cells with effective distance estimates derived from the translocation experiment. The effective distance of cells that lack old-growth forest structure but are within the perceptual range of old-growth elements, as estimated from our spool experiment, will remain unchanged. Alternately, cells that lack old-growth forest structure and are further from any old-growth forest element than a distance equivalent to the perceptual range will be re-coded 10^3 X the highest effective distance recorded; essentially rendering these cell impermeable. Then, using centroids of focal old-growth patches as points of origin, we will model a least-cost surface (ArcGIS 8.3; Spatial Analyst) to depict relative movement capability by flying squirrels. The final least-cost surface will represent the total lowest effective distance (e.g. path of lowest resistance) between points of origin and every other cell on the surrounding landscape (Fig. 6).

For the model to perform well, we expect that flying squirrels will disperse to locations in the landscape that have lower associated movement costs: flying squirrels should exhibit selectivity for sites that the model indicates has lower movement costs, relative to random points that are the same Euclidean distance away from points of origin. We will compare the model to empirical dispersal data collected during 2 potential long-distance movement phases of flying squirrels: (1) in Spring, when adult males are moving long distances in seek of mates; and (2) in Fall, when juvenile animals disperse from natal territories. We will overlay dispersal locations (dens) on the least-cost surface and, using the maximum effective distance of any dispersal event observed, eliminate from further consideration any area (cells) that are 1000m greater than this effective distance. We will calculate the effective distance of each dispersal location and a all points that are "available" at the same Euclidean distance away from each point of origin. We will calculate Ivlev's electivity index for each dispersal location. Then, we will create a randomized set of "dispersal" locations, and repeat the calculation of electivity for these locations and an "available" set of associated points. We will use MANOVA to test for differences in electivity between observed and random dispersal locations as well as the effect of covariates, such as dispersal (Euclidean) distance, on patterns of landscape selection.

We will also calculate threshold effective-distance values at which dispersal probability is 100% by calculating the minimum effective distance value dispersed by all animals. We will repeat the analysis for successive deciles (90%, 80%, etc.) of dispersal probability.

III-b: GIS-Based Old-Growth Reserve Assessment. Using the movement-capability modeling approach described above, we will conduct an analysis of connectivity for individual OGR's on the Prince of Wales landscape. This analysis will help identify high-priority areas of the POW landscape that currently lack connectivity and identify non-OGR portions of the landscape that may also be critical for the maintenance of connectivity. Two complementary types of OGR assessment will be conducted. First, we will conduct a concentric analysis of connectivity in the matrix surrounding individual reserves. We will create a least-cost surface from reserve boundaries into the surrounding matrix; constraining dispersal to the maximum effective distance observed in our flying squirrel sample (above). Then we will calculate the % area

surrounding each reserve in which the likelihood of dispersal is (a) ≥90% and (b) ≥50%. We will then rank OGR based on this % for each of the 2 dispersal probabilities. Second, we will extend the least-cost analysis to broader portions of the landscape around individual OGR. We will calculate (a) the lowest effective distance between each OGR and the closest OGR and (b) the mean lowest effective distance between each OGR and all OGR in local networks (ca. 3-7 OGR). OGR will be ranked for each of the 2 effective-distance values. The first assessment (Fig 7a) described will allow for the identification of OGR populations that are at risk of isolation due to matrix considerations; incorporating only information relevant to the scale of individual animals dispersing from an OGR. The second assessment (Fig. 7b) will allow for identification of OGR that are at risk of isolation due to loss of broader landscape-level processes such as demographic rescue and/or gene flow.

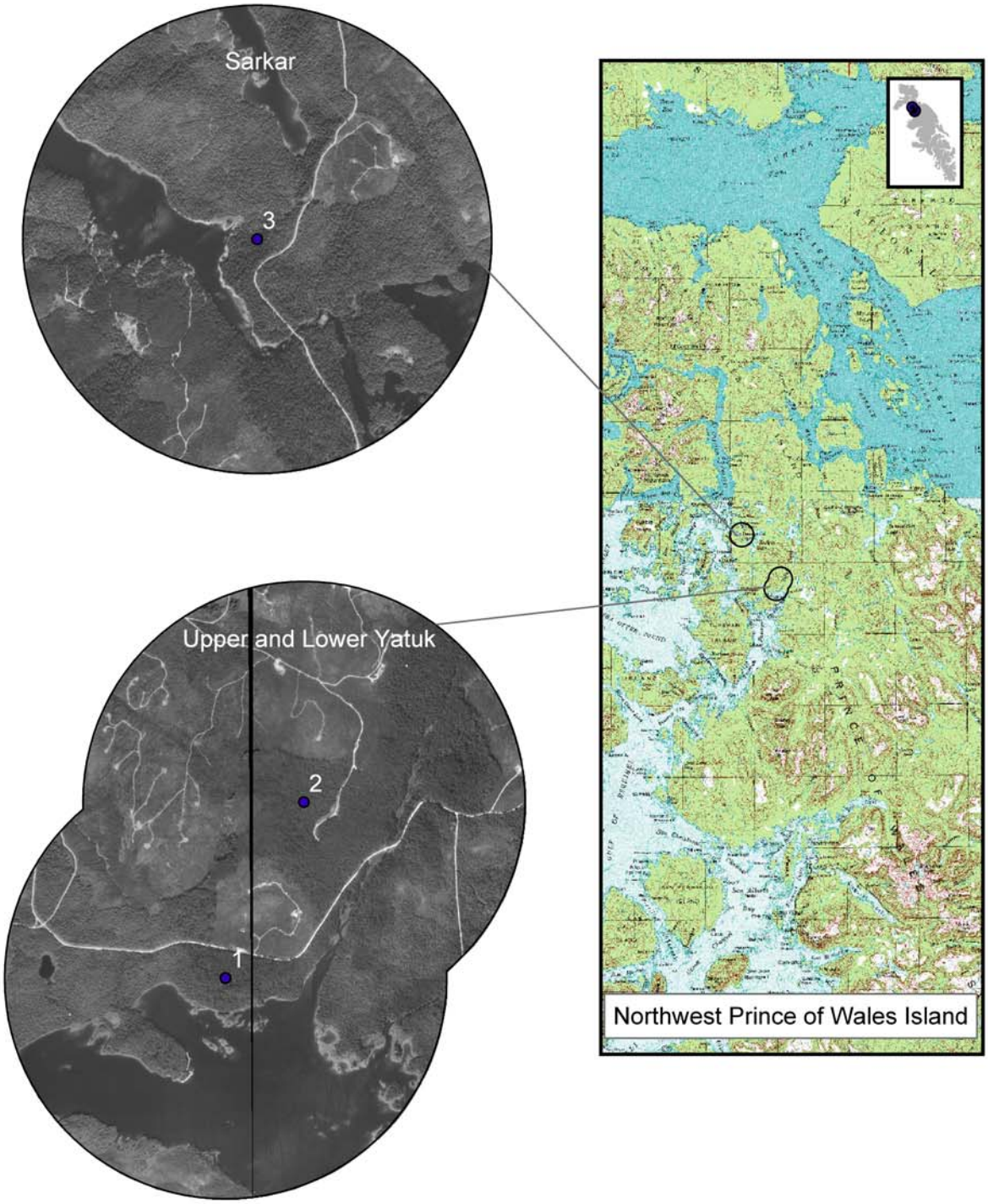


Fig. 2. Location of study grids (blue points) on the managed landscape of northwest Prince of Wales Island. Digital photos do not depict harvesting activity that has occurred in the study area (primarily on state lands) since 1997.

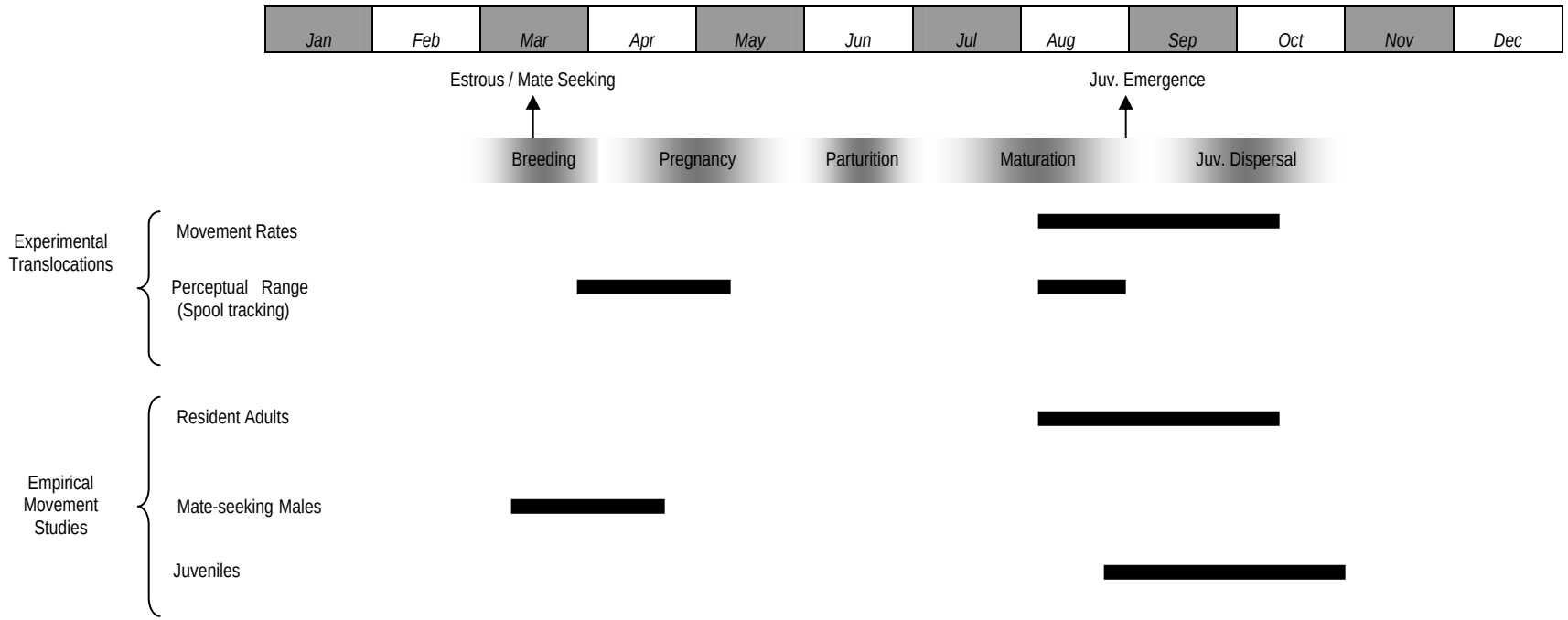


Fig. 3. Organization and timing of experimental and empirical field components relative to phases of flying squirrel life-history in Southeast Alaska. Life history stages are derived from 2003 pilot-study data and from a previous study of flying squirrel demography (Smith and Nichols 2003).

Fig. 4a. Old-growth habitat elements are large (>100ha) patches or larger reserves composed of either spruce-hemlock or a more open mixed-conifer (peatland) type. Stands are typically heterogeneous, are multistory, reach 75m in height, and provide numerous microhabitat elements important for food, cover, and denning, as well as a basis for canopy-based gliding.

Fig. 4b. Young second-growth habitat elements are homogeneous, pre-stem exclusion stands of regenerating spruce-hemlock trees 20-40yrs old. Stands are dense, often very large (>1000ha), lack more than a single story, and are 5-15m high. These stands provide relatively limited options for food and den microhabitats but may provide mechanisms for movement between primary habitats through quadrupedal movement on the floor or saltatorial movements on the rudimentary canopy.

Fig. 4c. Clearcut and/or young regenerating stands harvested 0-15 yrs currently interspersed in limited amounts throughout the study area, These stands are characterized as remnant slash piles with very little to no canopy development, and are <1m high. These stands provide very few options for food and den elements but may provide a basis for quadrupedal movement across the floor.

Fig. 4d. “100”-ft riparian buffer often have vertical components of more extensive old-growth stands but lack interior forest conditions. These elements may provide food and limited denning opportunities, and may provide movement corridors via canopy-based gliding.

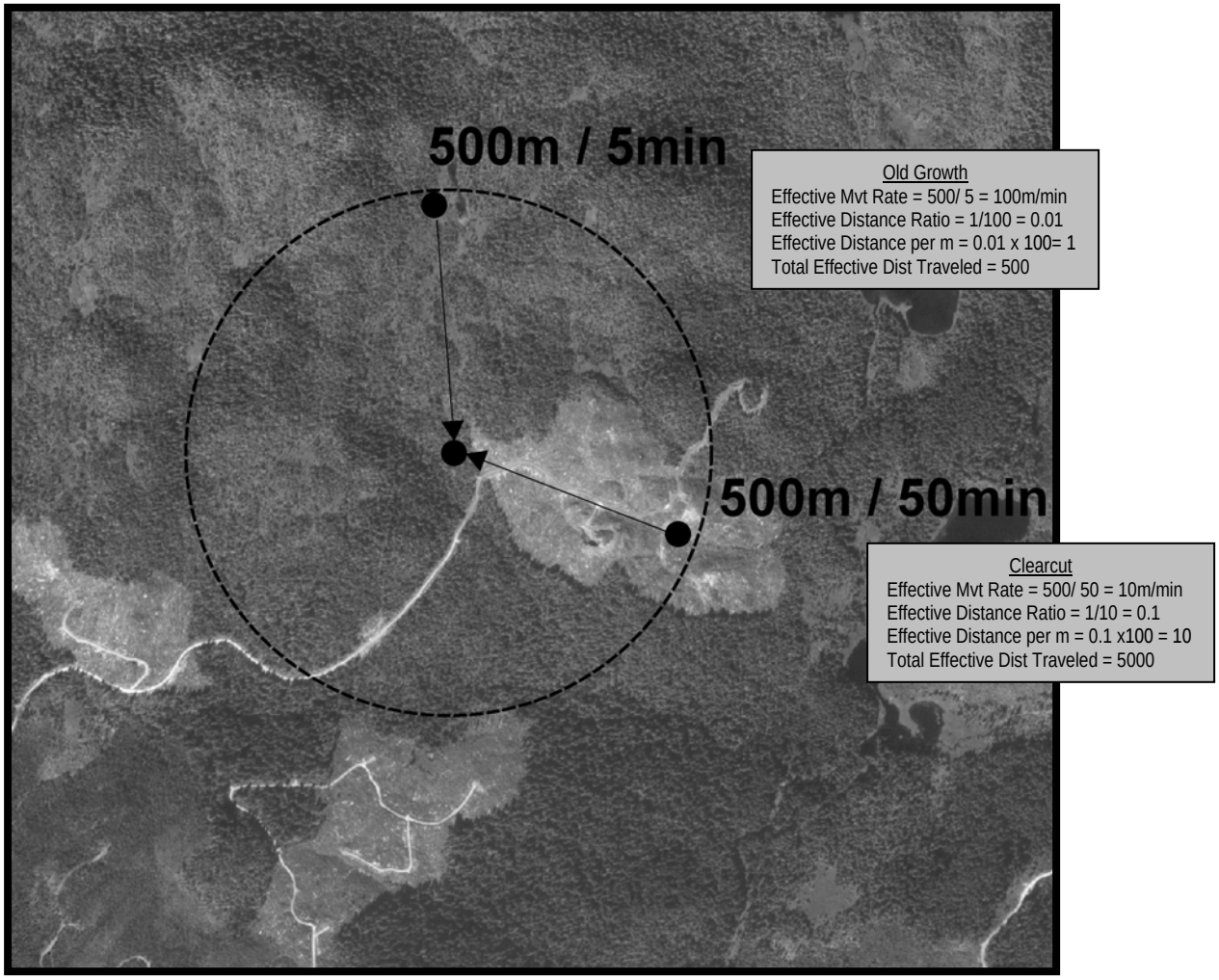


Fig. 5. Example of translocation (homing) experiment and the process used to calculate effective movement rates and hence the effective distance traveled in different landscape elements. Squirrels are released with transmitters at specified distances from points of origin; in these 2 cases 500m in two different landscape elements – old growth and recent clearcuts. Animals are radiotracked intensively while homing, and homing time is recorded. Arrows do not represent actual paths traveled; these simply represent Euclidean distance between points of release and origin.

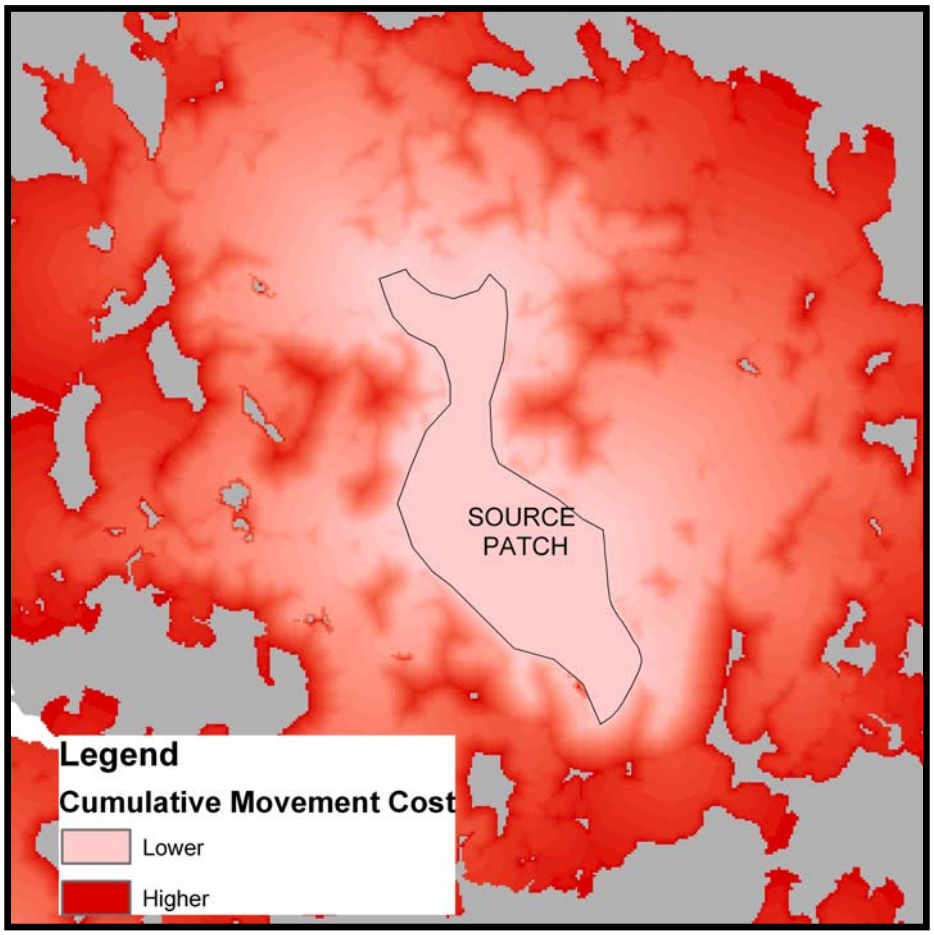


Fig. 6. Example of a "least-cost" movement surface that represents the cumulative lowest effective distance (e.g. cost of the path with lowest resistance) between a point of origin and every other point on the surrounding landscape for a dispersing flying squirrel. The surface incorporates information about points (stands) of origin, landscape structure, the effective distance (e.g. resistance) that each landscape element represents, and the perceptual range of flying squirrels.

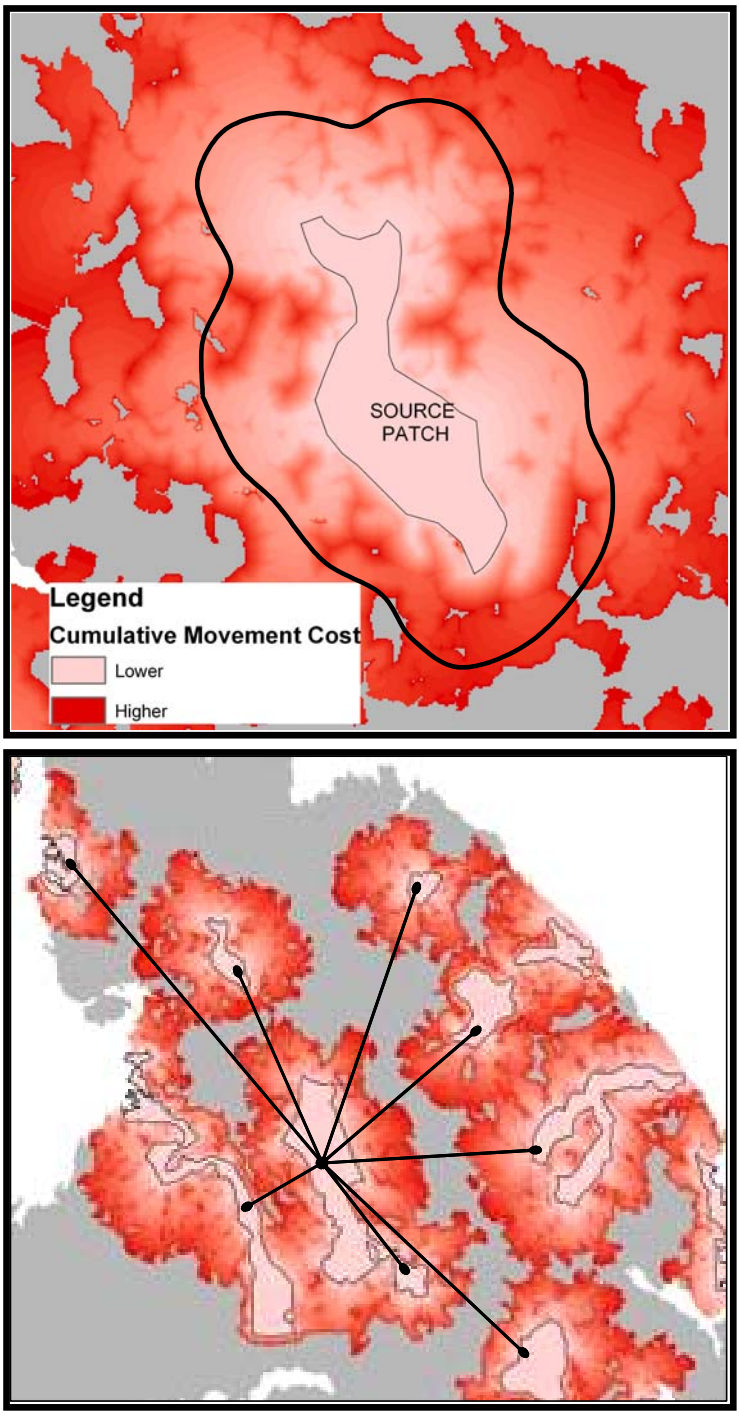


Fig. 7. Schematic comparison of 2 complementary types of connectivity-based assessments that will be conducted to rank Tongass OGR's: (a) a concentric analysis of connectivity in the matrix surrounding individualOGR, constrained by the effective distance of a dispersal event by flying squirrels; and (b) broader measures of effective distance (as opposed to Euclidean distance depicted by arrows) between each OGR and surrounding OGR.

Table 1. 3 Different opportunities to collect empirical data on movements of flying squirrels in fragmented landscapes.

Animal Class	*Projected n*	*Min. Frequency of Relocation*	*Attributes Studied*
Adult & subadult residents	15-20	Once / 2 nights Den location: Once/week	• Frequency of occurrence in different landscape elements • Den locations relative to landscape composition
Juveniles, during dispersal	25-40	Pre-dispersal: Once / 2 nights During dispersal: Once/night Den location: Once / week	• Frequency of occurrence in different landscape elements • Total dispersal distance • Dispersal locations relative to landscape composition • Den locations relative to landscape composition
Males, during mate seeking	20-30	Locate Animal: Once / 2 nights Den location: Once / week	• Frequency of occurrence in different landscape elements • Travel distances • Dispersal locations relative to landscape composition • Den locations relative to landscape composition

Table 2. Existing and possible sources of data for validation of movement capability model.

Possible Validation Data Sets	Sources of data	Status
Occurrence and den locations during juvenile dispersal phase	Empirical study of radio-collared juveniles	Current, Fall of 2004 and 2005
Occurrence and den locations during mate-seeking phase	Empirical study of radio-collared adult males	Current, Spring of 2005, possibly 2006
Occurrence of flying squirrels in matrix and patch elements	Non-invasive sampling with scat traps	Tentatively planned through funding provided by the Earthwatch Foundation and in collaboration with University of Alaska Fairbanks graduate student (L.Burner)
Genetic estimates of connectivity	Non-invasive hair sampling and DNA microsatellite analysis	Tentatively planned in collaboration with University of Wyoming (M. Ben David, L. Flaherty)

Table 3. Data incorporated into models of movement capability for flying squirrels.

Data Type	Sources, layer name
Elevation	GIS, 30m DEM
Forest Cover	GIS, Tim Type & Veg ILC
Water	GIS, FS Lakes
Roads	GIS, Roads 95
Forest type	GIS, Tim Type & Veg Mod
Forest size class	GIS, Tim Type
Watershed boundaries	GIS, VCU
Old Growth Reserves	GIS, LUD
Harvest history	GIS, Managed Stands
Landscape resistance (effective distance)	Experimental data
Perceptual range	Experimental data

Progress and Preliminary Conclusions

I-a: Estimation of Movement Capability. Thus far, we have conducted n=33 trials of the translocation experiment in old growth (n=9), young second growth (10), riparian buffer (7), and clearcut (7) landscape elements. Preliminary estimates of effective movement rates (Fig. 7) in intact old-growth are approximately 10X greater than in clearcuts, 2X greater than in young second growth, and similar in small or narrow fragments of old-growth such as 100-ft riparian buffers. Therefore, 100m of Euclidean distance traveled horizontally represents approximately 100m, 1000m, 200m, and 100m in old growth, clearcut, second growth, and small old-growth elements, respectively. We expect to conduct additional trials as needed in Spring and Fall of 2005, and perhaps Spring of 2006, contingent on evaluation of effect sizes for these data.

I-b: Estimation of Perceptual Range. We have conducted a total of n=31 spool trials at 100m (n=11), 150m (17), and 175m (3) release points. We initially found little evidence that the perceptual range of flying squirrels was < 150m (Table 4; 2003 data only), however we suspect that distances between 150-200m begin to approach this limit. Brief evaluation of spool data from the 3, 175m trials suggest that flying squirrels exhibit noticeably more circuitous movements when initially navigating to old-growth habitat elements. Additional trials with release points $\geq$ 175 are planned for Spring and Fall of 2005, and these data will require more thorough quantitative analysis to evaluate this hypothesis.

II: Natural Movement Patterns in Fragmented Landscapes. Although initially we had poor success trapping juveniles and affixing transmitters to young animals, we have captured and radiotracked 21 juveniles during Fall of 2003 and 2004. Dispersal by juveniles appeared to occur between mid-September to mid-October in 2003 and 2004. Euclidean distances of dispersal from our old-growth stands ranged from 100m to 4km. Locations dispersed to consist of old-growth habitat elements, although some animals appeared to cross open mixed-conifer areas, possibly young second-growth, and major and minor roads. We did not document any deaths of juveniles that were attributed to natural (i.e. non-handling-related) causes. We anticipate radiotracking movements of another 15-20 juveniles in Fall 2005.

We also trapped and radiotracked 19 adult males during a 6-wk period in Spring 2004. Based on animal condition and trapping patterns in 2003 and 2004, we believe these animals dispersed relatively long distances in search of females that were in estrous (Fig. 8; 2004 data only). Transient males that we trapped and affixed with transmitters dispersed from locations as far as 6km away (and returned, in a single night), utilized riparian buffers and crossed major streams (Fig. 9). All animals denned in remnant old-growth stands during this period. We believe dispersal events by these animals represent the most productive opportunity to empirically study functional connectivity; and we plan on repeating this portion of the study in Spring of 2006.

We have also collected supplementary information regarding flying-squirrel den use in fragmented landscapes. Thus far, we have evaluated characteristics at n=43 different den sites, and expect to collect such data at another 30-40 locations in Spring and Fall 2005. We expect to submit this portion of the study for publication in 2005.

III-a: GIS-Based Movement Capability Model. We have made significant progress refining our GIS-based modeling approach: we are reasonably confident that the model can be parameterized and validated with the types of empirical data we have been able to collect. Completion of the model is contingent on analysis of estimation of effective distances of different landscape elements and estimation of perceptual range. We expect to complete this portion of the study in Fall-Winter 2005.

III-b: GIS-Based Old-Growth Reserve Assessment. We have assembled all GIS information necessary to conduct this assessment, although the exact boundaries of small OGR's may be inaccurate because these are currently being determined and/or updated by TNF GIS personnel. In any case, we will utilize the latest mapped information we have available to us in order to complete the OGR assessment. Pending completion of field components and validation of the modeling approach for our local study area, we expect to complete this assessment by late Spring 2006.

Products completed or in progress:

L. Flaherty, S, Pyare, M. Ben-David, and W. P Smith. 2005. Poster to be given at the American Society of Mammalogists.

S. Pyare. 2004. Landscape connectivity and old-growth reserve design in the Tongass. Presentation given at the annual meeting for Society of Conservation Biology, New York, NY.

S. Pyare. 2003. Ecological indicators of forest connectivity in the Tongass. Presentation at the annual Yellowstone to Yukon conference sponsored by the Craighead Environmental Research Institute, Bozeman, MT.

S. Pyare, 2003. Evaluating landscape connectivity and old-growth reserve design using flying-squirrel movement capability. Presentation given at 2 interagency meetings held in Juneau, AK.

L. Bruner, 2003 and 2004. Various public presentations given to local communities and schools on Prince of Wales Island pertaining to ecological function of flying squirrels as dispersal agents and the importance of old-growth reserves.

C. Boser, S. Pyare, 2003, and W.P Smith. Den characteristics and use by flying squirrels in fragmented landscapes. Manuscript in preparation.

S. Pyare, W.P. Smith, R.W. Flynn, D. Person, and M. Ben David. A multi-species assessment of old-growth reserve functioning and design. Manuscript in preparation.

S. Pyare and W.P. Smith. Estimating landscape permeability using real animal-movement data. Manuscript in preparation.

S. Pyare and W.P. Smith. Notes on flying-squirrel homing ability. Manuscript in preparation.

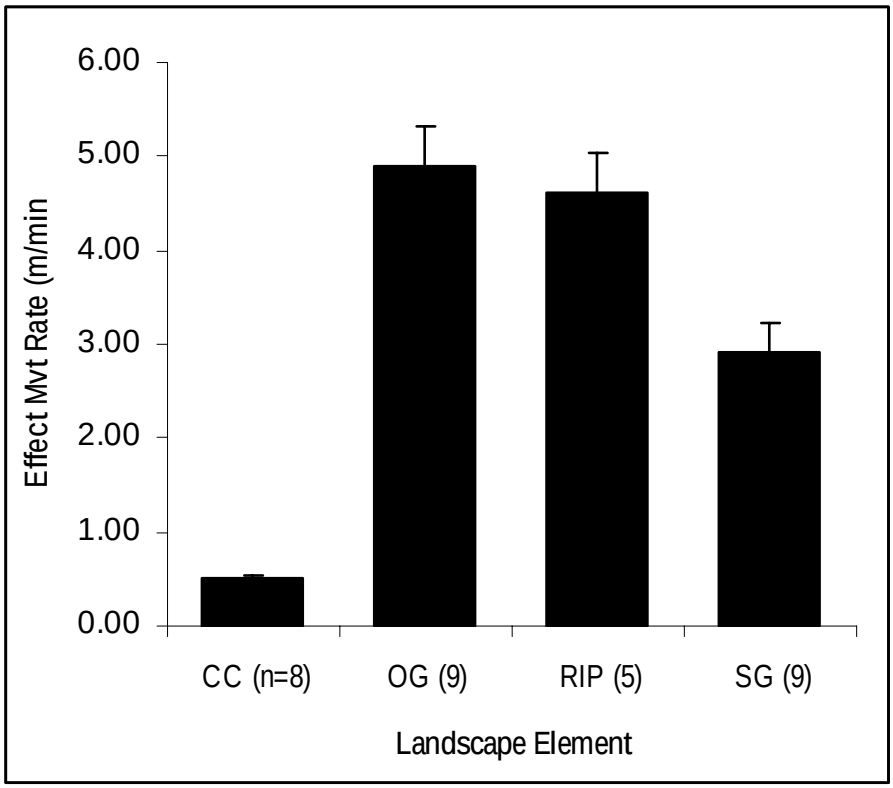


Fig. 7. Preliminary estimates of effective movement rates by flying squirrels in clearcut, old-growth, riparian buffers, and young second growth landscape elements in 2003 and 2004. Rates were significantly different among treatment types (single factor ANOVA; $p<0.0001$). This information will be used to calculate the effective distance that these different landscape elements represent to dispersing flying squirrels; a key parameter in GIS-based resistance models of OGR connectivity.

Table 4. Comparison of 3 movement-trajectory metrics between the 2 release-distance categories. Data are from 2003 trials only. Mean values were compared using single factor ANOVA.

Metric	Distance to Edge (m) 100 (n=6)	150 (12)	*P* <
No. Rotations x(σ)	93.833 (3670.967)	69.583 (3756.447)	0.438
Linearity x(σ)	0.828 (0.023)	0.855 (0.019)	0.654
Sinuosity x(σ)	0.769 (0.172)	0.692 (0.087)	0.706

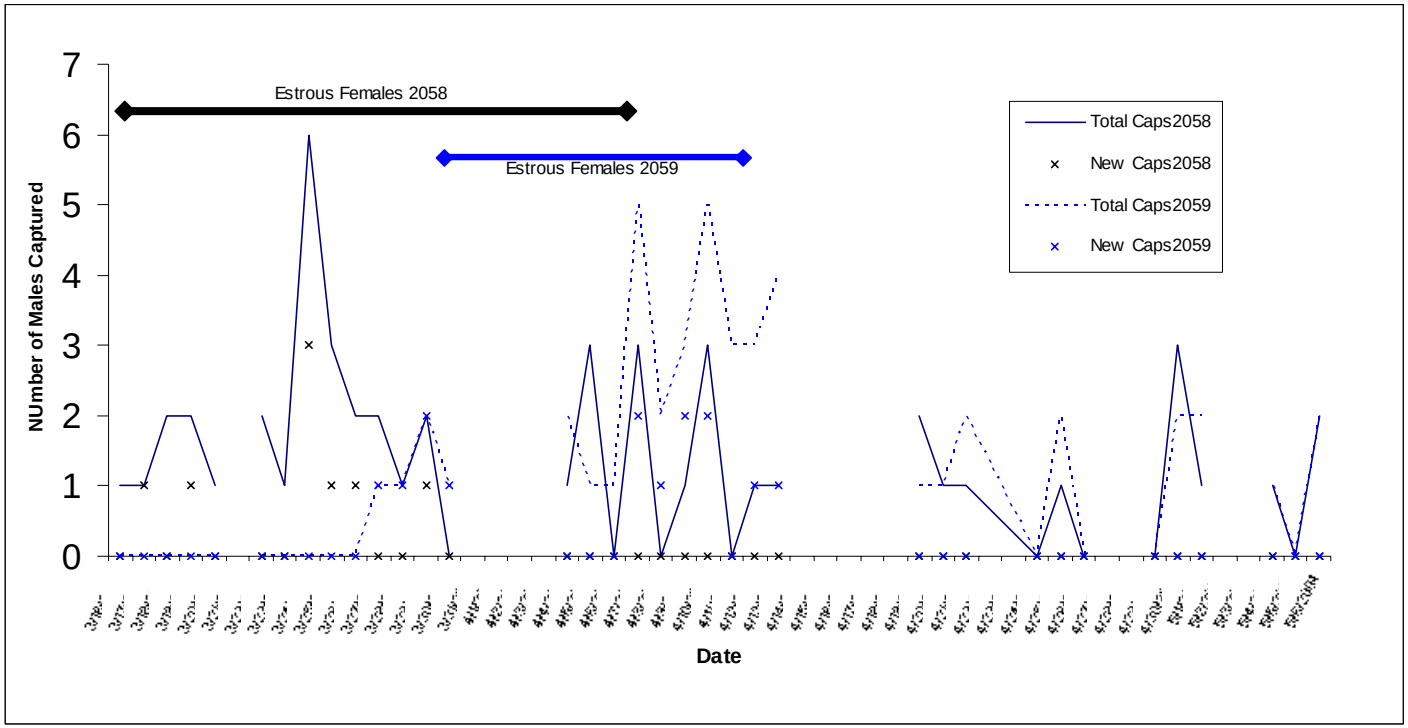


Fig. 8. Patterns in trapping success of transient adult males in 2 stands ("2058", "2059") during early Spring when females are in estrous.

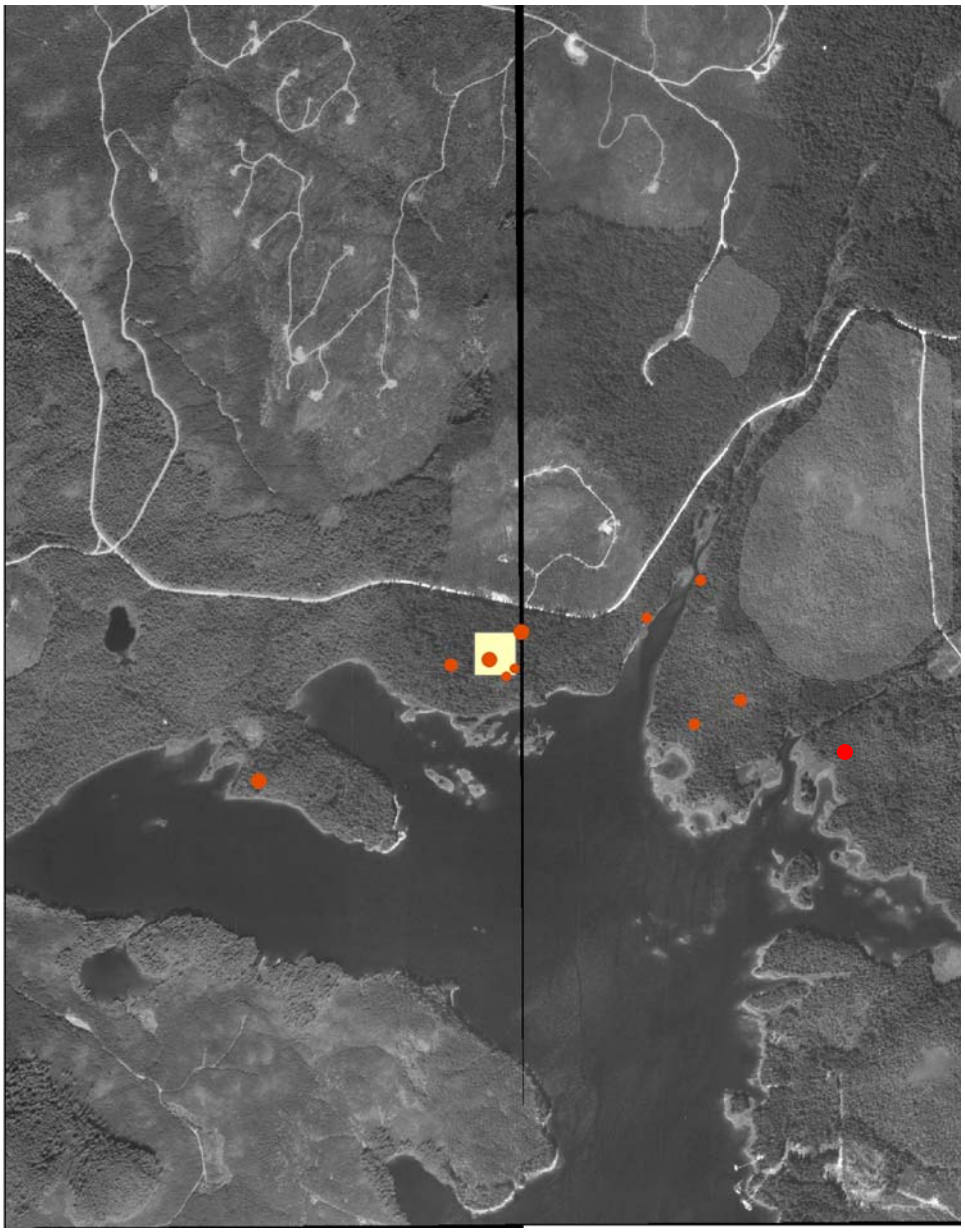


Fig. 9. Den locations of transient adult males (April 2005), relative to trapping grid location (approximated as 250m x 250m square).

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