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In Cooperation with Olympic National Park

# Monitoring Small Mammal Populations in Coniferous Forest Ecosystems of Olympic National Park: Preliminary Assessment

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The USGS Forest and Rangeland Ecosystem Science Center (FRESC) was established in 1994. The Center was established to consolidate and coordinate research in support of Department of the Interior agencies in the Pacific Northwest. The mission of FRESC is to provide scientific understanding and the technology needed to support sound management and conservation of our Nation's natural resources, with an emphasis on western ecosystems. This mission is derived from the needs of natural resource managers for science-based monitoring systems and reputable research to assist in management of forest, arid and semi-arid ecosystems.

## SUMMARY

- We conducted a 3-year pilot study to evaluate the feasibility of estimating and monitoring populations of small mammals in low-elevation old-growth coniferous forests of Olympic National Park. Primary objectives of the study were to:

  (1) determine species present in low-elevation coniferous forests of Olympic National Park,
  (2) evaluate performance of closed-model population estimators of species abundance,
  (3) evaluate spatial and temporal variation in indices of abundance derived from constant-effort trapping grids, and
  (4) make recommendations for future monitoring of small mammal populations.

- We conducted preliminary monitoring studies in 4 low-elevation Sitka Spruce and Western Hemlock Zone forests in the Hoh, East Fork Quinault, Elwha and Skokomish drainages. We sampled small mammals by live trapping on a 4 x 25 array of trapping stations spaced 15 m apart (i.e., 100 trap-stations total covering 60 x 375 m) in each site. We placed three live-traps at each station, generally a small Sherman trap (Sherman Co., Tallahassee, Fl., 5.1 x 6.4 x 16.5 cm), a large Sherman trap (7.6 x 8.9 x 22.9 cm), and a Tomahawk trap (15.2 x 15.2 x 48.3 cm). We set the traps on each grid for two 4-night trapping sessions conducted within 11 nights each summer.

- We captured 18 species of small mammals, predominately mice (*Peromyscus* spp., 59% of total captures), shrews (*Sorex* spp., 19%), southern red-backed vole (*Clethrionomys gapperi*,13%) and Oregon vole (*Microtis oregoni*, 4%). Capture frequencies summed for all species varied among years but tended to be greater in the east-side drainages (i.e., Elwha and Skokomish; 12-30 captures/100 trap-nights) than in west-side drainages (Hoh and Quinault; 7-19 captures/100 trap-nights).

- Morphological similarities of two species of *Peromyscus* prevented unequivocal identification to species in the field, particularly for juveniles. Nonetheless, we estimated 95% of adult mice captured were Keen's mouse (*Peromyscus keeni*; note formerly *P. oreas*), and 5% deer mice (*P. maniculatus*) on the basis of adult tail length. We verified one deer mouse on the basis of genetic analysis. These results confirm the prevalence of Keen's mice over deer mice in old-growth forests of the Olympic Peninsula.

- We estimated abundance of mice (*Peromyscus* spp.) and southern red-backed voles using Program CAPTURE. Abundance, capture rates, and precision of those estimates were highly variable between species, years and trapping sites. In many cases, low capture rates and population estimates may have negatively influenced the reliability of model selection in Program CAPTURE. Further, capture histories revealed violation of the important assumption of population closure during trapping sessions. We concluded that variation in model selection, inadequate adherence to model assumptions, and low precision of population estimates are significant obstacles for monitoring trends in

mammalian abundance using the preliminary sampling design.

- We computed catch per unit effort (CPUE) as the number of animals captured per 100 trap-nights of effort as an index of relative abundance among years and sampling areas. Relative abundance of mice (*Peromyscus* spp.) varied both among years and trapping sites, with greatest abundance in the Elwha Valley. Abundance indices of mice varied 4-7 fold between successive years, with an apparent pattern of alternating high- and low-density years. Abundance indices of southern red-backed voles, Oregon voles, and shrews were relatively constant among years.

- We make several recommendations for adjustments to monitoring design and methods for future monitoring of small mammals.

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# INTRODUCTION

Biologists from the USGS and National Park Service are collaborating in developing a program to monitor the ecological integrity and health of coniferous forest ecosystems of national parks in the Pacific Northwest. Olympic National Park was selected to develop a 'prototype' or 'model' program for monitoring coniferous forests in Pacific Northwestern parks, in part because Olympic National Park preserves the largest pristine coniferous forest ecosystem remaining in the Pacific Northwest, and has played an important role in regional forest monitoring initiatives (i.e., northern spotted owl monitoring mandated by the President's Northwest Forest Plan). An ambitious goal of ecological monitoring in Olympic National Park is to identify unacceptable trends in park resources that threaten long-term integrity and sustainability of park ecosystems. Early discussions in the development of this monitoring program focused on identifying the most important 'vital signs' of ecosystem integrity upon which to focus monitoring efforts (Jenkins et al. 2002).

Small mammals were identified as an important species group to monitor in recognition of the abundant and varied ecological functions of small mammals in coniferous forest ecosystems (Marcot and Aubry 2003). Forest mammals are important vectors in the dispersal of mushrooms and truffles, including the ectomycorrhizal fungi that play a critical role in the uptake of nutrients by conifers (Maser et al. 1978, Johnson 1996). Small mammal populations also consume arthropods, seeds, and small vertebrates (e.g., eggs and fledglings of songbirds, J. Marzluff, pers. comm.). As consumers, small mammals may influence the regulation of populations of forest invertebrates (Holling 1959, Elkington et al 1996), nutrient dynamics of ecosystems (Sirotnak and Huntly 2000), or distributions and demographics of plant populations (Tallmon et al. 2003). As prey, small mammals sustain higher trophic levels of both avian and mammalian carnivores, notably the northern spotted owl, a federally-listed threatened species in Pacific Northwestern forests, and rare, declining or locally-extinct populations of martens (*Martes americana*) and fishers (*Martes pennanti*) (Rugierro et al. 1994, Zielinski et al. 2001).

Though the ecological importance of small mammals has been identified, the final selection of ecological vital signs in Olympic National Park will depend on the feasibility and cost-efficiency of sampling, and the ability to detect meaningful change. There are very few studies of small mammal populations in Olympic National Park upon which to evaluate the logistical and statistical properties of sampling and monitoring. Reed (1987) reported very low capture frequencies associated with small mammal trapping in the Hoh Valley in Olympic National Park, suggesting potential problems in the estimation of small mammal population size. Lair (2001) estimated abundances of the Keen's mouse (*Peromyscus keeni*) successfully along forest/clearcut ecotones on the boundary of Olympic National Park, but those results cannot be generalized to interiors of large forested blocks. A rich literature on population estimation of small mammals in general, however, reveals that estimation of population abundance may be problematic when animal densities or capture probabilities are low (White et al. 1982, Menkens and Anderson 1988).

In 1998, we initiated a 3-year pilot study to evaluate the feasibility of estimating and monitoring populations of small mammals in low-elevation old-growth coniferous forests of Olympic National Park. Primary objectives of the study were to:

1) determine species present in low-elevation coniferous forests of Olympic National Park,
2) evaluate performance of closed-model population estimators of species abundance,
3) evaluate spatial and temporal variation in indices of abundance derived from constant-effort trapping grids, and
4) make recommendations for future monitoring of small mammal populations.

This pilot study was designed around the goal of determining trends in mammalian abundance in low-elevation (<500 m) coniferous forests in Olympic National Park. We examined closed-population estimators (Otis et al. 1978) and indices of abundance (Slade and Blair 2000) based on our interest in developing relatively cost effective monitoring tools. These tools need to be suitable for maximum replication and making comparatively broad-scale inference to the park on a limited budget. We did not examine the feasibility of more intensive sampling methods that are required to estimate demographically open populations. We provide recommendations for future monitoring of small mammal populations in low-elevation forests of Olympic National Park.

In 1999, we began a second pilot study designed to inventory species richness and habitat associations of small mammal populations throughout Olympic National Park. We were unable to sustain that sampling effort due to budgetary constraints. Those results are presented as an appendix to this report, primarily as a means of cataloguing the data collected (Appendix D).

## STUDY AREA

Olympic National Park preserves approximately 3,800 km$^2$ of largely pristine forested, subalpine, and alpine wilderness at the core of the Olympic Peninsula in northwestern Washington (Figure 1). Eleven major river systems emanate from glaciers and snowfields in park's mountainous interior and flow radially outward to low-lying coastal areas to the southwest, west, north, east and southeast. The Olympic Mountains block the inland flow of moist air from the Pacific Ocean, producing very heavy precipitation on the western flanks of the Olympic Mountains and a rain-shadow effect on the leeward east side of the mountains. Precipitation ranges from in excess of 300 cm annually in the west-facing rainforest valleys to approximately 50 cm in the northeast. Distributions of seven primary vegetation zones are controlled largely by steep gradients in elevation, temperature, and precipitation (Henderson et al. 1989). Low-elevation forests of the western rainforest valleys fall within the Sitka Spruce (*Picea sitchensis*) Zone and are dominated by large Sitka spruce, western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*). The Western Hemlock Zone, characterized by large Douglas fir, western red cedar and western hemlock, occurs on slopes above the Sitka Spruce Zone on the west side of the park and is present at low and middle elevations elsewhere in the park.  Higher-elevation forests include the Pacific Silver Fir (*Abies amabilis*), Mountain Hemlock (*Tsuga mertensiana*), Subalpine Fir (*Abies lasiocarpa*) Zones and non-forest (alpine) vegetation.  Small-scale disturbances caused by wind throw and fluvial disturbances are frequent throughout forests of Olympic National Park.   Fire effects, which generally operate on a larger spatial scale and less frequently than wind throw, are most pronounced in the relatively dry eastern Olympic Peninsula than in the wetter west-side forests.  Most of the Western Hemlock Zone forests on the northern and eastern Peninsula burned approximately 300 years ago (Henderson et al. 1989).

## METHODS

### Sampling Design

The target population for preliminary monitoring studies included low-elevation (<500 m) Sitka Spruce and Western Hemlock Zone forests of Olympic National Park.  The sampling frame consisted of 11 primary watersheds present at low elevations, from which we randomly selected 4 watersheds.  We randomly selected the Hoh and East Fork Quinault on the west side of the park and the Elwha and Skokomish on the east side.  Within each drainage, we selected a representative mature forest stand within 400 m of a road (for logistical reasons).  Stands were representative of the prevailing late-seral forest types in each watershed.

### Sampling Procedures

*Trapping Grids:*--Each trapping grid encompassed 2.25 ha and consisted of a 4 x 25 array of trap stations spaced 15 m apart (i.e., 100 trap-stations arranged in a 60 x 375-m array).  We placed three live traps at each station, generally a small Sherman trap (Sherman Co., Tallahassee, Fl., 5.1 x 6.4 x 16.5 cm), a large Sherman trap (7.6 x 8.9 x 22.9 cm), and a Tomahawk trap (15.2 x 15.2 x 48.3 cm) (occasionally we used two large or two small Sherman traps within a site).  We used Tomahawk traps only during the last two years of this study.  We placed Sherman traps in the best microhabitats available within about 3 m of each station point (i.e., near logs, debris, or other habitat structures).  We alternated the placement of Tomahawk traps on the ground versus anchoring them about 1.5 m up the bole of a large tree or snag within 5-7 m of the sampling point center.  We baited Sherman live traps with 1:1 mixture of oat groats and sunflower seeds and a piece of apple.  We baited Tomahawk traps on the ground with alfalfa to target snowshoe hares, and those anchored on trees with pieces of apple and a mixture of strawberry jam, peanut butter, and oatmeal to target two species of squirrels (northern flying squirrel and Douglas squirrel, all Latin names of mammals are provided in Appendix C).  We covered each of the Tomahawk traps with a waxed cardboard milk carton to provide protection from sun and rain, and placed hydrophobic polyester batting within each trap for bedding.  We set the traps on each grid each summer for two 4-night trapping sessions conducted within 11 consecutive nights (i.e., a total of 8 trapping occasions, with traps closed for 2-3 nights).  We trapped during late July-early September based on  logistic considerations and to avoid periods of high immigration (Carey and Johnson 1995).

*Animal handling*:--Field technicians baited and set traps on the first day of each trapping session, and checked traps each morning to record captures, adjust treadle sensitivity, and clean and rebait traps as needed. Traps were left active 24 hours a day during each trapping session. We determined and recorded species (except shrews; see below), gender, age (juvenile versus adult), weight, and capture status (new versus recapture) of each animal caught. We distinguished between two closely related species of *Peromyscus* (deer mice), *P. maniculatus* and *P. keeni*, on the basis of tail length (*P. keeni* with tail ≥96 mm; Allard et al. 1987). We did not distinguish among species of shrews captured in 1998 and 1999, during which years all shrews were recorded as *Sorex* sp. In 2000, we collected, labeled, and froze all captured shrews and submitted them to the Burke Memorial Museum at the University of Washington for species, sex, and age determination. Excepting shrews, we distinguished males from females by examining genitalia and juveniles from adults based on pelage characteristics, breeding condition, and body size. When it was difficult to determine juvenile from adult mice or voles, we distinguished on the basis of body weight (juveniles <15 g; Wilson and Carey 2000). We uniquely marked each captured animal prior to release (except shrews) using hair dye to mark hares, squirrels, and chipmunks, or by clipping a unique sequence of toes to mark mice and voles. Additionally we hole-punched a different ear (left v. right) of mice and voles captured during 1998 and 1999 to identify individuals captured in a previous year.

*Environmental Site Characteristics*:-- We described environmental characteristics of each trapping grid to permit general comparison between sampling sites. At every second trapping station (e.g., 50 stations total), we described the prevailing forest association following Henderson et al. (1989), and recorded slope and aspect using a Silva Ranger compass and a clinometer. We calculated the mean annual precipitation at each sampling site by extrapolating data collected at various weather stations throughout Olympic National Park based on modeled relationships of precipitation to elevation, aspect, and forest type (R. Hoffman, pers. comm.).

We recorded locations of the four corner points of each trapping grid using a Trimble GeoExplorer Global Positioning System (Appendix A). Further, we described vegetation and habitat characteristics at each trapping station. We measured and recorded distance, diameter at breast height, and species of the nearest live tree in each of four sampling quadrants defined by the cardinal directions from each trap station (Mueller-Dombois and Ellenberg 1974). We recorded an ocular estimate of overstory canopy cover within a radius of approximately 30 m from the point center. We also estimated vertical projections of cover of three understory vegetation classes, including shrubs, ferns, and forbs, within a 2.5-m radius of each trapping station. Lastly we recorded the number of downed logs in each of five diameter size classes: 10-23 cm, 23-53 cm, 53-81 cm, 81-122 cm, >122 cm, within a 2.5-m radius of each trapping station.

**Data Analysis**

*Environmental Site Characteristics*:-- We computed densities, basal area, and dominance of tree species on each trapping grid using the point-center-quarter method (Mueller-Dombois and Ellenberg 1974). To promote independence among points, we based computations on data from alternating trapping stations (i.e., 30-m spacings).

*Small Mammal Abundance*:--A wide variety of methods exist to estimate and monitor small mammal populations and trends. The simplest method uses counts of individual animals captured on a standardized array of trapping stations as an index of population abundance (Slade and Blair 2000). Total counts of individuals are generally less than the total number of animals present, so trend detection requires the assumption that the proportion of the population captured remains constant. Alternatively, trapping records may be used to calculate unbiased estimates of population size, based on marking and recapture histories of individual animals obtained from multiple capture sessions (Skalski and Robson 1992). Two general classes of estimation methods are distinguished by the assumption of whether or not the small mammal population remains closed to any additions or losses of animals during the trapping sessions (i.e., through births, deaths, emigration, immigration). Closed population estimators (e.g., Program CAPTURE) allow capture probabilities to vary among individuals (Model $M_h$), among trapping occasions ($M_t$), among individuals with behavioral responses to trapping history ($M_b$; i.e., trap-shyness or trap-happiness), or for various combinations of individual, temporal, or behavioral effects (Otis et al. 1978, White et al. 1982). Open population models allow for births and deaths (including immigration and emigration) between capture sessions, and permit the computation of birth and survival rates between successive sampling sessions (Pollack et al. 1990).

We used Program CAPTURE to estimate abundances of mice (*Peromyscus* spp.) and southern red-backed voles based on 8 daily trapping occasions (Otis et al. 1978, White et al. 1982). Program CAPTURE requires population closure throughout the trapping session, but several different estimators in Program CAPTURE allow capture probabilities ($p$) to vary. An estimator based on the null model ($M_o$) assumes $p$ is constant. The Zippin estimator, based on model $M_b$, allows $p$ to vary due to behavioral responses to trapping (i.e., animals become uniformly trap-'happy' or 'shy' after their first capture). The jackknife estimator, based on model $M_h$, allows $p$ to vary among different individuals captured, whereas estimators based on model $M_t$ allow $p$ to vary among trapping occasions. Mixed model estimators are also computed in Program CAPTURE (models $M_{bh}$, $M_{th}$, and $M_{tb}$), allowing for various combinations of behavioral, individual, and temporal variation in $p$. A model selection procedure in Program CAPTURE, based on goodness-of-fit tests, tests for sources of variation of $p$, and ranks the various models with regard to model fit. Further, a goodness-of-fit test in Program CAPTURE tests the assumption of population closure during the capture session.

For each data set we estimated abundance using the 'best' model identified from Program CAPTURE's model selection procedure and using the jackknife estimator, based on model $M_h$. Individual heterogeneity is a common source of variation in capture probabilities, and generally represents the best tradeoff between reliability and trapping effort (Manning et al. 1995). Further, model $M_h$ is often robust to temporal and behavioral factors that may influence capture probabilities (Otis et al. 1978).

We examined the assumption of population closure using the closure test in Program CAPTURE. The closure test is robust to heterogeneous capture probabilities (i.e., model $M_h$), but behavioral variation in capture probabilities is indistinguishable from failure of demographic or geographic closure (Otis et al., 1978). We also used a newer test for population closure that was developed for time-specific capture-recapture data (Stanley and Burnham 1999, Stanley and Richards, IN PRESS). Because our interpretation of both tests was very similar and both methods fail to test closure adequately with behavioral effects, here we report only closure tests using Program CAPTURE.

We also computed indices of relative abundance for all species as the catch per unit effort (CPUE). For species that were uniquely marked at initial capture (all species except shrews), we computed CPUE as the number of different animals captured on a trapping grid (i.e., $M_{t+1}$ in the notation of Program CAPTURE, White et al. 1982) per 100 trap-nights of effort. For genus *Sorex*, which we did not individually mark, we computed CPUE as the total number of captures (n. in the notation of Program CAPTURE, White et al. 1982) per 100 trap-nights. We corrected for sprung traps by considering them to represent ½ of a night of trapping effort (Nelson and Clarke 1973).

We examined differences in relative abundance of the four most common small mammal groups—mice (*Peromyscus* spp.), shrews (*Sorex* spp.), red-backed vole, and Oregon vole—among years and sample sites of this study using a repeated measures analysis of variance. To help normalize the count data we transformed indices of abundance as ln(CPUE+1) prior to analysis following Carey and Johnson (1995). For any significant annual or site differences, we examined all pairwise comparisons using the Student-Newman-Kuels multiple comparison test (Zar 1984). We used SAS v 8.10 statistical software (SAS/STAT 1998) for all statistical comparisons.

## RESULTS AND DISCUSSION

### Environmental Site Characteristics

Trapping grids encompassed a variety of low-elevation forested environments of Olympic National Park (Table 1). Elevations of sampling sites ranged from 138-276 m. Annual precipitation at the Quinault, Hoh, Elwha, and Skokomish trapping grids averaged 457, 364, 156, and 357 cm, respectively, reflecting the primary precipitation gradient from southwest to northeast. Trapping grids in the Elwha and Skokomish Valleys were on gentle south to west-facing slopes, whereas trapping grids in the Hoh and Quinault drainages were on flat upper-level terraces of the riverine floodplain. Three of the four trapping grids, those in the Elwha, Skokomish and Quinault, were in Western Hemlock Zone forests (*sensu* Henderson et al. 1989), whereas the Hoh trapping grid was within the Sitka Spruce Zone. Plant understories were dominated by Oregongrape (*Berberis nervosa*) and swordfern (*Polystichum munitum*) in the Elwha, indicative of a relatively dry site, and by swordfern, western foamflower (*Tiarella trifoliata*) and Oregon woodsorrel (*Oxalis oregana*) in the Hoh and Skokomish, reflecting greater soil moisture. Understory of the Quinault trapping grid was dominated primarily by Alaska huckleberry (*Vaccinium alaskaense)*.

Each of the trapping grids was in a characteristic old-growth forest stand, typified by the presence of large (>150 cm dbh) ancestral trees, incomplete canopy closure, multilayered canopies, diverse understories and an abundance of course woody debris (Franklin et al. 1981; Carey and Johnson 1995; Table 2). Overstory canopies tended to be denser and trees smaller in the Elwha and Skokomish sites than in the Hoh and Quinault, perhaps reflecting younger age. Ground cover of shrubs and forbs, and prevalence of downed woody debris, particularly the larger size classes of logs, all tended to be greater in the Hoh and Quinault than in the Elwha and Skokomish (Table 2).

**Species Presence**

We captured 18 species of small mammals (Table 3). We captured the greatest number of species on the Skokomish trapping grid (16 species) and fewer species in the Hoh, Quinault, and Elwha grids (9-10 species) (Table 3). We captured mice (*Peromyscus* spp.), shrews (*Sorex* spp.), Oregon vole (*Microtis oregoni*) and shrew mole (*Neurotrichus gibbsii*) widely on all trapping grids. Of the shrews, the montane shrew (*S. monticolus*) and Trowbridge's shrew (*S. trowbridgii*) were distributed most widely, and the vagrant shrew (*S. vagrans*) and water shrew (*S. palustris*) were most limited in capture locations. We captured southern red-backed vole and northern flying squirrel (*Glaucomys sabrinas*) in both the east-side trapping grids, but not on any west-side sampling area. We caught four species—snowshoe hare (*Lepus americanus*), Townsend's chipmunk (*Tamias townsendii*), long-tailed vole (*Microtus longicaudus*), and western spotted skunk (*Spilogale gracilis*)—only on the Skokomish trapping grid despite the presumed widespread distribution of those species throughout low elevations of the park.

Morphological similarities between two sympatric species of deer mice, *Peromyscus maniculatus* and *P. keeni*, prevented unequivocal field identification. Karyotypic analyses indicate that adult *Peromyscus* can be distinguished on the basis of tail length with 95% accuracy, with about equal probability of mistaking *P. keeni* and *P. maniculatus* on the basis of tail length alone (Gunn and Greenbaum 1986, Allard et al 1987). There is no acceptable field method of distinguishing between two species for juveniles. We classified 360 of 380 (95%) adult *Peromyscus* captured in this study as *P. keeni* based on tail length (Table 4), indicating that the large majority of *Peromyscus* reported are *P. keeni*, but also suggesting the possibility that the 5% identified as *P. maniculatus* could have resulted from classification error. We verified one specimen of *P. maniculatus*, however, on the basis of karyotype from a sample of 19 *Peromyscus* submitted to the University of Washington's Burke Museum in 2000 (i.e., also ~5% of the sample). The one specimen of *P. maniculatus* taken from the Elwha Valley verifies the presence of both species of *Peromyscus* in Olympic National Park, and substantiates the conclusion that the *P. keeni* dominates in old-growth forests of the Olympic Peninsula (Gunn and Greenbaum 1986, Songer et al. 1997).

Based on previous trapping studies in Olympic National Park, we were surprised by the absence of southern red-backed voles in our samples from the Quinault and Hoh watersheds. Southern red-backed voles have been captured previously in both the Hoh (Reed 1987; Lair 2001) and Quinault (Taylor 1999) watersheds, verifying their occurrence in the western drainages of the park. Southern red-backed voles have been associated with relatively dry sites within old-growth forests (West 1991). We speculate that absence of southern red-backed voles from our samples in the western drainages of the park likely reflects our limited sampling rather than breaks in the species' distribution. Southern red-backed voles trapped in both the Hoh and Quinault drainages previously were found on upland, side-slope forest communities that were presumably drier and better drained than the low-lying floodplains we sampled. Clearly, a more extensive inventory of species presence is needed to understand distribution patterns of small mammals throughout Olympic National Park.

**Species Abundance**

We logged 3168 captures of small mammals during 19,200 trap-nights between 1998- 2000 (Table 5). Four groups of small mammals comprised greater than 95% of the total captures. Mice (*Peromyscus* spp.) comprised 59% of the total, shrews (*Sorex* spp.*)* 19%, southern red-backed vole 13%, and Oregon vole 4% of the total captures (Table 5). Capture frequencies, summed for all species, varied among years but generally were greater on the east-side drainages (12-30 captures/100 trap-nights) than in the west-side drainages (7-19 captures/100 trap-nights) (Table 5).

Raw capture frequencies provide the crudest index of mammalian abundance for comparison to other studies conducted on the Olympic Peninsula. Reed (1987) reported a total of only 3.8 live captures of 9 species per 100 trap-nights in the Hoh Valley. We cannot speculate on the reasons for such low capture rates recorded previously, but we conclude that capture frequencies are not nearly as low as previous reports indicated. The raw capture efficiencies we reported are more comparable to those reported by Carey and Johnson (1995) derived from kill-trapping efforts in old-growth forests of the Olympic National Forest (22 captures/100 trap-nights).

*Performance of closed-model population estimators of species abundance*:--The evaluation of Program CAPTURE's performance is a subjective exercise involving scrutiny of the Program's tests of model assumptions and model selection procedure, while also considering sample size, power of tests involved in the selection process, and visual examination of capture histories (White et al. 1982). The following interpretation is based on Program CAPTURE's output for mice (*Peromyscus* spp.) and southern red-backed vole (Table 6). Although we report abundances of *Peromyscus* generically, we interpret these as being comprised almost exclusively of *P. keeni* (>95%), based on their prevalence in our sample (Table 4) and general preponderance of *P. keeni* in old-growth coniferous forests on the Olympic Peninsula (Songer et al 1997, Taylor 1999).

Estimated abundance, precision and capture probabilities of mice and southern red-backed vole from Program CAPTURE were highly variable between species, years, and trapping grids (Table 6). Capture probabilities of mice (average for $M_h$=0.38) and southern red-backed voles (average=0.26) varied 2- and 5-fold, respectively, among sample sites and years. Low capture rates combined with small populations in several cases did not provide enough information for reliable model selection and precise estimation of population size (White et al. 1982, Manning et al. 1995).

Despite problems with population estimation, Program CAPTURE is useful to examine sources of variation in capture probabilities (Menkens and Anderson 1988). In an attempt to adhere to the assumption of closure, we used only the adults of each species for this analysis. We noted significant behavioral responses of mice and southern red-backed voles to trapping in 2/3 of populations estimated (Table 6). Capture probabilities increased between initial captures and subsequent recaptures by factors ranging from 2.5-25 (Table 6), indicating a high level of 'trap-happiness' in both mice and southern red-backed voles (i.e., mice and voles become favorably accustomed to traps thereby increasing their capture probabilities over time).

Further, we rejected the important assumption of population closure for all but two populations estimated (Table 6). This indicates that the population may not have been free of births, deaths, immigration, or emigration during the trapping session, or the population was not adequately defined geographically. The closure test strongly rejects the hypothesis of closure when behavioral effects on capture probabilities are present (i.e., Model $M_b$ or $M_{bh}$; Otis et al. 1978). Consequently, closure tests reported in Table 6 are likely biased in approximately 2/3 of the tests. We rejected closure, however, in 4 of 5 tests in populations with $M_h$ selected as the best estimation model, conditions under which the closure test is relatively unbiased (Otis et al. 1978). We concluded that geographic or demographic closure was likely violated in the majority of cases investigated.

In conclusion, uncertainties associated with model selection, model assumptions, together with imprecise population estimates pose significant problems for monitoring trends in small mammal populations in low-elevation forests of Olympic National Park. We conclude that variation in model selection among years and imprecision of population estimates my obscure trends in mammalian abundance.

*Spatial and temporal variation in indices of abundance*:--Catch per unit effort of mice varied both among years and trapping sites, with greatest abundance in the Elwha Valley (Figure 2). Abundance indices of mice varied about 4- to 7-fold between successive years, with an apparent pattern of alternating high and low-density years. Coincidentally, high and low years of reproductive success in northern spotted owls correspond with high and low relative abundance of mice (Rosenberg et al. 2003, Olympic National Park, Unpublished data). Additional research is needed to determine if there is a consistent relationship between rodent abundance and reproduction in northern spotted owls inhabiting Olympic National Park.

Abundance indices of the southern red-backed vole, Oregon creeping vole and shrews (Figures 2 and 3) did not differ among three years of this study, suggesting much less short-term variation in those populations than in *Peromyscus*. As mentioned, we did not catch southern red-backed voles in the Hoh and Quinault study areas, so abundance indices differed among watersheds. Abundance indices of Oregon creeping vole and shrews, however, did not vary among study sites (Figures 2 and 3).

Abundance indices derived in this study were not directly comparable to those of other studies on the Olympic Peninsula. The catch-per-unit-effort index derived from kill-trapping of

*Peromyscus* in old-growth forests of the Olympic National Forest (5 captures/100 trap-nights) was similar to our results, but different capture methods obscure the comparison. Abundance indices of Keen's mice in old growth forests on the Quinault Indian Reservation (15.4 captures/100 trap-nights; Taylor 1999) and in the Hood Canal district of Olympic National Forest (about 20 individuals/100 trap-nights; Songer et al. 1997), both appear higher than our estimates (0.6-5.3 individuals/100 trap-nights). However, we cannot determine if results from the Quinault Indian Reservation represent total number of captures (i.e., captures and recaptures) or different individual animals captured. Further, both studies derived indices from relatively small index lines and trapping arrays that were pre-baited in the Olympic National Forest, which perhaps increased capture efficiency. These differences obscure direct comparison of results among areas of the Olympic Peninsula.

## RECOMMENDATIONS

We identified several limitations for monitoring trends in abundance of small mammals in low-elevation forests of Olympic National Park. Low capture probabilities, violations of closure assumptions, and high interannual variation of some species all present problems for reliable estimation of abundance and trend detection.

Given problems with model selection and assumptions of program CAPTURE, it may be tempting to use capture indices of population abundance (i.e., $M_{t+1}$) as surrogates for population estimation (Slade and Blair 2000). Reliable inference from capture indices requires that capture proportions remain constant among populations compared across space or time. We documented average capture probabilities varying among sites and years by factors of two (0.23-0.46) and five (0.07-0.35) for *Peromyscus* spp. and southern red-backed vole, respectively. Such variation would obscure trends as well as the interpretation of results. Therefore, we recommend modifying sampling procedures and investing additional resources in an effort to better adhere to estimation assumptions while improving model selection, precision of estimates, and overall reliability of closed population estimators. We recommend the following:

- <u>Improve geographic closure of population.</u> We suspect that the rectangular shape of the trapping grid contributed to problems with geographic closure of the sampled populations. We recommend using square rather than rectangular trapping grids. The use of a square trapping grid would reduce the amount of perimeter and would minimize ingress and egress of individual animals from the trapped area.

- <u>Improve demographic closure of population.</u> We attempted to minimize problems with births, deaths, immigration, and emigration by sampling during late summer and restricting analyses to adults captured. Demographic closure may be enhanced further by sampling during fall and reducing the length of trapping sessions from 11 days to 7-8 days.

- <u>Improve reliability of model selection and precision of estimates.</u> Reliability of model selection and precision of estimates depend upon capture probabilities and population size. To increase capture probabilities we recommend increasing the size and intensity of the trapping grids. Increasing the size of trapping grids will also help with maintaining closure in the estimated population and increasing the size of population estimated.

- <u>Reduce behavioral responses.</u> We recommend prebaiting traps for 2-3 days before initiating the trapping session. Prebaiting may have the added benefit of increasing capture probabilities while reducing variation in behavioral responses to trapping.

- <u>Customize trapping techniques to target different small mammal guilds.</u> It may be possible to improve capture probabilities by using multiple trapping techniques within a trapping grid or by placing traps within specific microhabitats to target individual species.

In addition to these field-based recommendations, open population estimators should be examined. The robust design described by Pollock et al. (1990) is based on sampling multiple primary periods that are separated in time (i.e., weeks apart) and sampling secondary sessions (i.e., consecutive days) conducted within primary periods. Lair (2001) estimated abundance of Keen's mice along forest clearcut edges using 3-4 primary sampling periods three weeks apart, and 7-day secondary sampling sessions within each primary period. The added benefit of the robust design is that estimates of natality (including immigration) and mortality (including emigration) are possible.

Abundance and density of small mammals are directly related to biomass, and provide perhaps the best measure of the importance of small mammals in fulfilling several key ecosystem functions, such as providing prey for higher trophic levels or predating upon lower trophic levels (including vegetation). Results of this study, however, indicate that greater effort needs to be expended to obtain precise and reliable trends in abundance or density of small mammal populations. Increased investment of sampling effort on each trapping grid is needed to improve both the reliability and precision of population estimates of small mammals, and even greater effort may be needed to use open population estimators. Further, additional studies are needed to provide guidance on the number of trapping grids necessary to detect trend throughout low-elevation forests of the park. Results from this study, indicating populations of Oregon vole, shrews, and red-backed vole are less variable among years than *Peromyscus*, suggests that fewer trapping grids will be required to detect trends in those species. For species with highly variable population abundance estimates (i.e., *Peromyscus* spp.), methods to detect change based on identifying extreme values in time series data may have greater merits than methods based on identifying trends (E. Rexstad, University of Alaska, Personal Communication).

We recommend that park managers and scientists continue working together to identify and refine goals for monitoring small mammal communities and populations in Olympic National Park. Several community and population attributes of small mammals may meet certain information and management needs of the National Park Service at lower costs than required to estimate abundance. For example, monitoring changes in species richness and functional diversity of small mammalian communities will determine changes in park fauna at the most fundamental level; i.e., the loss of species. In recent years a rich literature has developed describing procedures for sampling and estimating species richness and community composition (Nichols and Conroy 1996, Boulinier et al. 1998, Yoccoz et al. 2001). Alternately, monitoring changes in site occupancy (i.e., proportion of sampling sites occupied by a species) might provide useful measures of changes in a species status or distribution at large spatial scales (MacKenzie et al. 2002, MacKenzie et al. 2003). Sampling species richness, community composition, and occupancy may all be accomplished with broadly replicated index plots rather than intensive study plots required in abundance estimation. Additional work examining sampling effort and efficiency would be required to design and evaluate sampling protocols for monitoring changes in community composition and species distributions. Further, additional discussion is required to determine if species composition or distribution patterns of small mammals meet the goals of the National Park Service monitoring program. We reiterate the need to clearly establish monitoring goals before choosing indicators of small mammal community and population trends and investing additional resources in developing monitoring protocols.

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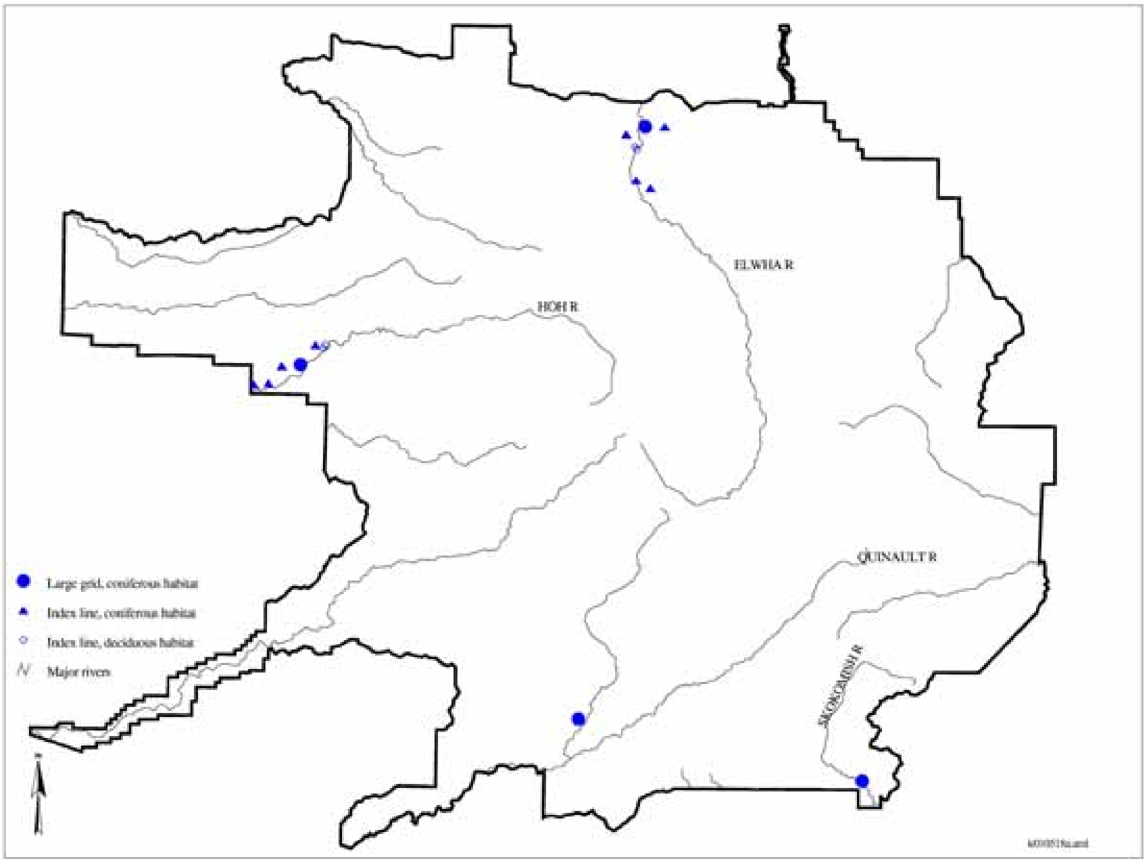


Figure 1. Location of trapping grids and inventory sampling sites for monitoring and inventorying small mammals in Olympic National Park, 1998-2000. Trapping grids (●) represent sampling sites for this project. Index lines (▲, ◦) represent inventory sampling sites reported in Appendix D.

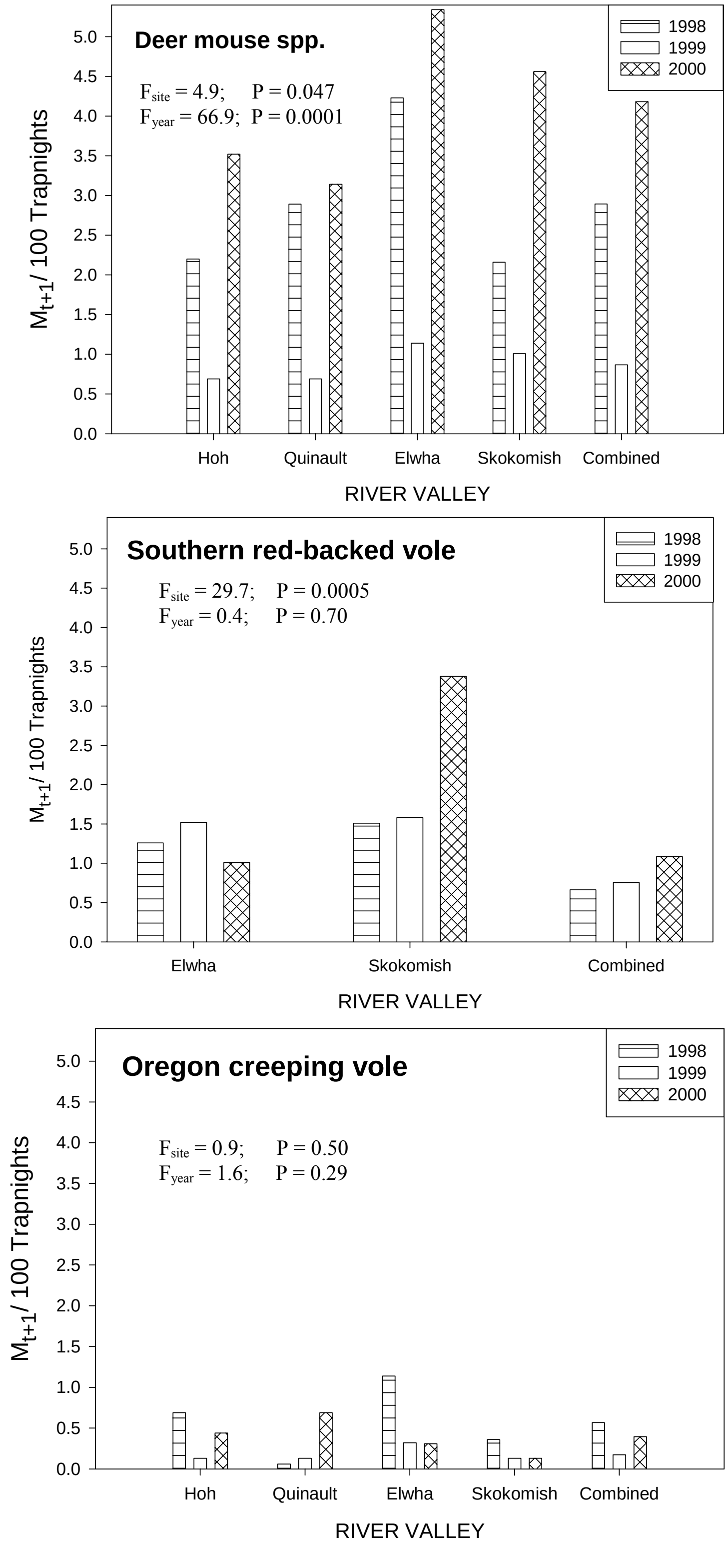


Figure 2. Number of individuals captured ($M_{t+1}$) per 100 trap-nights for three species of small mammals caught on trapping grids in the Elwha, Skokomish, Hoh, and Quinault Valleys, Olympic National Park, 1998-2000. Deer mouse spp. refers to *P. keeni* and *P. maniculatus* combined. Raw data are contained in Table 7.

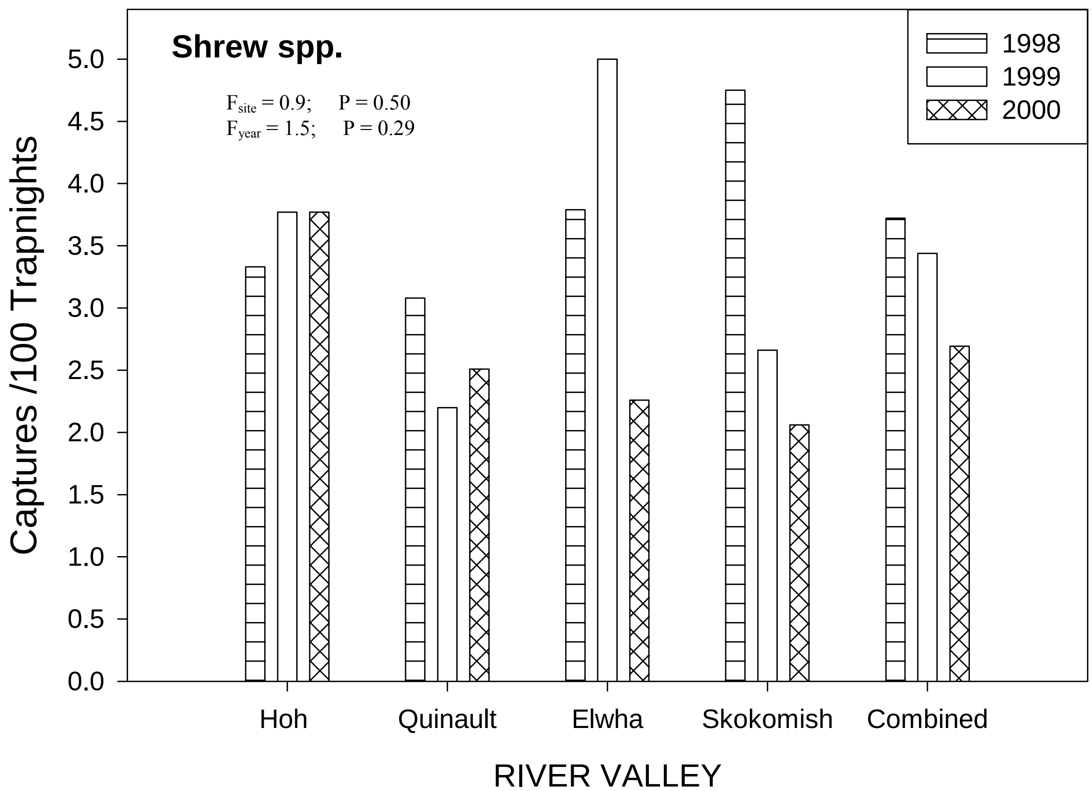


Figure 3. Total captures per 100 trap-nights of shrew species caught on trapping grids in the Elwha, Skokomish, Hoh, and Quinault Valleys, Olympic National Park, 1998-2000. Raw data are contained in Table 7.

Table 1. Environmental characteristics of small mammal study sites in Olympic National Park.

| Site Name | Prevailing Plant Association[a] | Mean Annual Precipitation (cm) | Slope[b] (°) | Prevailing Aspect[b] (°) | Elevation (m) |
|---|---|---|---|---|---|
| Elwha | Western Hemlock/Oregongrape/Swordfern | 156.5 | 18 | 270 | 138 |
| Skokomish | Western Hemlock/Swordfern-Foamflower | 357.1 | 22 | 180 | 276 |
| Hoh | Sitka Spruce/Swordfern-Oxalis | 364.0 | 0 | -- | 165 |
| Quin | Western Hemlock/Alaska Huckleberry | 457.2 | 0 | -- | 176 |

[a] Most frequently occurring plant association (*sensu* Henderson et al. 1989) based on plant association classification at 50 trap sites on each grid.
[b] Slopes and aspects are reported as modes based on measurements at 50 trap sites on each grid.

Table 2. Mean vegetation and habitat characteristics of small mammal trapping grids in Olympic National Park[a].

| | ELWHA | | SKOKOMISH | | HOH | | QUINAULT | |
|---|---|---|---|---|---|---|---|---|
| Characteristic | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Overstory[b] | | | | | | | | |
| Deciduous Tree Density (#/ 100m$^2$) | 3.5 | -- | 0.1 | -- | 0 | -- | | -- |
| Conifer Tree Density (#/ 100m$^2$) | 1.2 | -- | 7.3 | -- | 2.1 | -- | 2.3 | -- |
| Tree Diameter (cm dbh) | 42.9 | 5 - 192 | 36.6 | 1 - 169 | 60.3 | 3 - 260 | 55.4 | 6 - 184 |
| Canopy Closure (%) | 79.6 | 50 - 90 | 77.3 | 60 - 90 | 62.7 | 0 - 90 | 69.5 | 40 - 90 |
| Understory | | | | | | | | |
| Shrub Cover (%) | 6.1 | 0 - 63 | 10.9 | 0 - 38 | 34.6 | 0 - 86 | 21.3 | 0 - 63 |
| Fern Cover (%) | 31.3 | 0 - 86 | 16.6 | 0 - 86 | 22.5 | 0 - 86 | 21.7 | 2.5 - 63 |
| Forb Cover (%) | 7.4 | 0 - 63 | 14.9 | 0 - 63 | 44.7 | 0 - 86 | 41.3 | 0 - 86 |
| Log Density (#/ 20m$^2$) | | | | | | | | |
| 10 - 23 cm | 1.3 | 0 - 10 | 1.6 | 0 - 7 | 0.8 | 0 - 5 | 1.3 | 0 - 6 |
| 23 - 53 cm | 1.2 | 0 - 4 | 1.8 | 0 - 6 | 0.9 | 0 - 4 | 1.4 | 0 - 6 |
| 53 - 81 cm | 0.3 | 0 - 2 | 0.5 | 0 - 3 | 0.8 | 0 - 5 | 0.7 | 0 - 4 |
| 81 - 122 cm | 0.1 | 0 - 2 | 0.1 | 0 - 1 | 0.4 | 0 - 3 | 0.2 | 0 - 2 |
| > 122 cm | 0.01 | 0 - 1 | 0 | 0 | 0.05 | 0 - 2 | 0.05 | 0 - 2 |

[a] Means are derived from measurements at 96 - 100 trap sites.

[b] Detailed overstory and stand characteristics in Appendix B.

Table 3. Occurrence of mammals captured on trapping grids in the Elwha, Skokomish, Hoh, and Quinault Valleys, Olympic National Park, 1998-2000.

| SPECIES[a] | Elwha | Skokomish | Hoh | Quinault |
|---|---|---|---|---|
| Keen’s mouse[b] | X | X | X | X |
| Deer mouse[c] | X | X | X | X |
| Douglas squirrel | | X | | X |
| Ermine | | | X | X |
| Northern flying squirrel | X | X | | |
| Oregon (creeping) vole | X | X | X | X |
| Pacific jumping mouse | X | X | | |
| Shrew spp. | X | X | X | X |
| Shrew, montane | X | X | X | X |
| Shrew, Pacific water | X | X | X | |
| Shrew, Trowbridge's | X | X | X | X |
| Shrew, vagrant | | X | X | |
| Shrew, water | | | | X |
| Shrew mole | X | X | X | X |
| Snowshoe hare | | X | | |
| Townsend chipmunk | | X | | |
| Vole, long-tailed | | X | | |
| Vole, Southern red-backed | X | X | | |
| Vole, unknown | X | | | |
| Western spotted skunk | | X | | |
| N species identified[d] | 10 | 16 | 9 | 9 |

[a]Latin names of species in Appendix C.
[b]Identified on the basis of adult tail length $\geq$96 mm (Allard et al. 1987).
[c]Identified on the basis of adult tail length <96 mm (Allard et al. 1987).
[d]Excluding unknown or unidentified species

Table 4. Numbers of *P. keeni* (tail length ≥96mm) and *P. maniculatus* (tail length <96mm) (Allard et al. 1987) individuals captured in Olympic National Park, 1998-2000. Juveniles were distinguished from adults by weight (Wilson and Carey 2000).

| | | | Adults (>15g) | | Juveniles (<15g) | |
|---|---|---|---|---|---|---|
| Site | Plot Type | Year | <96mm | ≥96mm | <96mm | ≥96mm |
| Elwha | Large | 1998 | 6 | 42 | 19 | 0 |
| | | 1999 | 0 | 11 | 4 | 2 |
| | | 2000 | 1 | 71 | 10 | 4 |
| Skokomish | Large | 1998 | 2 | 18 | 4 | 6 |
| | | 1999 | 1 | 14 | 2 | 0 |
| | | 2000 | 0 | 49 | 2 | 22 |
| Hoh | Large | 1998 | 4 | 18 | 8 | 5 |
| | | 1999 | 0 | 10 | 0 | 1 |
| | | 2000 | 2 | 41 | 2 | 10 |
| Quinault | Large | 1998 | 3 | 31 | 6 | 5 |
| | | 1999 | 0 | 9 | 0 | 1 |
| | | 2000 | 1 | 46 | 1 | 2 |
| TOTALS | | | 20 | 360 | 58 | 58 |
| | | | 380 | | 116 | |

Table 5. Total and annual captures of small mammals on four trapping grids in the Elwha, Skokomish, Hoh, and Quinault Valleys, Olympic National Park, 1998 - 2000.

| | EAST | | | | | | | | WEST | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIES | ELWHA | | | | SKOKOMISH | | | | HOH | | | | QUINAULT | | | | GRAND |
| | 3-yr Total | 1998 | 1999 | 2000 | 3-yr Total | 1998 | 1999 | 2000 | 3-yr Total | 1998 | 1999 | 2000 | 3-yr Total | 1998 | 1999 | 2000 | TOTAL |
| Deer mouse[a] | 646 | 256 | 48 | 342 | 460 | 116 | 55 | 289 | 368 | 123 | 35 | 210 | 387 | 146 | 43 | 198 | 1861 |
| Douglas squirrel | 0 | 0 | 0 | 0 | 11 | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 12 |
| Ermine | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 4 |
| Northern flying squirrel | 6 | 4 | 0 | 2 | 8 | 6 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 |
| Oregon (creeping) vole | 53 | 34 | 12 | 7 | 14 | 9 | 3 | 2 | 43 | 20 | 3 | 20 | 28 | 1 | 6 | 21 | 138 |
| Pacific jumping mouse | 2 | 0 | 0 | 2 | 15 | 0 | 3 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 |
| Shrew spp. | 175 | 60 | 79 | 36 | 141 | 66 | 42 | 33 | 173 | 53 | 60 | 60 | 124 | 49 | 35 | 40 | 613 |
| Shrew, Pacific water | 2 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| Shrew, water | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| Shrew mole | 5 | 2 | 3 | 0 | 22 | 12 | 3 | 7 | 29 | 12 | 13 | 4 | 20 | 8 | 2 | 10 | 76 |
| Snowshoe hare | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Southern red-backed vole | 152 | 55 | 72 | 25 | 270 | 65 | 77 | 128 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 422 |
| Townsend chipmunk | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Townsend vole | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Western spotted skunk | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Vole, Unknown | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total captures[b] | 1042 | 411 | 217 | 414 | 947 | 289 | 184 | 474 | 617 | 209 | 112 | 296 | 562 | 204 | 87 | 271 | **3168** |
| No. Sherman trap-nights[b] | 4800 | 1600 | 1600 | 1600 | 4600 | 1400 | 1600 | 1600 | 4800 | 1600 | 1600 | 1600 | 4800 | 1600 | 1600 | 1600 | **19200** |
| Sprung traps[b] | 92 | 34 | 41 | 17 | 50 | 19 | 15 | 16 | 58 | 21 | 22 | 15 | 61 | 20 | 41 | 0 | **261** |
| Catch /100 trap-nights [b,c] | 22 | 26 | 14 | 26 | 21 | 21 | 12 | 30 | 13 | 13 | 7 | 19 | 12 | 13 | 6 | 17 | **17** |

[a] *P. keeni and P. maniculatus* combined

[b] Capture summaries pertain to Sherman live-traps only. They exclude snowshoe hare and Western spotted skunks, which were caught in Tomahawk live traps.

[c] Sprung traps have been deleted for calculations.

Table 6. Population estimates and program CAPTURE output for *Peromyscus* spp. (PESP) and southern red-backed voles (CLGA) in the Elwha, Skokomish, Hoh, and Quinault Valleys, Olympic National Park, 1998-2000.

| Drainage | Species | Year | $M_{t+1}$[a] | Model[b] | Closure[c] | Estimate | SE | 95% Confidence Limits | p-hat[d] | c-hat[e] |
|---|---|---|---|---|---|---|---|---|---|---|
| Elwha | PESP | 1998 | 67 | Mbh[f] | no | 90 | 15.2 | -- | 0.155 | -- |
| | | | | Mh | | 80 | 6.1 | 73-98 | 0.39 | |
| Elwha | PESP | 1999 | 18 | Mh | yes | 22 | 3.6 | 19-35 | 0.23 | -- |
| Elwha | PESP | 2000 | 84 | Mb | no | 137 | 35.6 | 101-259 | 0.11 | 0.72 |
| | | | | Mh | | 98 | 5.9 | 91-114 | 0.42 | |
| Elwha | CLGA | 1998 | 20 | Mbh | no | 26 | 7.3 | 21-59 | 0.06-0.57 | -- |
| | | | | Mh | | 21 | 2.7 | 21-38 | 0.32 | |
| Elwha | CLGA | 1999 | 24 | Mh | no | 26 | 3.3 | 25-41 | 0.32 | -- |
| Elwha | CLGA | 2000 | 16 | Mo | no | 45 | 12.3 | 30-80 | 0.07 | -- |
| | | | | Mh | | 45 | 12.3 | 30-80 | 0.07 | |
| Hoh | PESP | 1998 | 35 | Mh | no | 41 | 4.5 | 37-57 | 0.37 | -- |
| Hoh | PESP | 1999 | 11 | Mh | no | 13 | 3.3 | 12-30 | 0.34 | -- |
| Hoh | PESP | 2000 | 56 | Mtb | no | 106 | 128 | 60-873 | 0.18-0.05 | -- |
| | | | | Mh | | 64 | 4.6 | 59-78 | 0.4 | |
| Quinault | PESP | 1998 | 45 | Mb | no | 264 | 673 | 62-5280 | 0.02 | 0.54 |
| | | | | Mh | | 58 | 7.4 | 50-81 | 0.29 | |
| Quinault | PESP | 1999 | 10 | Mbh[f] | no | 10.3 | 1.41 | -- | 0.278 | -- |
| | | | | Mh | | 11 | 1.3 | 11-17 | 0.45 | |
| Quinault | PESP | 2000 | 48 | Mh | no | 54 | 4.1 | 50-68 | 0.44 | -- |
| Skokomish | PESP | 1998 | 30 | Mb | no | 44 | 15.3 | 33-109 | 0.15 | 0.81 |
| | | | | Mh | | 31 | 3 | 31-48 | 0.46 | |
| Skokomish | PESP | 1999 | 16 | Mbh | yes | 17 | 2.4 | 17-30 | 0.25 | -- |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Mh | | 17 | 2.6 | 17-33 | 0.39 | |
| Skokomish | PESP | 2000 | 73 | Mbh | no | 82 | 6.1 | 76-103 | -- | -- |
| | | | | Mh | | 91 | 9.4 | 81-120 | 0.38 | |
| Skokomish | CLGA | 1998 | 21 | Mb | no | 32 | 13.8 | 23-95 | 0.14 | 0.54 |
| | | | | Mh | | 24 | 3.2 | 22-38 | 0.31 | |
| Skokomish | CLGA | 1999 | 24 | Mb | no | 30 | 6.4 | 25-57 | 0.18 | 0.49 |
| | | | | Mh | | 27 | 3.3 | 25-41 | 0.35 | |
| Skokomish | CLGA | 2000 | 54 | Mb | no | 109 | 54 | 65-332 | 0.08 | 0.3 |
| | | | | Mh | | 66 | 5.4 | 60-82 | 0.22 | |

[a] $M_{t+1}$=number of animals (i.e., unique individuals) captured

[b] The first model listed for each entry is the 'best' model selected on the basis of Program CAPTURE model selection criteria (Mo=null model, Mh=model for heterogeneous capture probability, Mb=model for behavioral responses, Mbh=model for heterogeneous capture probability and behavioral response) (White et al. 1982). Models Mh is included for each entry.

[c] Significance of test for population closure (Otis et al. 1978) (Yes=closure test not rejected at P<0.05; conclude population closed; No=closure test rejected at P<0.05; conclude population not closed)

[d] Initial capture probability calculated by Program CAPTURE

[e] Re-capture probability calculated by Program CAPTURE

[f] These Program CAPTURE runs presented results, but infinite loop errors occurred.

Table 7. Population indices (catch per unit effort [per 100 trap-nights]) of small mammals captured on trapping grids in the Elwha, Skokomish, Hoh, and Quinault Valleys, Olympic National Park, 1998 - 2000.

| | | EAST | | | | | | | | WEST | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Index | ELWHA | | | | SKOKOMISH | | | | HOH | | | | QUINAULT | | | | GRAND |
| SPECIES | Type | 3-yr Total | 1998 | 1999 | 2000 | 3-yr Total | 1998 | 1999 | 2000 | 3-yr Total | 1998 | 1999 | 2000 | 3-yr Total | 1998 | 1999 | 2000 | TOTAL |
| Deer mouse[d] | $m_t+1$[a] | 3.55 | 4.23 | 1.14 | 5.28 | 2.60 | 2.16 | 1.00 | 4.59 | 2.14 | 2.20 | 0.69 | 3.52 | 2.16 | 2.83 | 0.63 | 3.00 | 2.59 |
| Douglas squirrel | $m_t+1$[a] | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.43 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.06 | 0.00 | 0.04 |
| Northern flying squirrel | $m_t+1$[a] | 0.08 | 0.19 | 0.00 | 0.06 | 0.15 | 0.36 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 |
| Oregon (creeping) vole | $m_t+1$[a] | 0.59 | 1.14 | 0.32 | 0.31 | 0.20 | 0.36 | 0.13 | 0.13 | 0.42 | 0.69 | 0.13 | 0.44 | 0.29 | 0.06 | 0.13 | 0.69 | 0.37 |
| Pacific jumping mouse | $m_t+1$[a] | 0.02 | 0.00 | 0.00 | 0.06 | 0.17 | 0.00 | 0.13 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 |
| Shrew spp. | n.[b] | 2.69 | 2.97 | 3.55 | 1.57 | 1.29 | 0.50 | 1.82 | 1.44 | 2.72 | 2.83 | 2.58 | 2.76 | 1.61 | 2.08 | 1.52 | 1.25 | 2.07 |
| Shrew, Pacific water | n.[b] | 0.02 | 0.00 | 0.06 | 0.00 | 0.02 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Shrew, water | n.[b] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Shrew mole | n.[b] | 0.11 | 0.13 | 0.19 | 0.00 | 0.48 | 0.86 | 0.19 | 0.44 | 0.61 | 0.75 | 0.82 | 0.25 | 0.42 | 0.50 | 0.13 | 0.63 | 0.40 |
| Snowshoe hare | $m_t+1$[a] | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Southern red-backed vole | $m_t+1$[a] | 1.26 | 1.26 | 1.52 | 1.01 | 2.16 | 1.51 | 1.51 | 3.39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 |
| Townsend chipmunk | $m_t+1$[a] | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Townsend vole | $m_t+1$[a] | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Total individuals captured | | 396 | 157 | 107 | 132 | 337 | 91 | 78 | 168 | 281 | 103 | 67 | 111 | 215 | 87 | 39 | 89 | **1229** |
| Number trap-nights | | 4800 | 1600 | 1600 | 1600 | 4600 | 1400 | 1600 | 1600 | 4800 | 1600 | 1600 | 1600 | 4800 | 1600 | 1600 | 1600 | **19200** |
| Sprung traps | | 92 | 34 | 41 | 17 | 50 | 19 | 15 | 16 | 58 | 21 | 22 | 15 | 61 | 20 | 41 | 0 | **261** |
| Catch /100 corrected trap-nights[c] | | 8.33 | 9.92 | 6.77 | 8.29 | 7.37 | 6.54 | 4.90 | 10.55 | 5.89 | 6.48 | 4.22 | 6.97 | 4.51 | 5.47 | 2.47 | 5.56 | **6.44** |

[a] $m_{t+1}$ refers to the number of different individuals captured per 100 corrected trap-nights.

[b] n. refers to the total number of captures and recaptures per 100 corrected trap-nights.

[c] Catch per unit effort (CPUE) corrected for sprung traps (Nelson and Clarke 1973).

[d] *P. keeni* and *P. maniculatus* combined

Appendix A. Universal Transverse Mercator coordinates of small mammal trapping grids in Olympic National Park, 1998-2000.

| Grid/Corner | Easting Coordinate | Northern Coordinate |
|---|---|---|
| Elwha | | |
| Corner 1 | 456194 | 5319104 |
| Corner 2 | 456220 | 5319103 |
| Corner 3 | 456109 | 5318762 |
| Corner 4 | 456130 | 5318746 |
| Hoh | | |
| Corner 1 | 426934 | 5298894 |
| Corner 2 | 426926 | 5298854 |
| Corner 3 | 427122 | 5299164 |
| Corner 4 | 427163 | 5299132 |
| Quinault | | |
| Corner 1 | 450496 | 5268781 |
| Corner 2 | 450458 | 5268820 |
| Corner 3 | 450708 | 5269061 |
| Corner 4 | 450674 | 5269091 |
| Skokomish | | |
| Corner 1 | 474652 | 5263414 |
| Corner 2 | 474668 | 5263444 |
| Corner 3 | 474340 | 5263565 |
| Corner 4 | 474386 | 5263597 |

Appendix B. Density, basal area, and dominance (mean basal area*density) of tree species present on small mammal trapping grids and index sites in Olympic National Park, 1998 - 2000.

**TRAPPING GRIDS (2.25 ha)**

**ELWHA** n = 50

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Pseudotsuga menziesii | 0.78 | 7802.2 | 6082.6 | 1 |
| Tsuga heterophylla | 2.53 | 1026.9 | 2595.9 | 2 |
| Acer macrophyllum | 1.23 | 1479.5 | 1817.5 | 3 |
| Abies grandis | 0.14 | 2132.1 | 302.2 | 4 |
| Thuja plicata | 0.05 | 3688.3 | 174.3 | 5 |
| Overall | 4.7 | 3225.8 | | |

**SKOKOMISH** n = 50

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Pseudotsuga menziesii | 1.37 | 7511.8 | 10310.4 | 1 |
| Thuja plicata | 1.22 | 2974.5 | 3641.4 | 2 |
| Tsuga heterophylla | 4.60 | 452.8 | 2082.9 | 3 |
| Abies grandis | 0.11 | 600.3 | 66.8 | 4 |
| Acer macrophyllum | 0.11 | 276.3 | 30.8 | 5 |
| Overall | 7.42 | 2363.1396 | | |

**QUINAULT** n = 50

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Tsuga heterophylla | 2.11 | 2440.9 | 5148.5 | 1 |
| Pseudotsuga menziesii | 0.20 | 15781.4 | 3126.4 | 2 |
| Picea sitchensis | 0.01 | 9672.0 | 112.7 | 3 |
| Overall | 2.33 | 9298.1 | | |

**HOH** n = 50

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Tsuga heterophylla | 1.65 | 3839.3 | 6331.3 | 1 |
| Picea sitchensis | 0.47 | 8925.9 | 4151.6 | 2 |
| Overall | 2.11 | 6382.6 | | |

**Appendix B. Continued**

## INVENTORY SITES (0.18-ha)

HOH/SANDPIPER n = 8

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Acer macrophyllum | 0.50 | 5728.9 | 2888.5 | 1 |
| Picea sitchensis | 0.45 | 3364.5 | 1507.9 | 2 |
| Alnus rubra | 0.73 | 1113.7 | 811.1 | 3 |
| Populus balsamifera | 0.06 | 9156.2 | 512.9 | 4 |
| Tsuga heterophylla | 0.06 | 6936.3 | 388.6 | 5 |
| Overall | 1.79 | 5259.9 | | |

HOH/BIG MAPLE n = 8

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Alnus rubra | 1.53 | 1547.8 | 2363.8 | 1 |
| Picea sitchensis | 0.69 | 2474.7 | 1718.0 | 2 |
| Overall | 2.22 | 2011.2 | | |

HOH/ELK n = 8

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Picea sitchensis | 2.53 | 3647.4 | 9240.3 | 1 |
| Tsuga heterophylla | 1.15 | 3749.2 | 4317.3 | 2 |
| Overall | 3.68 | 3698.3 | | |

HOH/BIG SPRUCE n = 8

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Tsuga heterophylla | 2.06 | 3887.0 | 8016.3 | 1 |
| Picea sitchensis | 1.24 | 3082.7 | 3814.6 | 2 |
| Overall | 3.30 | 3484.8 | | |

HOH/SWORD

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Picea sitchensis | 0.6 | 7594.9 | 4692.4 | 1 |
| Tsuga heterophylla | 0.3 | 1529.1 | 494.9 | 2 |
| Overall | 0.94 | 4562.0 | | |

**Appendix B. Continued.**

HOH/BOGACHIEL

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Picea sitchensis | 1.2 | 16020.3 | 20018.0 | 1 |
| Tsuga heterophylla | 1.9 | 2689.2 | 5193.1 | 2 |
| Overall | 3.2 | 9354.7 | | |

ELWHA/HORNET

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Alnus rubra | 1.01 | 1132.5 | 1140.4 | 1 |
| Acer macrophyllum | 0.25 | 3426.8 | 862.7 | 2 |
| Populus balsamifera | 0.05 | 1673.0 | 505.4 | 3 |
| Pseudotsuga menziesii | 0.30 | 13063.2 | 657.7 | 4 |
| Overall | 1.61 | 4823.9 | | |

ELWHA/HURRICANE

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Pseudotsuga menziesii | 12.48 | 540.4 | 6744.7 | 1 |
| Tsuga heterophylla | 0.83 | 7.1 | 5.9 | 2 |
| Overall | 13.31 | 273.7 | | |

ELWHA/BRUSHY

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Pseudotsuga menziesii | 3.71 | 1855.5 | 6888.6 | 1 |
| Abies grandis | 0.81 | 1399.2 | 1129.2 | 2 |
| Tsuga heterophylla | 0.48 | 510.3 | 247.1 | 3 |
| Alnus rubra | 0.16 | 283.4 | 45.7 | 4 |
| Overall | 5.17 | 890.3 | | |

ELWHA/HERRICK

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Pseudotsuga menziesii | 5.00 | 3015.9 | 15090.2 | 1 |
| Acer macrophyllum | 0.58 | 624.6 | 360.6 | 2 |
| Tsuga heterophylla | 0.38 | 490.6 | 188.8 | 3 |
| Thuja plicata | 0.19 | 176.6 | 34.0 | 4 |
| Overall | 6.16 | 1076.9 | | |

**Appendix B. Continued.**

ELWHA/YELLOW JACKET

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Acer macrophyllum | 0.93 | 6276.8 | 5807.7 | 1 |
| Alnus rubra | 0.42 | 2066.4 | 860.4 | 2 |
| Abies grandis | 0.09 | 3284.8 | 303.9 | 3 |
| Tsuga heterophylla | 0.05 | 2732.6 | 126.4 | 4 |
| Overall | 1.48 | 3590.1 | | |

ELWHA/ELWHA CAMP

| SPECIES | # trees /100m$^2$ | Mean basal area (cm$^2$) | Dominance (cm$^2$) | Rank |
|---|---|---|---|---|
| Pseudotsuga menziesii | 0.20 | 20096.0 | 4115.7 | 1 |
| Tsuga heterophylla | 5.73 | 634.1 | 3636.4 | 2 |
| Acer macrophyllum | 0.61 | 519.9 | 319.4 | 3 |
| Overall | 6.55 | 7083.4 | | |

Appendix C. List of common and Latin names of small mammal species identified in Olympic National Park.

| Common Name | Latin Name |
|---|---|
| Keen’s mouse | *Peromyscus keeni* |
| Deer mouse | *Peromyscus maniculatus* |
| Douglas squirrel | *Tamiasciurus douglasii* |
| Ermine | *Mustela erminea* |
| Northern flying squirrel | *Glaucomys sabrinas* |
| Oregon (creeping) vole | *Microtus oregoni* |
| Pacific jumping mouse | *Zapus trinotatus* |
| Shrew spp. | *Sorex sp.* |
| Shrew, montane | *Sorex monticolus* |
| Shrew, Pacific water | *Sorex bendirii* |
| Shrew, Trowbridge's | *Sorex trowbridgii* |
| Shrew, vagrant | *Sorex vagrans* |
| Shrew, water | *Sorex palustris* |
| Shrew mole | *Neurotrichus gibbsii* |
| Snowshoe hare | *Lepus americanus* |
| Townsend chipmunk | *Tamias townsendii* |
| Vole, long-tailed | *Microtus longicaudus* |
| Vole, Southern red-backed | *Clethrionomys gapperi* |
| Vole, unknown | *Microtus sp.* |
| Western spotted skunk | *Spilogale gracilis* |

**Appendix D. Pilot Study: Inventory of small mammals in Olympic National Park**

*Introduction:*-- In 1999, we began a small pilot study initiating an inventory of mammals of Olympic National Park. The inventory goal was to establish an up-to-date listing of small mammals present in the park, as well as information on distribution of each species. Objectives of the pilot study were to inventory species present within three vegetation classes of the Elwha and Hoh Valleys in Olympic National Park. We established 12 trapping sites distributed evenly among 4 Sitka spruce-dominated stands in the Hoh Valley, 4 Douglas fir-dominated stands in the Elwha Valley, and 4 hardwood stands in the Elwha and Hoh Valleys (2 hardwood stands in each valley; Table D1). For logistic reason we selected stands within 400 m of roads present in the Hoh and Elwha Valleys. It was our intention to sample approximately 12-24 such inventory sites each year to build up inventory of species present in various habitats sampled broadly throughout the park. We were not able to sustain the inventory beyond the first year due to lack of funding support. Here we report initial results of that effort. Because data are inconclusive we do not discuss the data in detail. We tabulate data on mammals captured as well as environmental characteristics of the sampling sites for future reference (Tables D1-D6).

*Methods:* -- Location of each of the trapping sites is shown in Figure 1 in the main body of this report. Each of the inventory trapping sites consisted of a 2 x 8 array of trap stations spaced 15 m apart (16 stations total). We placed two Sherman traps at each station, generally one large and one small, baited and equipped the same as reported in the body of this report. We did not set any Tomahawk traps at the inventory sites. We set traps for 7 consecutive nights, keeping them open each day and checking them each morning. Animal handling and data recording procedures were the same as reported in the body of this report.

Table D1. General characteristics and locations of inventory sampling sites in the Hoh and Elwha drainages, 1999.

| Site Name | Drainage | Vegetation | Slope[a] (°) | Prevailing Aspect[a] (°) | Elevation (m) | UTM Easting Coordinate | UTM Northing Coordinate |
|---|---|---|---|---|---|---|---|
| Sandpiper | Hoh | Hardwood | 0 | -- | 175 | 428997 | 5300586 |
| Big Maple | Hoh | Hardwood | 0 | -- | 168 | 428676 | 5300247 |
| Elk | Hoh | Sitka spruce | 0 | -- | 180 | 428187 | 5300272 |
| Big Spruce | Hoh | Sitka spruce | 0 | -- | 161 | 426668 | 5298760 |
| Sword | Hoh | Sitka spruce | 0 | -- | 144 | 424200 | 5297306 |
| Bogachiel | Hoh | Sitka spruce | 0 | -- | 214 | 423457 | 5297183 |
| Hornet | Elwha | Hardwood | 0 | -- | 120 | 455315 | 5317424 |
| Hurricane | Elwha | Douglas fir | 26 | 240 | 412 | 456609 | 5313866 |
| Brushy | Elwha | Douglas fir | 14 | 270 | 292 | 455796 | 5314557 |
| Herrick | Elwha | Douglas fir | 18 | 140 | 219 | 455245 | 5318438 |
| Yellow Jacket | Elwha | Hardwood | 0 - 23 | 340 | 138 | 455459 | 5317162 |
| Elwha Camp | Elwha | Douglas fir | 4 - 38 | 80 - 330 | 154 | 456288 | 5319075 |

[a] Slopes and aspects are reported as modes based on measurements at 7-8 trap sites. A reported range of values indicates a tie.

Table D2. Mean vegetation and habitat characteristics of small mammal inventory sites in Douglas fir stands of the Elwha Valley, Olympic National Park, 1999[a].

| | HURRICANE | | BRUSHY | | HERRICK | | ELWHA CAMP | | Between Sites | |
|---|---|---|---|---|---|---|---|---|---|---|
| Characteristic | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | SE |
| Overstory[b] | | | | | | | | | | |
| Deciduous Tree Density (#/ 100m$^2$) | 0.4 | -- | 0.2 | -- | 0.1 | -- | 0.6 | -- | 0.3 | 0.1 |
| Conifer Tree Density (#/ 100m$^2$) | 6.7 | -- | 5.0 | -- | 0.9 | -- | 5.9 | -- | 4.6 | 1.3 |
| Tree Diameter (cm dbh) | 22.9 | 3 - 45 | 38.9 | 10 - 95 | 44.1 | 5 - 162 | 28.9 | 6 - 160 | 33.7 | 2.4 |
| Canopy Closure (%) | 75.9 | 60 - 100 | 71.3 | 60 - 90 | 77.5 | 60 - 100 | 83.8 | 80 - 90 | 75.9 | 1.7 |
| Understory | | | | | | | | | | |
| Shrub Cover (%) | 37.7 | 0 - 86 | 56.4 | 15 - 86 | 30.6 | 0 - 86 | 2.9 | 0 - 16 | 37.7 | 6.2 |
| Fern Cover (%) | 5.9 | 0 - 38 | 2.6 | 0 - 16 | 11.2 | 0 - 38 | 8.7 | 0.1 - 16 | 5.9 | 1.5 |
| Forb Cover (%) | 8.1 | 0 - 38 | 16.3 | 2.5 - 38 | 10.2 | 2.5 - 38 | 0.7 | 0 - 2.5 | 8.1 | 2.0 |
| Log Density (#/ 20m$^2$) | | | | | | | | | | |
| 10 - 23 cm | 1.4 | 0 - 4 | 1.4 | 0 - 4 | 1.9 | 1 - 4 | 1.1 | 0 - 3 | 1.4 | 0.2 |
| 23 - 53 cm | 0.9 | 0 - 3 | 0.75 | 0 - 2 | 1.3 | 0 - 3 | 1.4 | 1 - 3 | 0.9 | 0.2 |
| 53 - 81 cm | 0.1 | 0 - 1 | 0.25 | 0 - 1 | 0 | 0 | 0.3 | 0 - 1 | 0.1 | 0.1 |
| 81 - 122 cm | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| > 122 cm | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |

[a] Means are derived from measurements at 7 - 8 trap sites.

[b] Detailed overstory and stand characteristics in Appendix B.

Table D3. Mean vegetation and habitat characteristics of small mammal inventory sites in Sitka spruce stands of the Hoh Valley, Olympic National Park, 1999[a].

| | ELK | | BIG SPRUCE | | SWORD | | BOGACHIEL | | Between Sites | |
|---|---|---|---|---|---|---|---|---|---|---|
| Characteristic | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | SE |
| Overstory[b] | | | | | | | | | | |
| Deciduous Tree Density (#/ 100m$^2$) | 0 | -- | 0 | -- | 0 | -- | 0 | -- | 0.0 | 0.0 |
| Conifer Tree Density (#/ 100m$^2$) | 3.7 | -- | 3.3 | -- | 0.9 | -- | 3.2 | -- | 2.8 | 1.3 |
| Tree Diameter (cm dbh) | 52.1 | 8 - 200 | 50.0 | 4 - 212 | 59.3 | 8 - 224 | 76.6 | 5 - 207 | 58.9 | 4.9 |
| Canopy Closure (%) | 77.5 | 70 - 90 | 66.2 | 30 - 90 | 60 | 30 - 90 | 74.3 | 60- 90 | 69.4 | 2.8 |
| Understory | | | | | | | | | | |
| Shrub Cover (%) | 11.2 | 0 - 38 | 56.4 | 16 - 86 | 17.3 | 0 - 38 | 28.4 | 16 - 38 | 28.3 | 4.3 |
| Fern Cover (%) | 23.9 | 16 - 38 | 24.3 | 16 - 63 | 56.1 | 38 - 86 | 24.6 | 2.5 - 38 | 32.5 | 3.9 |
| Forb Cover (%) | 71.4 | 63 - 86 | 59.6 | 38 - 86 | 53.3 | 38 - 86 | 47.2 | 2.5 - 63 | 58.2 | 3.4 |
| Log Density (#/ 20m$^2$) | | | | | | | | | | |
| 10 - 23 cm | 1.6 | 0 - 4 | 0.6 | 0 - 2 | 0.5 | 0 - 3 | 1.6 | 0 - 6 | 1.1 | 0.3 |
| 23 - 53 cm | 1.1 | 0 - 3 | 0.6 | 0 - 3 | 0.3 | 0 - 1 | 1.1 | 0 - 4 | 0.8 | 0.2 |
| 53 - 81 cm | 0.1 | 0 - 1 | 0.8 | 0 - 2 | 0.4 | 0 - 2 | 0.7 | 0 - 2 | 0.5 | 0.1 |
| 81 - 122 cm | 0 | 0 | 0.4 | 0 - 1 | 0.3 | 0 - 2 | 0.4 | 0 - 1 | 0.3 | 0.1 |
| > 122 cm | 0 | 0 | 0 | 0 | 0.3 | 0 - 1 | 0 | 0 | 0.1 | 0.0 |

[a] Means are derived from measurements at 7 - 8 trap sites.

[b] Detailed overstory and stand characteristics in Appendix B.

Table D4. Mean vegetation and habitat characteristics of small mammal inventory sites in deciduous forests of the Elwha and Hoh Valleys, Olympic National Park, 1999[a].

| | HOH RIVER | | | | ELWHA RIVER | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SANDPIPER | | BIG MAPLE | | HORNET | | YELLOW JACKET | | Between Sites | |
| Characteristic | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | SE |
| Overstory[b] | | | | | | | | | | |
| Deciduous Tree Density (#/ $100m^2$) | 1.3 | -- | 1.5 | -- | 1.3 | -- | 1.3 | -- | 1.4 | 0.1 |
| Conifer Tree Density (#/ $100m^2$) | 0.3 | -- | 0.7 | -- | 0.3 | -- | 0.1 | -- | 0.4 | 0.1 |
| Tree Diameter (cm dbh) | 55.5 | 7 - 156 | 55.1 | 25 - 320 | 44.8 | 5 - 129 | 28.9 | 6 - 160 | 53.2 | 6.2 |
| Canopy Closure (%) | 76.3 | 50 - 100 | 76.3 | 50 - 90 | 60 | 10 - 100 | 83.8 | 80 - 90 | 70 | 3.4 |
| Understory | | | | | | | | | | |
| Shrub Cover (%) | 9.7 | 0 - 16 | 10.2 | 2.5 - 38 | 1.9 | 0 - 16 | 2.9 | 0 - 16 | 5.5 | 1.6 |
| Fern Cover (%) | 18.8 | 0 - 38 | 41.8 | 16 - 86 | 2.9 | 0 - 16 | 8.7 | 0.1 - 16 | 18.4 | 4.2 |
| Forb Cover (%) | 50.2 | 38 - 86 | 27.1 | 16 - 63 | 59.3 | 16 - 86 | 0.7 | 0 - 2.5 | 42.6 | 4.9 |
| Log Density (#/ $20m^2$) | | | | | | | | | | |
| 10 - 23 cm | 0.8 | 0 - 4 | 0.4 | 0 - 1 | 0.8 | 0 - 3 | 1.1 | 0 - 3 | 0.7 | 0.2 |
| 23 - 53 cm | 0 | 0 | 1 | 0 - 3 | 0.9 | 0 - 3 | 1.4 | 1 - 3 | 0.6 | 0.2 |
| 53 - 81 cm | 0 | 0 | 0 | 0 | 0.3 | 0 - 1 | 0.3 | 0 - 1 | 0.1 | 0.1 |
| 81 - 122 cm | 0 | 0 | 0 | 0 | 0.1 | 0 - 1 | 0 | 0 | 0.03 | 0.03 |
| > 122 cm | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

[a] Means are derived from measurements at 7 - 8 trap sites.

[b] Detailed overstory and stand characteristics in Appendix B.

Table D5. Occurrence of mammals at 12 inventory sampling sites in the Elwha and Hoh Valleys, Olympic National Park, 1999.

| | Elwha Valley[b] | | | | | | Hoh Valley[b] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Douglas Fir | | | | Hardwood | | Sitka Spruce | | | | Hardwood | |
| SPECIES[a] | Hurr | Brus | Herr | Elwh | Horn | Yell | Elk | Big S | Swor | Bogy | Sand | Big M |
| *Peromyscus* spp. | X | X | X | X | X | X | X | X | | X | X | |
| Douglas squirrel | | | | | | | | | | | | |
| Ermine | | | | X | | | | | X | | | X |
| Northern flying squirrel | | | | | | | | | | | | |
| Oregon (creeping) vole | | | X | | X | X | X | X | X | X | | X |
| Pacific jumping mouse | | | | | | | X | | | | | |
| Shrew spp. | X | X | X | X | X | X | X | X | X | X | X | X |
| Shrew, montane | | | | | | | | | | | | |
| Shrew, Pacific water | | | | | | | X | | | | | |
| Shrew, Trowbridge's | | | | | | | | | | | | |
| Shrew, vagrant | | | | | | | | | | | | |
| Shrew, water | | | | | | | | | | | | |
| Shrew mole | | | | | | | | | | | | |
| Snowshoe hare | | | | | | | | | | | | |
| Townsend chipmunk | | | | | | | | | | | | |
| Vole, long-tailed | | | | | | | | | | | | |
| Vole, Southern red-backed | | | X | X | | | | | | | | |
| Vole, unknown | | | | | | | | | | | | |
| Western spotted skunk | | | | | | | | | | | | |

[a]Latin names of species in Appendix C

[b]Site name abbreviations as follows: Hurr=Hurrican, Brus=Brushy, Herr=Herrick, Elwha=Elwha Camp, Horn=Hornet, Yell=Yellow Jacket, Elk=Elk, Big S=Big Spruce, Swor=Sword, Bogy=Bogachiel

Table D6. Population indices (catch per unit effort) of small mammals at 12 inventory sampling sites Elwha and Hoh Valleys of Olympic National Park, 1999.

| SPECIES | Index Type | ELWHA[d] | | | | | | HOH[d] | | | | | | GRAND TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Douglas Fir | | | | Hardwood | | Sitka Spruce | | | | Hardwood | | |
| | | Hurr | Brus | Herr | Elwh | Horn | Yell | Elk | Big S | Swo | Bogy | Sand | Big M | |
| *Peromyscus* spp. | $m_{t+1}$[a] | 2.24 | 0.45 | 1.36 | 8.64 | 0.92 | 3.16 | 1.35 | 2.23 | 0.00 | 3.60 | 0.90 | 0.00 | 5.98 |
| Ermine | $m_{t+1}$[a] | 0.00 | 0.00 | 0.00 | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 | 0.00 | 0.00 | 0.90 | 0.15 |
| Oregon (creeping) vole | $m_{t+1}$[a] | 0.00 | 0.00 | 1.36 | 0.00 | 1.83 | 0.45 | 0.45 | 3.57 | 0.45 | 1.35 | 0.00 | 1.35 | 1.81 |
| Pacific jumping mouse | $m_{t+1}$[a] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 |
| Shrew spp.[1] | n.[b] | 1.34 | 1.36 | 2.73 | 4.09 | 3.20 | 3.61 | 1.35 | 0.45 | 2.25 | 1.35 | 1.81 | 3.16 | 2.63 |
| Shrew, Pacific water | n.[b] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 |
| Southern red-backed vole | $m_{t+1}$[a] | 0.00 | 0.00 | 0.45 | 3.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.53 |
| Total individuals captured | | 8 | 4 | 13 | 36 | 13 | 16 | 8 | 14 | 6 | 14 | 6 | 10 | **148** |
| Number trap-nights | | 224 | 224 | 224 | 224 | 224 | 224 | 224 | 224 | 224 | 224 | 224 | 224 | **2688** |
| Sprung traps | | 1 | 7 | 8 | 8 | 11 | 5 | 3 | 0 | 4 | 3 | 5 | 5 | **60** |
| Catch/100 trap-nights[c] | | 3.58 | 1.81 | 5.91 | 16.36 | 5.95 | 7.22 | 3.60 | 6.25 | 2.70 | 6.29 | 2.71 | 4.51 | **5.57** |

[a] $m_{t+1}$ refers to the number of different individuals captured per 100 corrected trap-nights.
[b] n. refers to the total number of captures and recaptures per 100 corrected trap-nights.
[c] Catch per unit effort (CPUE) corrected for sprung traps (Nelson and Clarke 1973).
[d] Site name abbreviations as follows: Hurr=Hurricane, Brus=Brushy, Herr=Herrick, Elwh=Elwha Camp, Horn=Hornet, Yell=Yellow Jacket, Elk=Elk, Big S=Bog Spruce, Swor=Sword, Bogy=Bogachiel Sand=Sandpiper, Big M=Big Maple