Designing Strategic Survey Protocols for Bats
Final Report

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Summary

I present results from a project that evaluated design components and field-tested survey protocols necessary to initiate a strategic survey program for 8 Sensitive Species of bats throughout the NWFP area. Survey protocols were evaluated in 8 study areas distributed across the NWFP from northern California to the Olympic peninsula. Sample units within study areas were located consistent with the sample frame used by the Forest Inventory and Analysis Program (FIA). Bats were detected and identified using capture, acoustic, and bridge surveys. One important product of this work is a preliminary key to identification of bats within the NWFP area from their echolocation calls. Surveys which combined capture and acoustic methods were an effective and efficient means of detecting most Sensitive Species. We conducted multiple surveys within a sample unit, which allowed us to account for spatio-temporal variation in habitat use and estimate the proportion of occupied sample units and detection probabilities. Five sensitive species, *Lasionycteris noctivagans, Myotis californicus, M. evotis, M. thysanodes*, and *M. volans* species produced estimates of occupancy and detection that suggested they would be good candidates for a large-scale inventory program with only minor modifications to the design used in this study. Three other Sensitive Species, *Antrozous pallidus*, *Corynorhinus townsendii*, and *Lasiurus cinereus* were infrequently detected using this inventory design and I suggest alternatives for inventorying these species.

Introduction

Eight species of bats appear on Sensitive Species lists under various jurisdictions within the Northwest Forest Plan (NWFP) area. Six of these 8 species were reviewed during the 2002 Annual Species Review (ASR) process of the former Survey and Manage (S&M) program. Assessments of species persistence were hampered by a lack of reliable information on the distribution, habitat associations, and population status for any of these species. The majority of previous research had addressed their roost site requirements and focused on identification of the structures in which they roost, the habitat immediately surrounding roost structures, and, in a handful of cases, compared roost to available habitat. Such information, while valuable for understanding the ecology of individual species, did not produce results suitable for addressing distribution or habitat associations at the broad spatial scales necessary to assess persistence at the scale of the NWFP area. Although a comprehensive database of species detection locations was also evaluated during the 2002 ASR, it only covered NWFP lands in Oregon, did not record surveys where no species were detected, and surveys that produced the detections were not conducted in standardized fashion.

It was clear that the information required to address persistence concerns (e.g., distribution, rarity, broad-scale habitat associations) across the NWFP area needed to be collected at larger spatial scales than individual roost sites or even individual national forests. As demonstrated for several S&M taxa, the most effective and efficient means of acquiring such information is by using strategic surveys conducted across the large areas of interest (Molina et al. 2003). This project was initiated to evaluate important design considerations necessary to implement a similar program for bats. Bats are excellent candidates for such a program because multiple species can be detected during a single survey using the same set of methods (Molina et al. 2003).

The process of designing a strategic survey program for bats was simplified significantly because guidance was available that helped identify, and provide recommendations for, many of the important considerations in the design of such a program (Molina et al. 2003). For instance, we focused on the most reliable measure of population status for forest bats: proportion of occupied sites (Weller, In Press). For initial implementation we limited inference to the 4 primary strata of the NWFP area: Reserve vs. Matrix and Late-successional/Old-growth (LSOG) vs. non-LSOG. We also linked survey locations to an existing sampling framework: the Forest Inventory and Analysis Program's (FIA) sample frame.

Additionally, I designed a program that applied recent analytical advances allow inventory and monitoring programs to account for imperfect detection of target taxa during surveys (e.g., MacKenzie et al. 2002). Such approaches require multiple surveys such that estimates of sample unit occupancy account for detectability during a survey which, as for most taxa, is < 1 for bats. For bats, detectability is < 1 because of spatio-temporal variation in their use of habitat, which means that will not be present during every survey, even at sites they may use frequently. Additionally, species may be present at a site during a survey, but not detected due to the imperfect tools available for their detection.

Conventionally, bat species occurrence has been documented using mist nets at foraging areas. This method is favored because it results of in detection of multiple species with unambiguous species identification established by the completion of the survey in most species. Mist nets are the most frequently employed inventory technique for practitioners of all experience-levels (Weller and Zielinski, in Press) and they are the primary method recommended for detecting bats in regional multiple species surveys in an upcoming U. S. Forest Service technical guide (Manley et al. 2005).

Nevertheless it is increasingly recognized that mist net surveys at foraging areas should be only one component of surveys with the goal of detecting the species that occur in an area (Kuenzi and Morrison 1998, Murray et al. 1999, O'Farrell and Gannon 1999). Some species may be present in an area but are not easily captured either because they avoid mist nets or the areas in which they are typically deployed. Acoustic surveys are increasingly used to improve accuracy of species inventories however their contribution to species lists has not been evaluated for the Pacific Northwest. Identification of bat species using their echolocation calls is a developing science and a key to echolocation calls of bats in the Pacific Northwest did not exist prior to this project. Because of their potential to improve accuracy and efficiency of species inventories, assessing the potential contributions of acoustic surveys to a regional bat inventory program was one of my goals. Forest bats can also be detected by inspection of man-made roosts, especially bridges, and we evaluated use of bridge surveys to detect species occurrence.

This project was initiated to address several basic information needs required to design an strategic survey program including: development of standardized survey protocols, evaluation of logistics and costs of surveys, comparison of the relative effectiveness of survey methods on multiple species (Molina et al. 2003). Additionally, it was to provide the first estimates of occupancy and detection necessary to determine the survey effort required to meet desired standards of detection. Pilot studies that address such concerns prior to full-scale implementation will improve the overall efficiency and effectiveness of inventory and monitoring programs (Vesley et al. 2005). Due to budget constraints, this pilot study required two years to obtain a sample of locations distributed throughout the NWFP area that was large enough to allow credible recommendations for implementing a strategic survey program for bats.

Additionally, I used species detection data to evaluate habitat associations of Sensitive Species of bats with respect to the 4 primary NWFP land categories. Although inferences from these analyses were limited due to a low sample size of non-randomly selected sample units, I wanted to evaluate whether there were any obvious trends in association and, more importantly, demonstrate the methods by which habitat associations would be evaluated based on occupancy estimates as opposed to raw detection data.

METHODS

Site Selection

Study Area Selection –

Study areas were selected to satisfy a number of often competing criteria. The most important criterion in selecting study areas for this effort was their proximity to biologists with the skills necessary to survey bats in the field using a variety of survey methods. This was a cost and logistical consideration as random point selection would have resulted in greater travel, greater costs, and fewer sample units completed. Nevertheless, because our objective was to evaluate the efficacy of bat surveys throughout the NWFP area, we distributed study areas over a variety of habitat and climate conditions that occur across the NWFP area (Figure 1). For instance, we

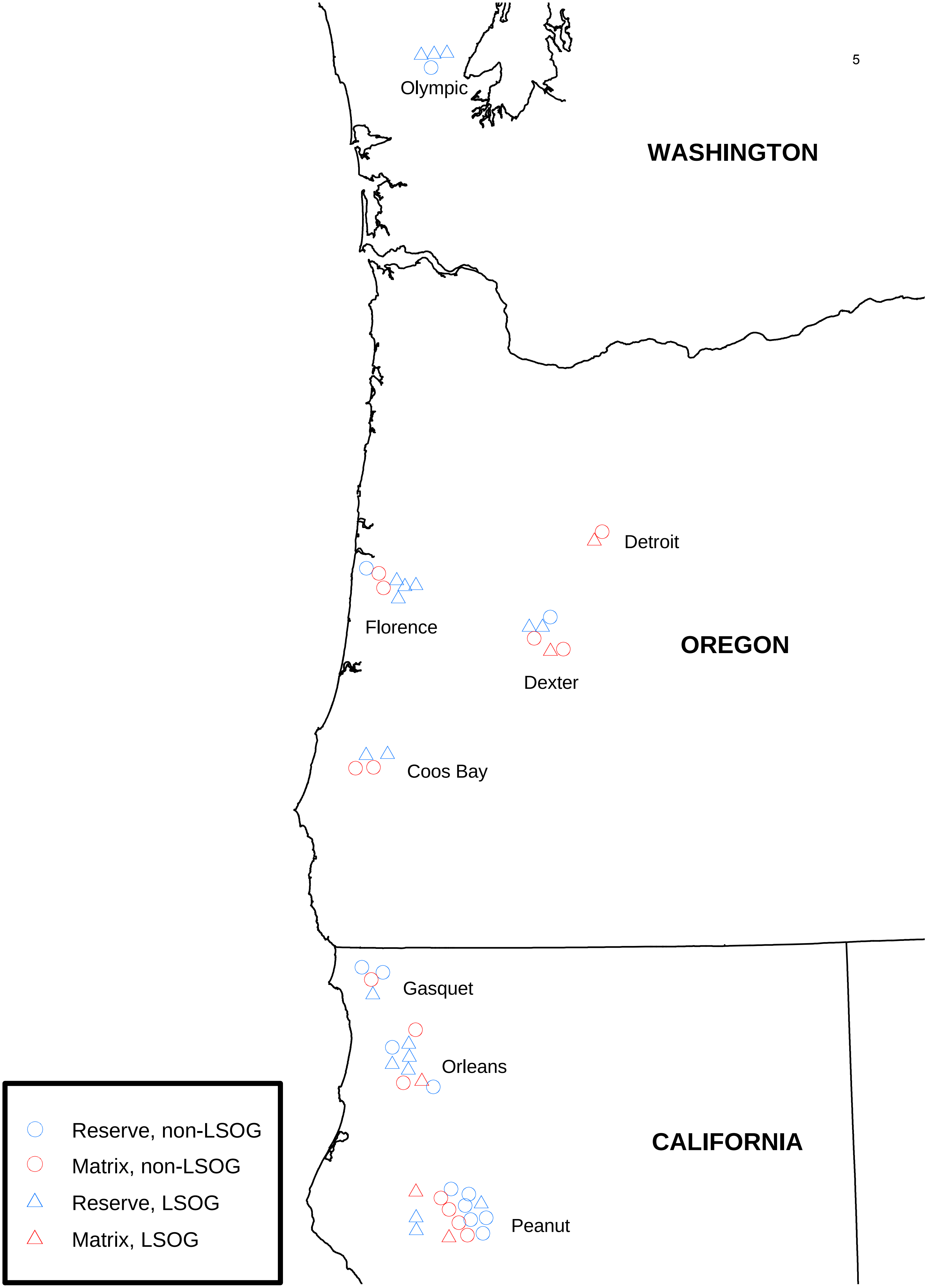

Figure 1. Location of sample units where bat surveys were conducted in 2003-2004.

expected that species detection rates would differ between sample units in the Oregon coast range and those on the Shasta-Trinity National Forest near the southeastern extent of the NWFP, and therefore surveyed multiple study areas to elucidate some of these differences. Once the general location of a study areas was established, its specific location was selected to maximize the number of different land allocation categories available within it (i.e. so that study areas were not all of one category e.g., matrix/non-LSOG).

Sample Unit Selection –

We used the Forest Inventory and Analysis Program's (FIA) systematic sample frame as the basis for distributing our sample units. In 2003 we used FIA points as center point of a 2.5 km radius circle to construct 4850 acre (1960 ha) sample units. We selected a 2.5 km radius as the largest sample unit size that would result in non-overlapping sample units using the FIA system. Based on results from a similar effort (Weller et al. 2002), we expected that sample units of this size would be necessary to locate 2 sites suitable for bat capture surveys within a sample unit. In 2004 we decided, in consultation with the FIA program, to use the center point of the hexagonal grid that provides consistent spatial control on FIA point locations as center point for sample units. Doing so allowed us to avoid entering into a Memorandum of Understanding with the FIA program, necessary to protect ownership concerns and damage to biological elements of the FIA points themselves, with little impact to our systematic selection of sample units for bat surveys. We used a circle with a fixed radius, rather than the hexagon itself to simplify field logistics: field crews used a GPS to determine which habitat elements were within the sample units based on their distance from the center point.

We selected sample units to approximate the distribution of land allocation categories throughout the NWFP. We used the 1993 FEMAT GIS layer from the Regional Ecosystem Office to define land areas as Matrix versus Reserve and as LSOG versus non-LSOG. We did not consider Riparian Reserves separately because most bat surveys locations are located in riparian areas. Instead, we considered land allocations surrounding riparian areas and characterized lands as either Matrix, Reserve, or non-Federal. We overlaid FIA point locations on these layers to determine the proportion of points that occurred within each of four categories throughout the

NWFP area and obtained the following results: Reserve/LSOG 39%, Reserve/non-LSOG 25%, Matrix/LSOG 9%, Matrix/non-LSOG 27%.

In order to designate sample units as belonging to one of these 4 land categories, we selected sample units that were most homogeneous with respect to land category (e.g. Reserve/non-LSOG). We attempted to select sample units comprised of ≥ 70% of a particular land category and assigned the sample unit to that land category. We selected sample units to approximate the amount of land within NWFP land categories on an annual basis and surveyed:

- 19 Reserve/LSOG Sample Units (37.3%)
- 13 Reserve/non-LSOG Sample Units (25.5%)
- 5 Matrix/LSOG Sample Units (9.8%)
- 14 Matrix/non-LSOG Sample Units (27.5%)

over 2003 and 2004. We attempted to select sample units to approximate these proportions in each study area as well, but this was not always possible because of the low number of sample units within a study area and homogeneity of land allocations within individual study areas (e.g. Olympic Study Area only had Reserve lands).

Wherever possible, we selected adjacent sample units to minimize travel time in the field and preferentially selected those with the most public land or easiest access when choosing between potential sample units that were similar in terms of proportion of area within a land category (e.g. if two potential sample units were ~ 85% Reserve/LSOG then we chose the one with the most public land or best access

Site Selection

Activity patterns of forest bats are highly variable in space and time (Hayes 2000), and species are thought to differ in detectability according to type of habitat element surveyed (e.g. small creek vs. lake). Thus we surveyed two sites per sample unit to provide some measure of spatial replication and increase the number of different types of habitat elements surveyed in an attempt to increase the number of species detected within a sample unit.

The center point of each sample unit was buffered by circles with radii of 1 km and 2.5 km in a GIS. The 1 km radius buffer (750 acre) was created to evaluate the potential of using a smaller sample unit size in future surveys -- one that would allow a greater spatial correspondence with surveys of vegetation and other taxa. Where suitable habitat elements occurred within the 1 km buffer they were preferentially selected as survey sites; otherwise sites were anywhere within the sample unit.

Survey sites were selected to maximize chances of detecting multiple bat species by capture and, secondarily, by acoustic detection. We selected habitat elements according to the following priority: low gradient streams that were medium (3 – 9 m wide), large (> 9 m wide), or small (< 3m wide), ponds, lakes, or roads. Bats are difficult to capture at lakes and on roads and these habitat elements were selected when other elements did not exist within the sample unit. Once the first survey site was selected, we chose a different type of habitat element as the second site wherever it was available. For instance if a pond was selected as the first survey site, we attempted to select something other than a pond as the second survey site Because our surveys targeted multiple species, we reasoned that surveying two different habitat features, where possible, would increase the number of species detected in a sample unit. In some cases, roads were the only habitat features available as survey sites. When both survey sites were roads, we attempted to locate one of them within the 1 km buffer.

Site selection began in the office using 7.5 minute quads overlaid by the 1 km and 2.5 km buffer. Habitat elements that were potential bat survey sites were identified on the map and prioritized for reconnaissance visits in the field. Field reconnaissance was essential for selection of suitable sites to conduct capture surveys for bats. For instance, medium-width, low-gradient streams are good survey sites for bats and easily identifiable on maps; however if they are overgrown by dense vegetation, which would reduce or eliminate the possibility for bats to access the stream, they are not suitable survey sites.

Standard Survey Protocol

We applied the "standard survey protocol", conducting 2 surveys that combined capture of bats using mist nets and detection of their echolocations using bat detectors at each of 2 sites per sample unit, in 46 of the 51 sample units surveyed. Surveys were conducted from 16 June – 9 September in 2003 and from 14 June – 11 September in 2004. On average, consecutive surveys at a site were 37.4 (SE = 1.4, range 13-83) days apart. Most surveys were conducted by 2 biologists, with one responsible for monitoring mist nets and processing animals while the other monitored echolocations. Occasionally, multiple animals would be captured requiring echolocation monitoring to be interrupted so that the second biologist could assist with removing bats from nets and processing animals. Surveys began at sunset and continued for 3.5 hours.

Capture

We set 2 – 4 (mean = 3.27, SE = 0.04), 2.6 m high mist nets per survey. The appropriate number and length (2.6 – 30 m) of mist net was selected according to the physical characteristics of the site. On average, 26.6 m (range 7.8 – 54 m) of mist net were deployed per survey.

Most captured bats were identified to species based on measurement and inspection of their external morphology. Two species, which were not Sensitive Species, *Myotis lucifugus* and *M. yumanensis,* could not be distinguished from each other in the field. For these species we extracted a 3mm tissue biopsy from the wing membrane for DNA analysis by Portland State University. We attempted to use a similar procedure at the Olympic Study Area, where the *M. keenii* and *M. evotis* are difficult to distinguish based on external morphology. However the DNA sequences collected for these individuals were not identifiable via the available markers.

Echolocation Monitoring

A Pettersson D-240X bat detector was used to monitor bat echolocation activity at the site. Echolocation activity was monitored at a variety of locations at each site, focusing on areas where bats may have been active but unlikely to be captured with mist nets. When an echolocation of sufficient intensity was detected, the biologist triggered the detector to save a recording of the call in time-expanded form (i.e. slowed down 10 times). This recording was then transferred to a either an analog tape recorder or directly to the hard drive of a lap top computer for storage. Once downloaded, active monitoring was re-initiated 1 - 3 minutes later. Audio tape recordings were later downloaded to computers using SONOBAT which converted files to .wav format. Echolocation calls were depicted as time vs. frequency sonograms in

SONOBAT. We measured time and frequency parameters of echolocation calls that contribute to species identification including, high frequency, low frequency, characteristic frequency, duration, slope, upper slope and lower slope. Call analysis was conducted in the lab.

Identification of species from their echolocation calls required multiple steps. Briefly, identification of echolocation calls detected during acoustic monitoring are compared to a set of calls produced by bats that have been identified by other means. The primary means of collecting such calls is to record echolocations from bats which have been previously captured and identified. After establishing their species identity via morphology, or subsequently via DNA analysis for *M. lucifugus* and *M. yumanensis*, we recorded echolocations of bats as they were released from the hand or while they flew on tethered zip-line (Szewczak 2004). We attached chemiluminescent light tags to many of the bats released from the hand to facilitate recording echolocations as long as possible after release, when calls produced are more representative of those produced under natural conditions. These reference calls were critical to improving our understanding of within- and among-species variability in echolocation call morphology which impacted our ability to identify species from their calls. Time spent recording reference calls during field surveys decreased the amount of time spent monitoring echolocations of un-captured bats during capture/acoustic surveys; but because the mean number of bats captured per survey was 3.7, the impact was minimal for most surveys.

I created a key to identification of bats within the NWFP area by their echolocation calls (Table 1). The key presents the range of values of several echolocation call parameters for each species. It also presents, in bold, call characteristics which allow an individual call to be assigned to species. An unknown echolocation call that met ≥ 1 of the bolded criterion, was assigned to species so long as values for all other parameters fell within those described for that species. The key was based on characteristics of reference calls recorded during this study, reference calls available within the SONOBAT software program used to analyze calls, and my understanding of how bats vary their echolocation calls according to their proximity to obstacles. Echolocations produced by bats immediately following release from the hand or while flying on tethered zip-line differ from those produced under natural conditions in predictable ways (Weller

Table 1. Echolocation call characteristics of bats in the Northwest Forest Plan area. Species identification requires at least one bolded criterion to be met and all other parameters to be within ranges presented.

Species	Characteristic Freq. (kHz)	Low freq. (kHz)	High Freq (kHz)	Duration (ms)	Upper Slope (kHz/ms)	Lower Slope (kHz/ms)	Special Characterisitics
MYCA	47.5-55	40-50	85-135	2.5-5.5	15-50 **(>32)**	5-25	Power distributed throughout lower slope on non-oversaturated calls. More frequently smooth curve than strong heel.
MYYU	47.5-55	40-50	70-130	3-8 **(>6)**	15-28	2-20 **(<3)**	Power focused around Fc: Oscillogram builds up to peak and drops off rapidly. Sometimes insert longer duration calls within sequence of short dur. Calls.
PIHE	**Same as Low f**	45-50	45-95	3.5-8	5-25	0-3	**Hockey Stick Shape**
LABL	Same as Low f or upturn	38-50	50-100	4-15 **(>10)**		0-5	**Up-turn at end of call, low F alternates throughout sequence**
MYVO	40-46.5 **(43-46.5)**	30-46	90-120 **(>110)**	2.5-6	10-45 **(>33)**	>4 **(>16)**	
MYLU	38-43	30-40	55-105 **(<85)**	2.5 -8 **(>6.5)**	6-28	0-15 **(<3)**	Sometimes w/ mult. power centers i.e. call looks clumpy. Fc may be as low as 37.5 on flat calls
MYEV	33-41 **(33-36)**	22-40	90-125	2.5-5.5	20-40	5-30	
MYTH	15-32 **(<31)**	12-35	90-125	2.5-6.5	15-50	6-40	
LANO	25-28	20-28	27-65 **(<30)**	4-15	0-15	0-5	**Flat calls (i.e. HiF < 30 kHz) diagnostic.** Flat LACI calls are lower. EPFU has more FM.
EPFU	same as low f or slight upturn	24-33	32-90 **(65-90)**	3-20	0-30	0-10	High f and steep upper slope distinguish from LANO, even long calls have some FM component
ANPA	same as low f	26-30	50-70	3-10	3-20	0-10	Can only distinguish from EPFU if < 6 calls/sec. No tail. Simpler shape than EPFU or LANO. Social calls diagnostic.
LACI	same as lowf or upturn	13-27 **(≤ 23)**	<50	4-20	0-12	0-5	subtle "U"-shape: may have slight up turn at end, low f may vary throughout sequence, **power builds toward center then gradual tails off**
TABR	same as lowf or downturn	18-27	22-65	6-18	<10	0-2	Variable. **Long calls that "turn on" rapidly with high energy at beginning (oscillogram carrot-like).** Calls often upswing into call and downswing out of call.
COTO	same as low f	17-23	35-50	2-8			Call-shape usually **simple slant**, (or upsweep prior to slant). Fmax alternates btwn H1 and H2. Must have harmonic to confirm prev. and call quality

Species Codes: MYCA=*Myotis californicus*, MYYU=*M. yumanensis*, PIHE=*Pipistrellus hesperus*, LABL=*Lasiurus blossevilli*, MYVO=*M. volans*, MYLU=*M. lucifugus*, MYEV=*M. evotis*, MYTH=*M.thysanodes*
LANO=*Lasionycteris noctivagans*, EPFU=*Eptesicus fuscus*, ANPA=*Antrozous pallidus*, LACI=*Lasiurus cinereus*, TABR=*Tadarida brasiliensis*, COTO=*Corynorhinus townsendii*

et al. 2004). I conservatively interpreted the range of call parameters such that species identification was indicated for only a narrow range of the call repertoire of most species.

Bridge Surveys

Bridges were surveyed opportunistically where they occurred within sample units. Reconnaissance surveys, which involved inspection of the underside of bridges for bats or sign of bats including guano or urine stains, were conducted during the day. When bats or bat sign was seen, the bridge was subsequently surveyed at night. The field protocol called for each bridge with bat sign to be surveyed on two occasions, but some bridges were only surveyed once.

Night surveys at bridges were conducted following mist net activities at capture/acoustic sites, approximately 4 hours after sunset. Biologists searched beneath bridges, starting in locations where the most bat sign was seen, for night roosting bats. Although a few species were identifiable based on visual observation (*Antrozous pallidus, Corynorhinus townsendii, Eptesicus fuscus*, and *Tadarida brasiliensis*), we attempted to capture roosting bats to confirm identification using a variety of capture devices (e.g. hand nets, "cluster busters). Captured bat were identified using inspection and measurement of external features (except *Myotis lucifugus* and *M. yumanensis*) and released above the bridge. If bats were observed, but not captured, we waited 15 minutes before making a second capture attempt.

Intensive Sample Units

We selected 5 sample units to be sampled more intensively than the standard protocol (2 sites surveyed twice) applied at the remainder of sample units. The goals of these sample units were to gain an empirical understanding of the extent to which additional survey effort within a sample unit might increase the number of species detected and to compare the relative effectiveness of various techniques. Intensive sample units were surveyed in study areas where labor was available to do so: the Peanut, Orleans, and Dexter study areas in 2003 and the Peanut and Florence study areas in 2004. Intensive sample units contained 6 capture/acoustic survey sites, 4 acoustic transects, and, where available, at least one bridge. Because it was difficult to locate > 2 capture/acoustic sites in most sample units, intensive sample units were non-randomly selected as the sample unit within the study area that had the greatest availability of sites that

would support capture/acoustic surveys. When selecting among two sample units with an equal number of capture/acoustic sites, if one contained it bridge it was selected.
Center points of intensive sample units were buffered by 3 concentric circles (Figure 2) and survey effort within each of the circles was allocated as follows:

- 1 km circle: 1 capture/acoustic site and 1 transect (along a road or forest opening).
- 1.75 km circle: 3 capture/acoustic sites and 2 transects (1 along a road and 1 in forest opening).
- 2.5 km circle: 6 mist net sites and 4 transects (2 along roads and 2 in forest openings).

The number of sites and transects selected within a given radius included those in all smaller circles. For instance, 3 of the four transects within the sample unit could occur within the 1.75 km buffer (Figure 2).

Acoustic Transects

We evaluated the use of acoustic transects as a means of detecting species that may not be present or detected at sites suitable for capture surveys. For example, species that fly high and fast may be more frequently detected using acoustic surveys in forest openings. We hypothesized that acoustic transects might be particularly effective to detect *Lasiurus cinereus*, *Lasionycteris noctivagans*, and non-Sensitive Species such as *Eptesicus fuscus* and *Tadarida brasiliensis*. Transects were located at two types of habitat elements: 1) roads and 2) forest openings.

We targeted narrow, tree-lined, dirt roads for road transects; those that passed through multiple habitat or age conditions were preferentially selected. For instance, road transects that began along a clearcut and continued into mature forest were selected over those that passed through one or the other of those habitat conditions. Road transects were 1 km long with recording points every 100 m for a total of 11 points. We located forest opening transects in openings with perimeters of at least 300 m and established 11 recording points at approximately equal intervals along the perimeter. Forest opening transects were conducted at lake edges, river edges, meadows, and clearcuts of varying age. Echolocation activity of bats using both the edge and middle of forest openings was surveyed by this method.

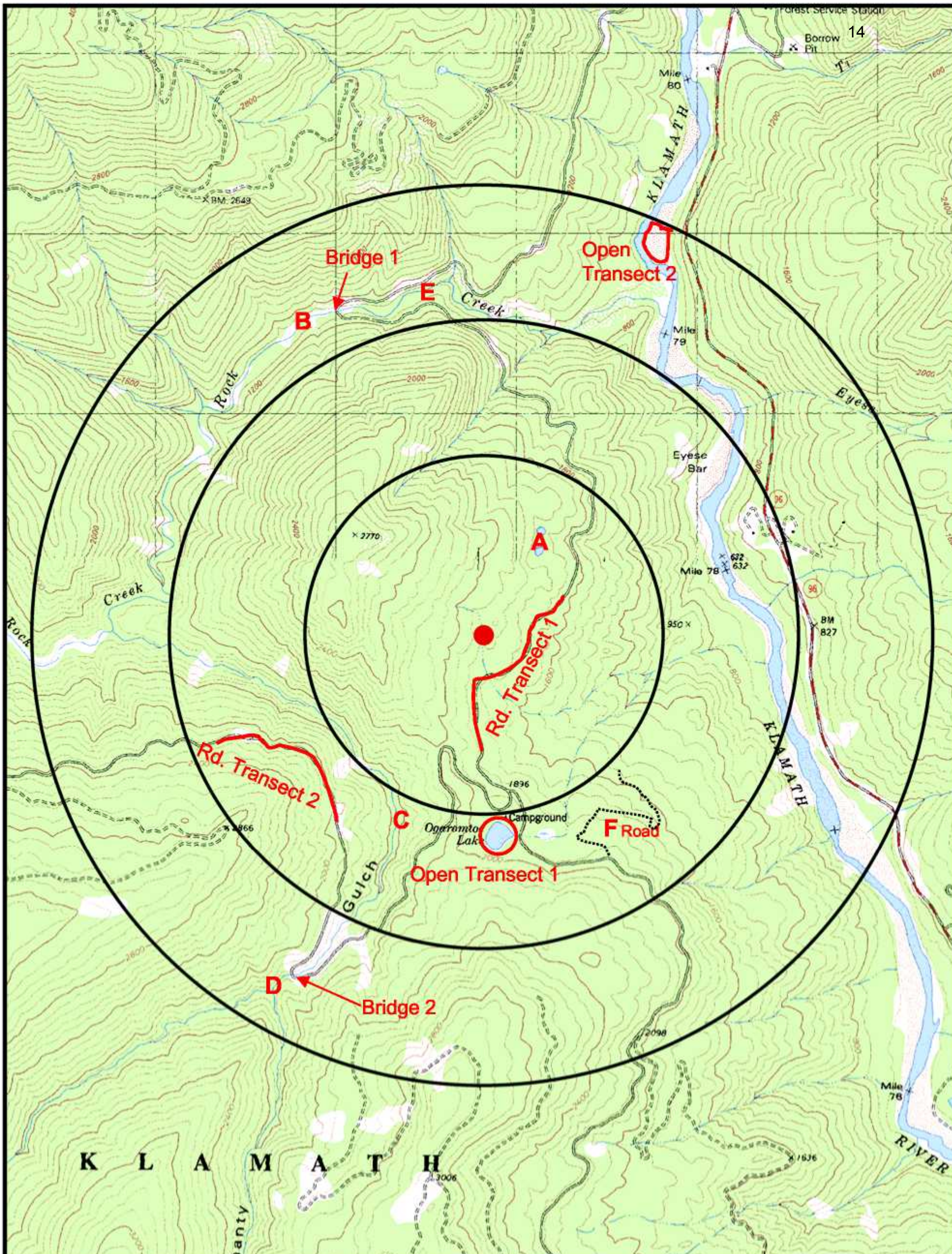

Figure 2. Intensive sample unit ORL12. FIA point (filled red circle) buffered by circles of radius 1 km, 1.75 km, and 2.5 km. Capture/acoustic survey sites are denoted by letters. Location of 2 road transects, 2 opening transects and 2 bridges are also noted. where

Acoustic transect surveys began 30 minutes after sunset at a randomly selected recording point. That point was sampled for 5 minutes and the biologist then proceeded in a random direction to the next point. Monitoring continued until each point had been sampled twice for 5 minutes. No monitoring occurred while moving between points. When bat calls were heard, they were immediately transferred from the temporary memory buffer of the bat detector to an audio tape. Echolocation calls were later downloaded to SONOBAT for analysis.

Data Analyses

We used chi-square tests to determine whether the type of habitat element where sensitive species were detected differed from that expected by chance. Chi-squared tests were also used to evaluate association with NWFP land categories using data from where species were detected in the field. All detections of a species within a sample unit were used in this analysis. In other words, detections made at bridges and at sites 3 – 6 and acoustic transects in intensive sample units were all included in the analysis.

Because capture/acoustic surveys were conducted simultaneously, species could be detected by capture, acoustic, or both methods. This allowed me to evaluate the relative effectiveness of the methods because detection by one method should indicate that the species was present at the site during the survey and available for detection. Species would be detected by both methods if they were equally effective and the proportion of surveys where a species was detected by only one method should be approximately equal.

Occupancy Models

As with most taxa, the probability of detecting a particular species of bat with a single survey is <1. Therefore I applied a maximum likelihood estimator that applied survey results to estimate the proportion of sample units occupied within specified land categories (MacKenzie et al. 2002). Use of this approach requires multiple surveys such that probabilities of occupancy and detection (given occupancy) can be estimated simultaneously. Occupancy estimates are useful for addressing ecological and conservation issues while the detection estimates are useful for informing design of the inventory.

I used PRESENCE, a freeware program, to estimate occupancy and detection for each species relative to NWFP land categories. Estimates of occupancy and detection were based solely on data from capture/acoustic surveys rather than all survey types (e.g., bridge surveys, acoustic transects) because they were the only survey type designed to detect all sensitive species during a single survey and for which multiple surveys were consistently conducted at each site. Occupancy estimation was necessary to improve estimates of occupied sites with respect to NWFP land categories and to evaluate the effectiveness of our basic survey protocol as a large-scale monitoring approach. Occupancy and detection were estimated using data configured as 4 surveys per sample unit, by combining surveys conducted at both sites. Detection probability was assumed constant with respect to NWFP land categories and a single estimate was produced for each species.

For each sensitive species, I created a set of 4 candidate models to explain sample unit occupancy: 1) constant among sample units, 2) status with respect to land allocation (reserve or matrix), 3) status with respect to forest age (LSOG or non-LSOG) 4) or status with respect to land allocation and forest age. I used the information-theoretic approach to determine the relative support for each of these models by species (Burnham and Anderson 2002). I ranked models using AIC_c which adjusts for small sample sizes (Burnham and Anderson 2002).

Program PRESENCE generates a single-survey detection probability which can be extrapolated using the following formula to determine detection probability as number of surveys increase:

$$P_n = 1 - (1 - p)^n$$

Where:

P_n = detection probability after n surveys

p = single-survey detection probability

n = number of surveys

I present p and P_n extrapolated for 4 surveys (standard protocol) and 6 surveys which was not tested, but represents an alternative sampling strategy for some species (e.g. 2 sites surveyed 3 times each).

RESULTS

Site Selection

We established 8 study areas across a variety of habitat and climate conditions within the Northwest Forest Plan area (Figure 1). Throughout this report, I list study areas in order from south to north. Study areas were located within the following National Forests and BLM districts:

Peanut: Mad River Ranger District, Six Rivers N. F. and
South Fork Mgmt. Unit. Shasta-Trinity N. F.
Orleans: Orleans Ranger District Klamath N. F.
Gasquet: Gasquet Ranger District, Six Rivers N. F.
Coos Bay: Coos Bay BLM
Dexter: McKenzie Ranger District, Willamette N. F.
Florence: Mapleton Ranger District, Siuslaw N. F.
Detroit: Detroit Ranger District, Willamette N. F.
Olympic: Hoodsport Ranger District, Olympic N. F.

We surveyed 2 – 15 sample units per study area during 2003 and 2004. We surveyed 2 sites in most sample units, but 5 intensive sample units contained 6 capture/acoustic sites and 4 acoustic transects each. In addition we surveyed all bridges with indications of bat activity and and report these as separate survey sites.

Peanut: 15 sample units (72,500 acres), 47 sites
Orleans: 9 sample units (43,650 acres), 29 sites
Gasquet: 4 sample units (19,400 acres), 9 sites
Coos Bay: 4 sample units (19,400 acres), 8 sites
Dexter: 6 sample units (29,100 acres), 27 sites
Florence: 7 sample units (33,950 acres), 22 sites
Detroit: 2 sample units (9,700 acres), 4 sites
Olympic : 4 sample units (19,400 acres), 12 sites

Total : 51 sample units (247,000 acres), 158 sites

The proportion of NWFP land categories within sample units varied according to study area (Table 2). For instance, all sample units in the Florence and Coos Bay study areas had at least some non-Federal land, which complicated both field logistics and potential inferences regarding habitat; and sample units in the Olympic study area were comprised entirely of Reserve lands.

We were only able to establish a survey site within 1 km of the center point for about half (26/51) sample units. Relaxing the standard to 1.1 km to adjust for relatively insignificant location errors only increased the number of sample units with sites within 1.1 km to 30.

The habitat elements selected as survey sites also varied among study areas (Table 3). Medium creeks were the most frequently surveyed habitat element in 5 study areas and large creeks were the most frequently surveyed habitat element at the other 3 study areas. Overall, creeks composed 76% of the 122 capture acoustic survey sites. Medium creeks (42.6%) were by far the most frequently surveyed habitat element followed by large creeks (18.9%) and small creeks (14.8%). Roads were the next most frequently selected habitat element selected type of habitat element (12.3%) and were selected in 11 different sample units. In the Orleans and Florence Study Areas, roads were the only available habitat element to survey in two of the sample units. Thirteen of the 15 capture/acoustic survey sites at roads were in the Florence and Orleans study areas. Ponds (8.2%) and lakes (3.3%) were infrequent components of sample units and thus few were selected.

Within intensive sample units, habitat elements surveyed varied according to their availability (Table 4). At least 2 medium creek sites were surveyed in each of the intensive sample units. Road sites were surveyed in 2 of the intensive sample units. Bridges were available to survey in 3 of the intensive sample units, 2 of which had 2 bridges each. Suitable locations for acoustic transects in openings were not available in the Florence study area, so all acoustic transects were along roads.

Table 2. Percent of land within sample units for Sensitive Species of bats that were in 4 Northwest Forest Plan land categories or were non-federal land.

Sample Unit	Designation	Reserve/LSOG	Reserve/non-LSOG	Matrix/LSOG	Matrix/non-LSOG	non-Federal
Peanut:						
PEA01	Matrix/LSOG	30	2	37	7	24
PEA02	Matrix/non-LSOG	0	0	0	100	0
PEA03	Reserve/LSOG	94	1	0	0	5
PEA04	Reserve/LSOG	100	0	0	0	0
PEA06	Reserve/non-LSOG	100	0	0	0	0
PEA07	Reserve/non-LSOG	97	0	0	0	3
PEA08	Matrix/non-LSOG	0	17	0	83	0
PEA10	Reserve/non-LSOG	0	97	0	3	0
PEA12	Reserve/LSOG	80	11	0	0	9
PEA13	Matrix/non-LSOG	0	8	0	92	0
PEA21	Reserve/non-LSOG	0	86	0	0	14
PEA22	Reserve/non-LSOG	1	88	0	0	11
PEA23	Reserve/non-LSOG	0	100	0	0	0
PEA24	Matrix/non-LSOG	0	0	0	100	0
PEA25	Matrix/LSOG	2	0	78	20	0
Orleans:						
ORL01	Matrix/LSOG	1	0	88	6	5
ORL03	Reserve/LSOG	100	0	0	0	0
ORL04	Matrix/non-LSOG	1	8	8	82	1
ORL05	Reserve/LSOG	100	0	0	0	0
ORL06	Reserve/LSOG	100	0	0	0	0
ORL07	Reserve/LSOG	87	13	0	0	0
ORL09	Reserve/non-LSOG	21	79	0	0	0
ORL12	Matrix/non-LSOG	0	37	0	63	0
ORL18	Reserve/non-LSOG	6	92	0	0	2
Gasquet:						
GAS21	Reserve/non-LSOG	0	100	0	0	0
GAS22	Reserve/non-LSOG	0	94	0	6	0
GAS23	Matrix/non-LSOG	0	23	0	77	0
GAS24	Reserve/LSOG	89	1	0	0	10

Table 2 (continued).

Sample Unit	Designation	Reserve/LSOG	Reserve/non-LSOG	Matrix/LSOG	Matrix/non-LSOG	non-Federal
Coos Bay:						
COO21	Reserve/LSOG	85	0	1	0	14
COO22	Reserve/LSOG	80	0	0	0	20
COO23	Matrix/non-LSOG	0	0	0	58	42
COO24	Matrix/non-LSOG	0	0	0	64	36
Dexter:						
DEX04	Reserve/non-LSOG	24	68	0	0	8
DEX07	Reserve/LSOG	55	18	5	19	3
DEX08	Reserve/LSOG	99	0	1	0	0
DEX12	Matrix/non-LSOG	0	0	85	15	0
DEX23	Matrix/LSOG	0	0	77	23	0
DEX24	Matrix/non-LSOG	0	3	0	97	0
Florence:						
FLO21	Reserve/non-LSOG	14	71	0	2	13
FLO22	Matrix/non-LSOG	0	5	0	77	18
FLO23	Matrix/non-LSOG	0	23	0	73	4
FLO24	Reserve/LSOG	73	2	4	6	15
FLO25	Reserve/LSOG	96	1	0	0	3
FLO26	Reserve/LSOG	95	1	0	0	4
FLO27	Reserve/LSOG	79	7	0	0	14
Detroit:						
DET21	Matrix/non-LSOG	0	4	9	87	0
DET22	Matrix/LSOG	1	0	74	22	3
Olympic:						
OLY21	Reserve/LSOG	97	3	0	0	0
OLY22	Reserve/LSOG	79	21	0	0	0
OLY23	Reserve/LSOG	100	0	0	0	0
OLY24	Reserve/non-LSOG	25	75	0	0	0

Table 3. Number of habitat elements surveyed with capture/acoustic surveys or bridge surveys within each study area during strategic surveys for bats in the Northwest Forest Plan area 2003 – 2004.

Study Area	Small Creek	Medium Creek	Large Creek	Pond	Lake	Road	Bridge
Peanut[a]	11	22	1	3	1	0	1
Orleans[a]	1	3	7	3	2	6	3
Gasquet	0	3	4	0	0	1	1
Coos Bay	1	3	1	3	0	0	0
Dexter[a]	4	3	8	1	0	0	7
Florence[a]	0	11	0	0	0	7	0
Detroit	1	2	0	0	0	1	0
Olympic	0	5	2	0	1	0	4
Total	18	52	23	10	4	15	16

[a] Does not include habitat elements where acoustic transects were conducted in intensive sample units.

Table 4. Survey type and habitat elements surveyed in 5 intensive sample units during 2003 and 2004.

Survey Type/ Habitat Element	PEA08	PEA23	DEX08	ORL12	FLO24
Capture/Acoustic					
Small Creek	3	1	0	0	0
Medium Creek	3	4	2	2	4
Large Creek	0	0	4	2	0
Pond	0	1	0	1	0
Road	0	0	0	1	2
Acoustic Transect					
Opening	2	2	2	2	0
Road	2	2	2	2	4
Bridge	1	0	2	2	0

Detection of Sensitive Species

Six of the 8 Sensitive Species were well distributed among the study areas we surveyed (Figures C – H). Three species were detected in all 8 study areas: *Myotis californicus* detected during 114 surveys in 39 different sample units (Figure E), *M. volans* detected in 74 surveys in 34 different sample units (Figure H), and *Lasionycteris noctivagans* detected during 76 surveys in 32 different sample units (Figure D). We detected *M. evotis* during 46 surveys 27 different sample units in all but the Gasquet Study Area (Figure F). We detected *M. thysanodes* during 40 surveys at 23 sample units in all but Gasquet and Olympic Study Areas (Figure G). We only detected *Lasiurus cinereus* during 18 surveys, but those detections were distributed over 10 sample units in 6 study areas (all but Coos Bay and Gasquet). We only detected *A. pallidus* during 5 surveys at 3 sample units in the Peanut study area near the southern extent of the NWFP area (Figure A). We detected *C. townsendii* during 5 surveys in different 5 sample units in 2 study areas, Peanut and Dexter (Figure B).

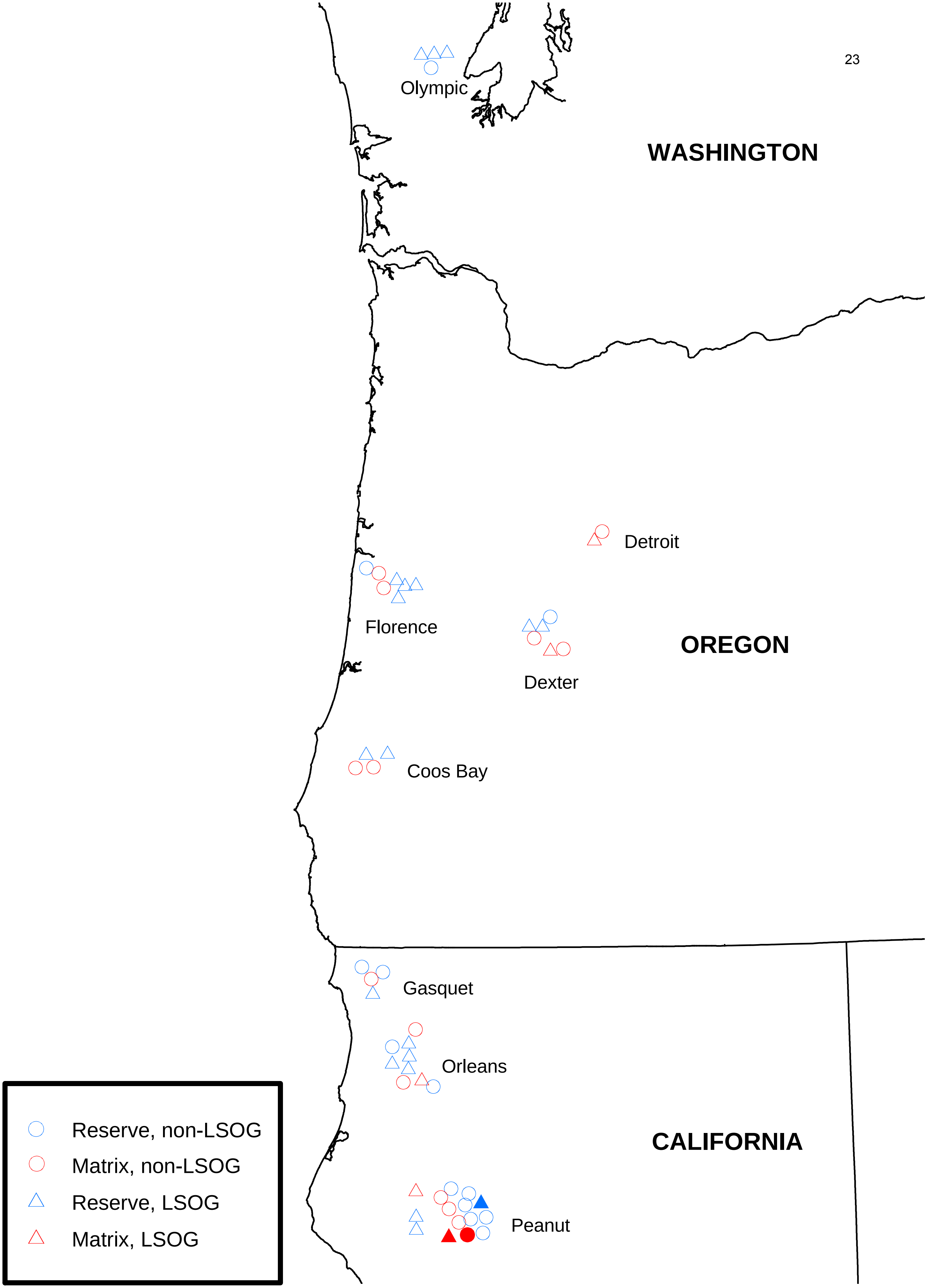

Figure A. Sample unit locations (open symbols) and sample units where *Antrozous pallidus* was detected (filled symbols) during bat surveys in 2003-2004.

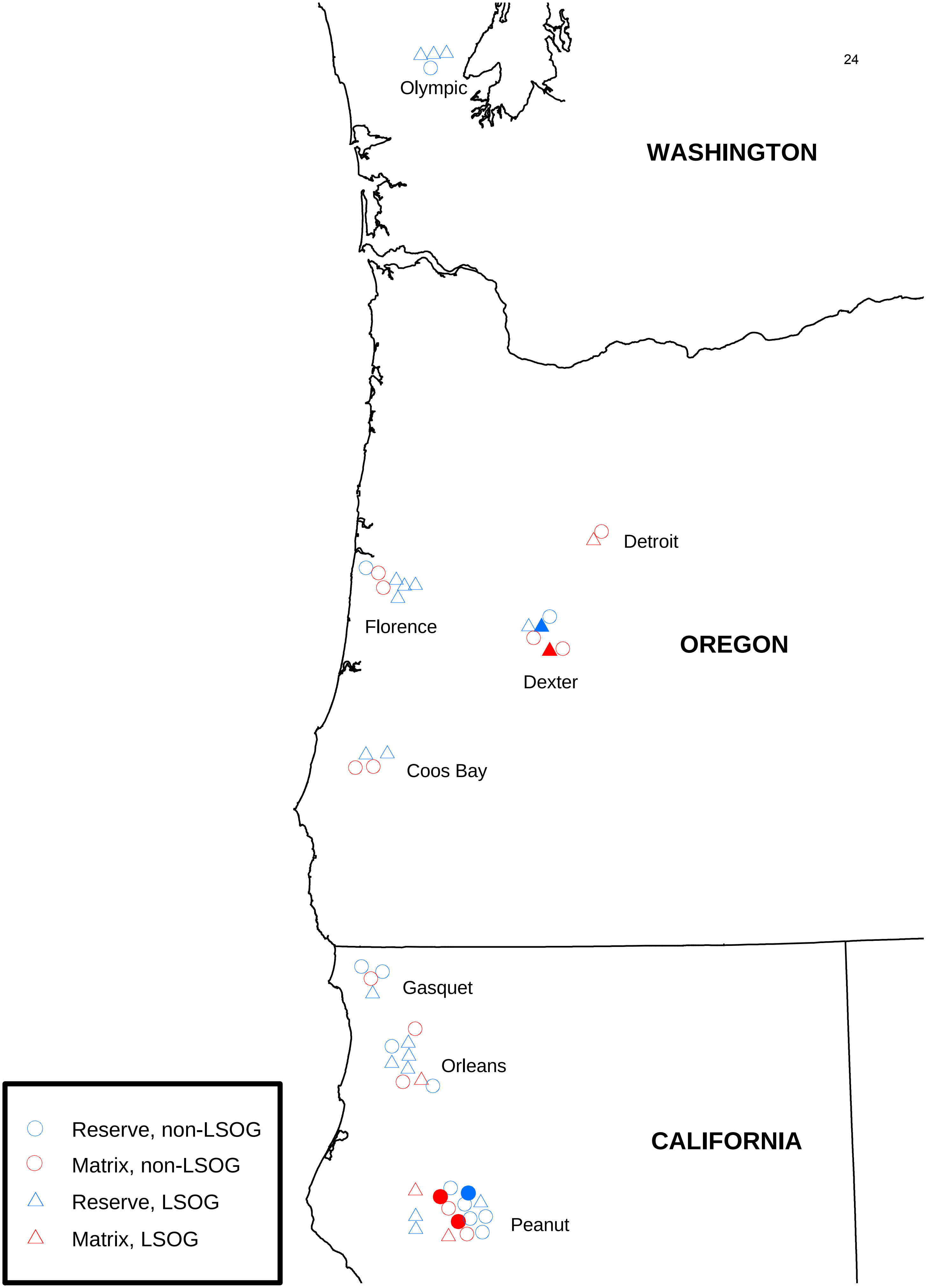

Figure B. Sample unit locations (open symbols) and sample units where *Corynorhinus townsendii* was detected (filled symbols) during bat surveys in 2003-2004.

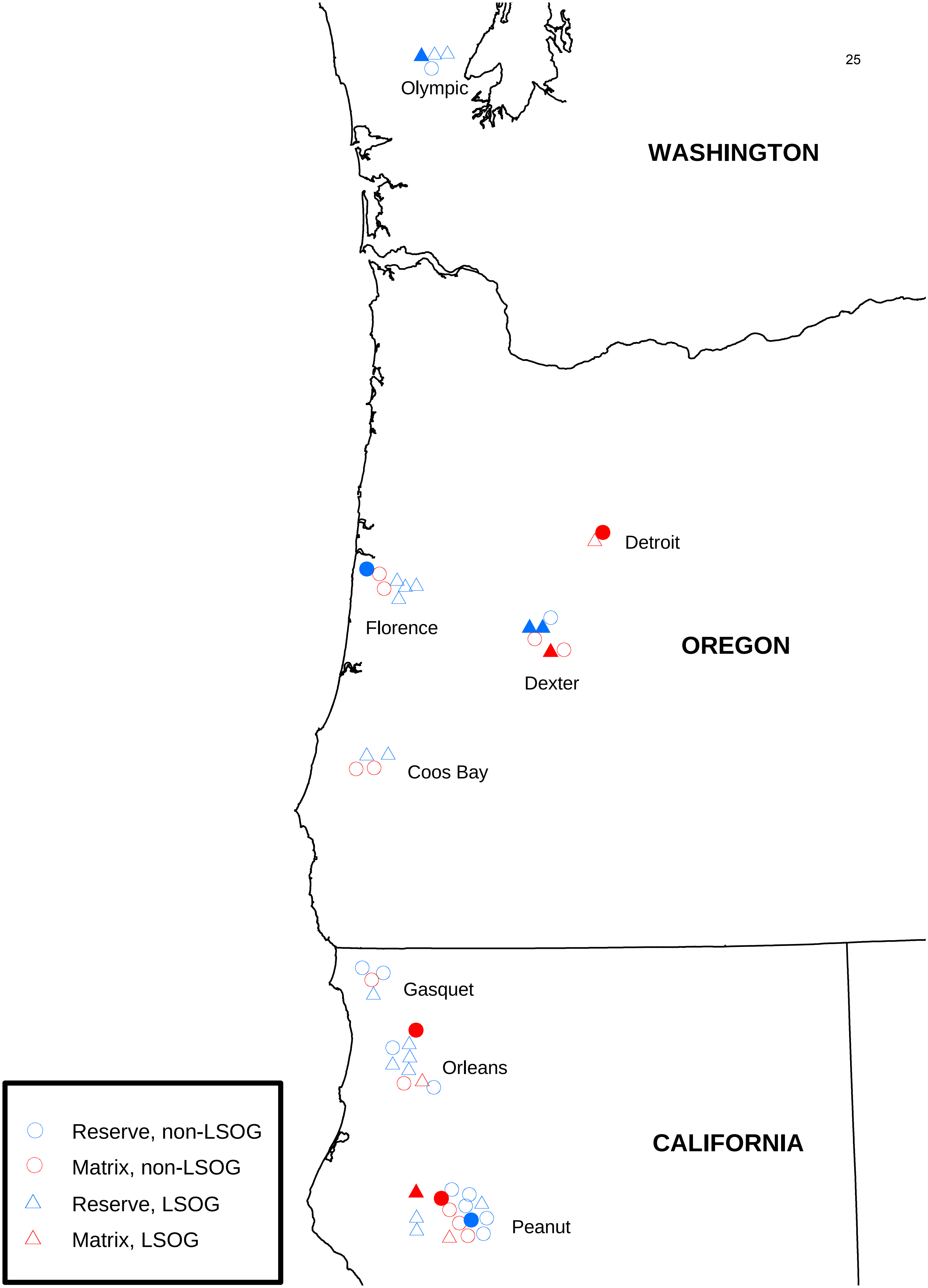

Figure C. Sample unit locations (open symbols) and sample units where *Lasiurus cinereus* was detected (filled symbols) during bat surveys in 2003-2004.

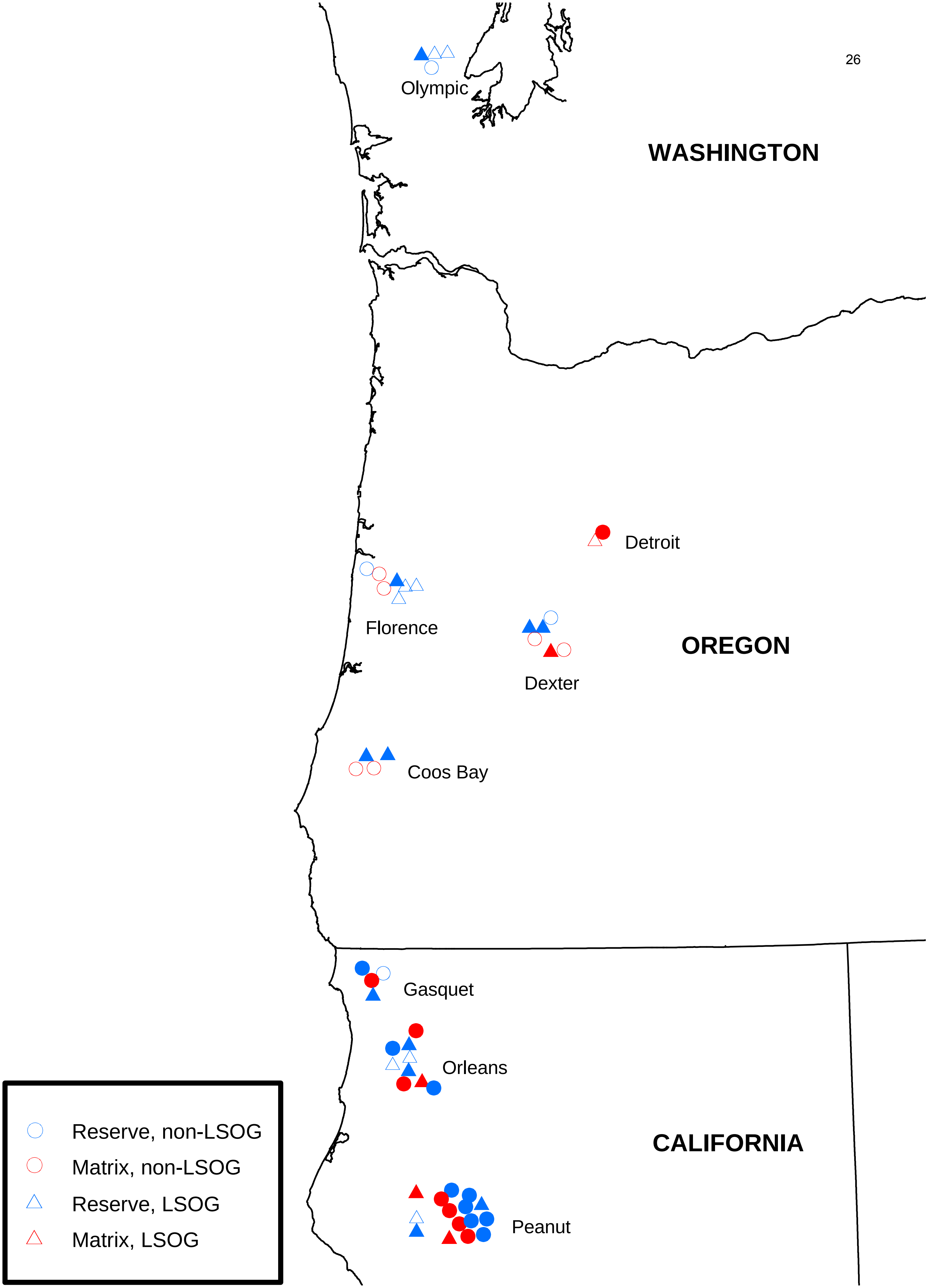

Figure D. Sample unit locations (open symbols) and sample units where *Lasionycteris noctivagans* was detected (filled symbols) during bat surveys in 2003-2004.

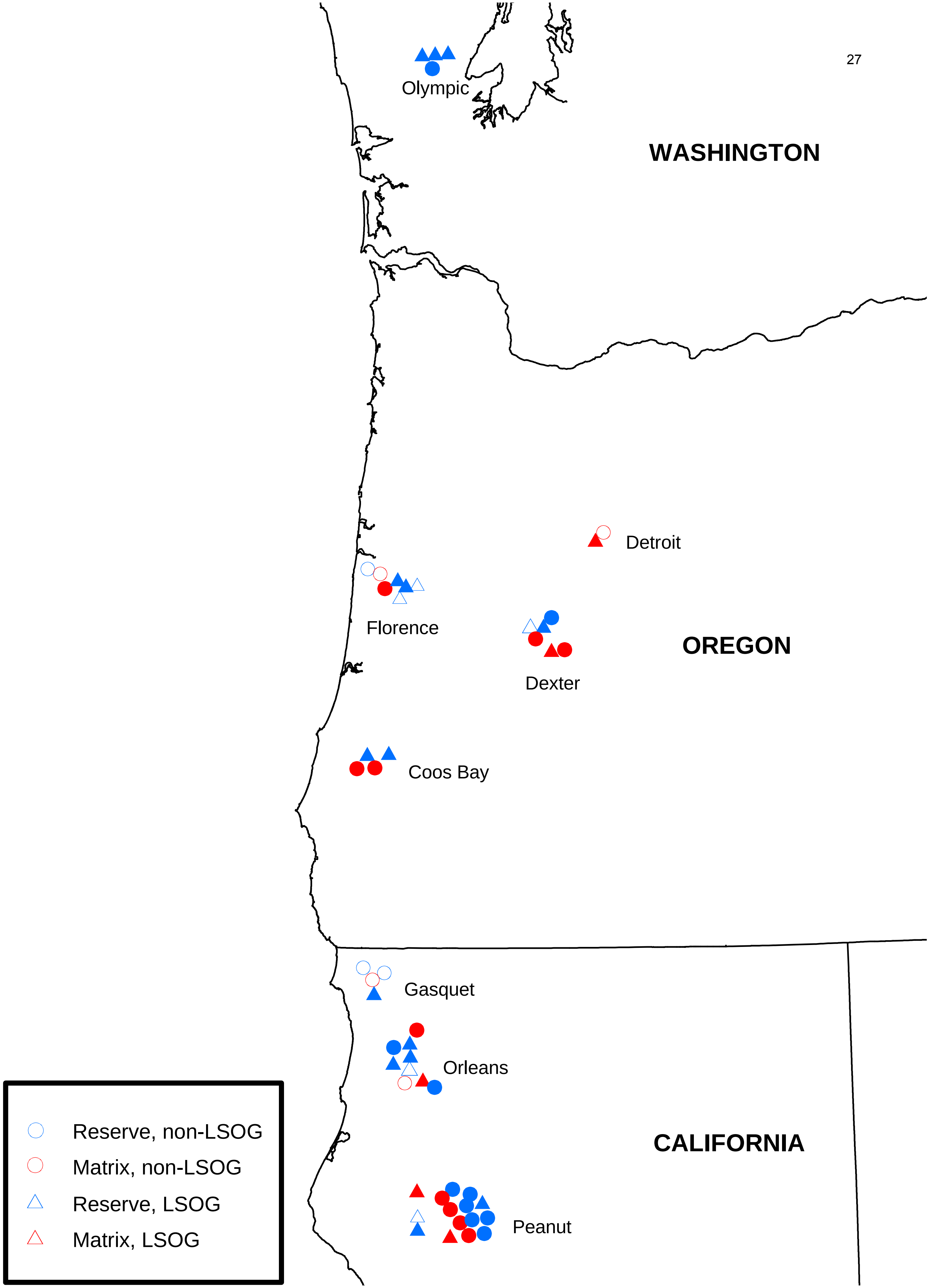

Figure E. Sample unit locations (open symbols) and sample units where *Myotis californicus* was detected (filled symbols) during bat surveys in 2003-2004.