STATE OF WASHINGTON March 2000

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FISH AND WILDLIFE
Wildlife Management Program
Wildlife Research Division

WDFW 677

Final Report

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Suggested Citation:
Watson, J.W., K.R. McAllister, D. J. Pierce, and A. Alvarado. 2000. Ecology of a remnant population of Oregon spotted frogs (*Rana pretiosa*) in Thurston County, Washington. Final Report. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Cover photo by Amy Alvarado

EXECUTIVE SUMMARY

The Oregon spotted frog (*Rana pretiosa*) is listed as a State Endangered species under Washington State law, and is a candidate for listing under the federal Endangered Species Act. The first Oregon spotted frog verified in Washington since 1968 was captured in 1990 along Dempsey Creek, a tributary of the Black River in Thurston County, Washington (McAllister et al. 1993). Only three additional populations of this species are known in Washington. Suggested reasons for population declines include altered hydrology, predation by exotic fish and amphibians, and physiologic effects from changes in water chemistry and ultraviolet radiation (Hayes et al. 1997).

Until recently, virtually all that was known about Oregon spotted frogs was from a study conducted in British Columbia along the Little Campbell River (Licht 1974). In 1996, we initiated a study of Oregon spotted frogs at Dempsey Creek to better understand this species ecology. The Dempsey Creek population was ideal for study because of the mutual interest of the landowner, Port Blakely Tree Farms, Ltd., in developing a better understanding of site-specific characteristics of the frog population. Furthermore, because the study area was grazed throughout the year by about 20 cows, it provided an opportunity to study the effects of grazing on frog habitat. We identified four topics of study: refinement of marking and capture techniques; population characteristics; home range and habitat use; and surveys for new frog populations on tributaries near Dempsey Creek.

Our initial study effort focused on refinement of capture and marking techniques for this species since Oregon spotted frogs are a highly aquatic ranid and difficult to capture (Licht 1986a), and marking techniques for amphibian research are not as well developed compared to other terrestrial wildlife (Ferner 1979). Intensive surveys for frogs revealed that capture success by hand or nets was enhanced by taking slow, infrequent steps in search pools, and scanning the surface of the water for floating or resting frogs before proceeding. Searches also were more productive when temperatures were >4°C (40°F) and under clear skies when frogs surfaced to bask and feed. We captured 568 different frogs at Dempsey Creek from October, 1996 through June, 1999. Thirty-six frogs were marked with numbered fingerling (knee) tags, 462 with subcutaneous passive integrated transponders (PIT-tags), and 60 with VHF transmitters attached to nylon waistbelts. We detected no difference in survival or body weight changes among frogs marked with the different methods ($P \geq 0.315$). However, knee-tags caused serious lacerations on four of 12 (33%) frogs that were recaptured, and this marking method was discontinued after March, 1997. PIT-tags were very effective for long-term marking of frogs, with no observed side-effects. Frogs were monitored via telemetry an average of 57 days (SE = 10), but we were only able to redeploy transmitters on 17 frogs (28%), largely because of transmitter belt slippage (35%) or our inability to recapture frogs before transmitters expired prematurely (21%). Nonetheless, telemetry provided unbiased location information that could not have been gleaned from marking alone.

The second study, Oregon spotted frog population characteristics, was designed to establish population size from egg mass counts, mark-recapture trials, and age class data. During six seasons between 1997-99, we conducted 48 mark-recapture surveys totaling 372 hours. Mark-recapture analyses for closed population models that assumed unequal capture probabilities between survey periods, yielded seasonal population estimates of between 101 to 674 males in the winters from 1997 and 1999, and between 50 and 200 females in fall and spring. Because most mark-recapture estimates were less than the known marked population (e.g., 341 animals), this method underestimated the population. This probably resulted from our failure to sample all frog habitats in the study area, even though our searches were conducted as completely as possible, so we tended to resample a subpopulation with increased numbers of marked frogs. In another mark-recapture analysis, we combined data by year to estimate annual population size using an open model. This analysis provided a more realistic population estimate (514), with reasonable precision (SE = 129), and a realistic annual survival rate (37%). We suggest application of the mark-recapture method for this species could be improved with use of capture methods that eliminate search bias in dense habitats (e.g., crayfish or funnel traps). The second method we used to estimate population size was by counting egg masses, and projecting the number of adults by assuming one egg mass was laid per female and that there was a 1:1 sex ratio of adults. We also estimated the subadult ($\leq$2 yr-old) population, projected from the ratio of subadults to adults that were captured. We differentiated sizes of suspected adults from subadults by measuring the snout-vent length of 27 frogs captured in amplexus. Total population estimates averaged 496 animals and ranged between 410 and 555 individuals for the period 1996-99. We believe estimates from egg mass counts could be improved by determining the annual percent of adult females that do not oviposit. The third method used to estimate the frog population in 1999 combined capture summary data and knowledge of a total lack of recruitment in 1998. This resulted in the highest population estimate of 853 adult frogs. This was a reasonable upper estimate of the Dempsey Creek population, and we conclude, based on the three methods we used, that there were between 500 and 850 adult frogs in the population during the study.

We assessed other population characteristics of Oregon spotted frogs including minimal actual survival rates, annual changes in age cohorts, the association of spring rainfall to juvenile recruitment, individual growth rates, and sources of mortality. Minimal adult survival based on numbers of frogs recaptured from the marked population was 28% in 1997, and 16% in 1998. Proportions of adults in the population based on annual egg mass counts varied from 53% to 67%, and were greatly affected by larval survival from the previous spring. Larval survival, in turn, was related to spring rainfall. Rates at which we encountered juvenile frogs were higher (>1 frog more/hr), though not statistically different (P = 0.146), in years of high rainfall in April and May (12.7 cm/mo) compared to years of low spring rainfall (4.4 cm/mo). However, we believe

these differences would be magnified in true drought years, and that drought conditions in April and May over 2 to 3 years could seriously affect population numbers. Based on recaptures of 88 frogs, we estimated that adult males grew an average of 2.2 mm/yr, and females grew an average of 6.2 mm/yr. Predictive models suggested males ceased to grow at 57.2 mm, and females at 75.9 mm. Growth rates and predicted maximum adult sizes were between those identified for Oregon spotted frogs in British Columbia, and for Columbia spotted frogs at higher elevations and colder climates in Wyoming. Observed mortality of Oregon spotted frogs was rare at Dempsey Creek. Of 11 mortalities identified, four (36%) were attributed to predation by endemic birds and mammals, four (36%) to unknown causes, two (18%) to disease, and one (9%) to humans. No bullfrogs (*Rana catesbeiana*), potential predators of Oregon spotted frogs, were observed at Dempsey Creek.

Our third study used radio-telemetry to investigate the year-long and seasonal distributions of the frog population, to determine the movement patterns and ranges of individuals, and to determine frog selection of habitats. The telemetered population of 60 frogs occupied a range that was a mosaic of 38.5 acres of wetlands and 32.5 acres of upland pasture. Spatial use of the range was closely related to seasonal behaviors and changing surface water conditions. During the breeding season (February through May), frogs occupied $\geq$50% of the population range, and selected shallow, backwater pools for oviposition sites. In the dry season (June through August), shallow pools disappeared and frogs were forced to move up to several hundred meters to deeper remnant pools. Frogs significantly reduced movements, and occupied an average of <10% of their home ranges. During the wet season (September through January) frogs again moved exceptional distances back up drainages and reoccupied the breeding area and peripheral shallow areas. Three frogs, that wintered in shallow water that inundated dense vegetation, buried themselves at the base of plants during the coldest period. We found that different life stages of Oregon spotted frogs had different critical seasons associated with aquatic needs: adequate water levels for egg and tadpole survival were most important in the breeding season; deep pools were most critical for survival of juveniles and adults in the dry season; and adequate water levels over emergent vegetation were important for survival of all age classes during the wet season and coldest time of the year. Further, a topographic gradient with overall gradual relief that maintained adequate water for inter-pool movements was vital to provide for all needs during the annual cycle. We documented only one instance of upland movement by an Oregon spotted frog, and concluded that disjunct, land-locked, shallow breeding pools and deep-water pools do not provide year-round needs of Oregon spotted frogs populations.

Individual frogs exhibited two types of annual movement patterns: infrequent, long-distance movements between widely separated pools, and frequent movement between pools in closer proximity. Home ranges of four frogs averaged 5.4 ac (100% fixed kernels), and on average frogs moved a minimum of 5 m/da (SE =1) throughout the year.

Plant structure within habitat communities, particularly wetlands influenced by grazing, were key influences on frog habitat use at Dempsey Creek. For coarse-scale analysis of habitat selection we used digital imagery to estimate proportions of nine wetland habitats, and determined habitat use from 654 telemetry locations. Frogs avoided dry uplands. Frogs selected sedge (*Carex obnupta, and C. utriculata*)/rush (*Juncus effusus*) habitat during the breeding season, which was closely associated with shallow and ephemeral waters at oviposition pools, and was grazed (i.e., sedge) more intensively by cows relative to other types. Hardhack (*Spiraea douglasii*) was an important emergent vegetation in the hottest part of the dry season as it shaded and maintained the remnant pools. Reed canary-grass (*Phalaris arundinacea*) was widely used (30%), but statistically found to be avoided because of its extensive distribution relative to other types. Microhabitat analysis, $\leq 0.25\ m^2$ from frog locations, showed reed canary-grass communities were used conditionally, depending on the degree of cattle grazing. Grazing created penetrable, open habitat in reed canary-grass communities that were otherwise too dense for frog use. Frogs preferred a moderate to high degree of water surface exposure (i.e., 50% to 75% water), or conversely, a low to moderate degree of emergent vegetation (i.e., 25% to 50%). Consequently, low emergent cover (0% to 25%), potentially resulting from overgrazing, was also unsuitable for frog use. We recommend further study of cattle grazing patterns, possibly through use of radiotelemetry, to investigate the timing and intensity of grazing that are the most beneficial to Oregon spotted frogs in reed canary-grass communities. Additional habitat analysis revealed that subsurface aquatic habitat associated with frog locations was largely (89%) open water, with the remainder submergent plants above a bottom layer of herbs, detritus, and sediment. Throughout the year frogs were located in water that averaged 19.0 cm in depth (mean monthly range = 8.5 cm to 26.2 cm), with average surface temperatures of 14.7 °C (mean monthly range = 5.6 to 19.1 °C) and average subsurface temperatures of 13.4 °C (mean monthly range = 6.1 to 18.5 °C).

Our final study was a survey for Oregon spotted frogs along portions of the Black River and the associated Chehalis River drainage using volunteers and agency personnel. During 58 searches totaling 123 hours Oregon spotted frogs were located at two new locations. The first, at Stony Creek was closely associated with the Dempsey Creek population. The second, at Beaver Creek was significant since it was located 16 km from the known population. Oregon spotted frog surveys, to date, have sampled suitable habitat over much of the Chehalis River basin.
A systematic attempt to identify suitable habitat within the basin should seek to identify habitat with the following features: 1) extensive (at least 20 acres) contiguous and shallow emergent palustrine wetland habitat; 2) low gradient stream course or ditch draining the wetlands; and 3) high seasonal hydrologic fluctuations such that surface water is extensive in winter and early spring, and extremely limited in late summer.

TABLE OF CONTENTS

TABLE OF CONTENTS cont'd.

LIST OF TABLES

LIST OF TABLES cont'd.

LIST OF FIGURES

LIST OF FIGURES cont'd.

LIST OF FIGURES cont'd.

Chapter 1

CAPTURE, MARKING, AND RADIOTELEMETRY

Marking techniques for amphibian research are not as well developed compared to other terrestrial wildlife (Ferner 1979). Traditionally, freeze-branding (Daugherty 1976), photo-identification (Hagstrom 1973), and toe-clipping (Clarke 1972) are some of the techniques used to mark anurans. Toe-clipping is inexpensive and provides unique marks, but the regeneration of toes and opportunity for infection are potential problems (Donnelly et al. 1994). More recent attempts to uniquely mark individuals for population or movement studies include the use of small tags attached with elastic bands above the knee or elbow (Elmberg 1989, Donnelly et al. 1994). This technique provides a durable mark, but increases the risk of the animal becoming ensnared on vegetation or suffering limb abrasions from the band (Elmberg 1989). Recent development of electro-magnetic microchips has resulted in the use of Passive integrated transponders (PIT-tags) as identification tags for amphibians (Donnelly et al. 1994). PIT-tags are inserted under the skin of the animal to avoid potential ensnarement, but they are also comparatively expensive (e.g., $ 5.35 per tag), and may increase the risk of infection (Camper and Dixon 1988).

Use of radio-telemetry for monitoring movements and determining range use of amphibians is also challenging because transmitters and trailing antennas are attached externally, typically around the waste of anurans (Van Gelder et al. 1986, Richards et al. 1994), requiring a precise fit with use of a beaded belt (Rathbun and Murphey 1996). Potential problems include transmitter loss from belts being too loose, or abrasions from the belts being too tight (Richards et al. 1994, Rathbun and Murphey 1996). Telemetry methods for anurans warrant refinement.

Oregon spotted frogs (*Rana pretiosa*) are a highly aquatic ranid (Licht 1986a). Their cryptic coloration, and association with silty substrates and aquatic vegetation make them difficult to locate and capture. To investigate the ecology of Oregon spotted frogs in western Washington in 1996-99, we used experimentation to test field methods necessary to capture, individually mark and identify frogs, and follow them in multiple years. We report here on capture techniques and marking and telemetry methods we found to be successful and unsuccessful to study Oregon Spotted frogs. We also analyze rates of weight change among frogs marked with different techniques to identify possible effects of marking.

STUDY AREA AND METHODS

Dempsey Creek is a tributary of the Black River in central western Washington (Fig. 1.1). The Creek meanders through pastureland, which is bordered by stands of Douglas-Fir (*Pseudotsuga menziesii*). About 4 km southwest of Black Lake, a slow-moving, ephemeral creek flows into a large basin in the floodplain of Dempsey Creek. A remnant population of Oregon spotted frogs inhabited approximately 70 acres that surrounded this portion of Dempsey Creek (Fig. 1.2). About half of this area was upland pasture grazed by dairy cows throughout the year. The

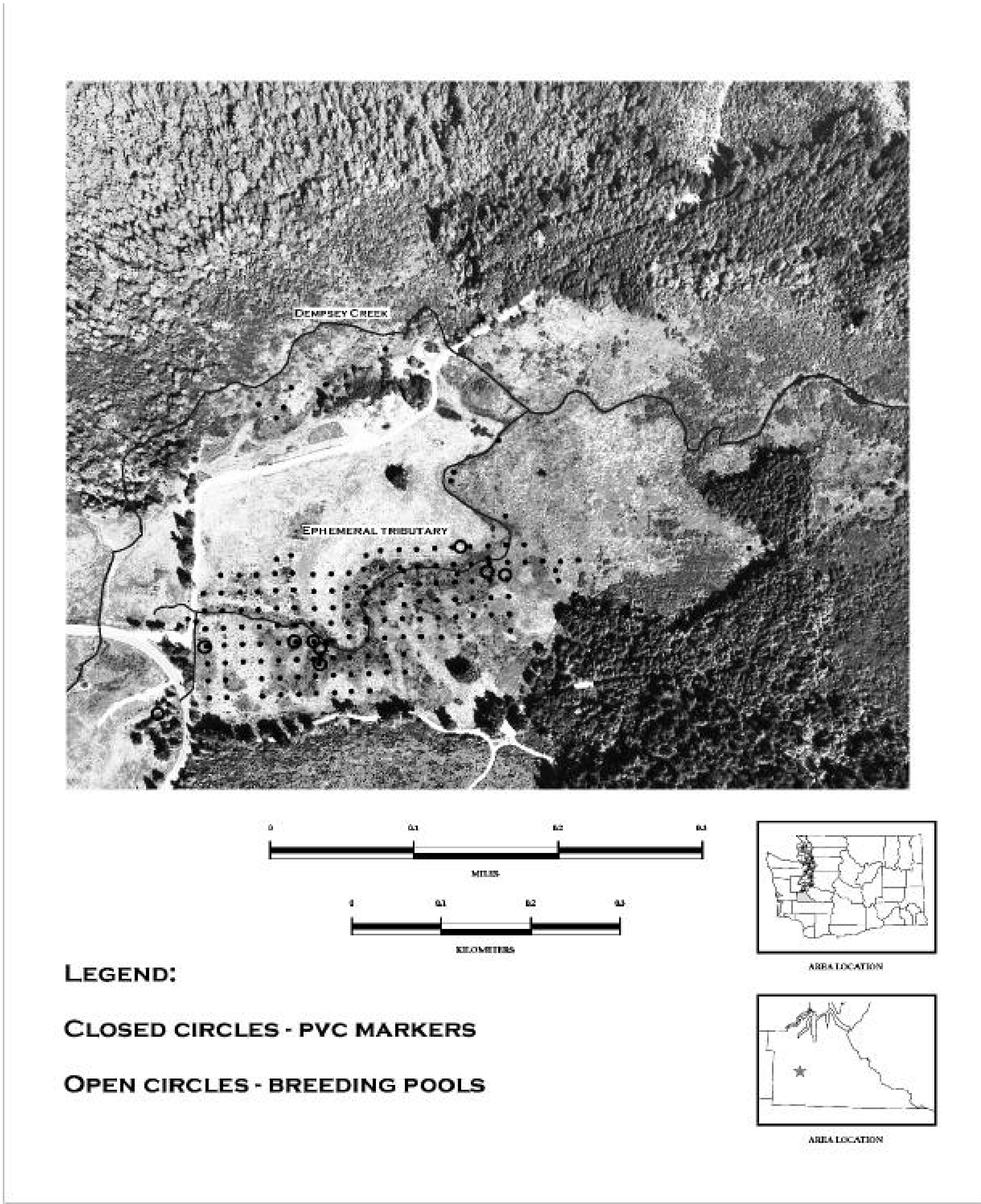


Fig. 1.1. Location of the Dempsey Creek population of Oregon spotted frogs in western Washington.

Fig. 1.2. Views of the Dempsey Creek Oregon spotted frog study area in March (top) and October (bottom).

drainage basin and creek fringes were predominated by emergent vegetation that included slough sedge (*Carex obnupta*), beaked sedge (*C. utriculata*), soft rush (*Juncus effusus*), reed canary-grass (*Phalaris arundinacea*), often existing as floating mats of vegetation, interspersed with both flowing and stagnant open water. Breeding pools were ephemeral depression wetlands in the floodplain of the creek, dominated by creeping buttercup (*Ranunculus repens*) and wall bedstraw (*Galium parisiense*), and fringed by slough sedge and soft rush. Submergent pond water-starwort (*Callitriche stagnalis*) and false loosestrife (*Ludwigia palustris*) dominated the more permanent pools where frogs were often located and captured outside the breeding period.

Frogs were captured when we conducted systematic population sampling (Chapter 2), when we deployed or replaced transmitters for monitoring activities (Chapter 3), and incidentally when we conducted other field activities. We captured frogs by hand and dip nets. Captured frogs were marked with one of two methods (Figs. 1.3, 1.4). Numeric-coded tags were attached over the knee of frogs with elastic thread (Elmberg 1989). On other frogs, 12 mm PIT-tags (Destron, 125 kHz models) were inserted under the dorsal skin through a 2 mm incision (Donnelly et al. 1994). PIT-tags were bathed in rubbing alcohol prior to insertion. No antiseptic was applied to the incision after insertion. PIT-tags were read by scanning with a portable reader. Frogs <42 mm long (snout to vent) were not PIT-tagged because of small size.

Beginning in March, 1997, we attached BD-2 and BD-2G transmitters from *Holohil Systems, Ltd.* to adult male (≥20 g) and adult female (≥30g) frogs with nylon ribbon waistbelts (Figs. 1.3, 1.4). BD-2 transmitters weighed between 0.9 and 1.2 g, had an expected life of 4 to 9 weeks, and were affixed to male frogs. BD-2G transmitters weighed from 1.2 to 2.0 g, had an expected minimum life of 17 weeks, and were affixed to females. Waistbelts were threaded through a tube at the anterior end of the transmitter and the ends stitched with cotton thread. Belts were fitted to provide a snug, but not tight fit, which allowed the transmitter to be manually removed from the frog when its legs were fully extended. Ends of the ribbon belt were sealed with a lighted match to prevent unraveling. Telemetered frogs were also marked with PIT-tags.

Captured frogs were put in holding containers. Frogs were weighed (g), measured (snout to vent, mm), marked, and telemetered. Gender of frogs >1.5 years of age was determined by the presence or absence of nuptial pads. Distance (m) and compass bearing from the capture location to the nearest gridpost (see Chapter 2) were recorded. Processing took <30 min, and frogs were released at capture locations.

We conducted two analyses to compare effects of marking techniques on frogs. First, we compared recapture rates (i.e., recaptured vs. not recaptured) of frogs marked by knee tags and PIT-tags using chi-square contingency analysis. Significant differences might indicate adverse effects on frog health or survival. Incidental recaptures of telemetered frogs were not recorded separately from telemetry relocations so we had to exclude this marking technique from this analysis. Secondly, for marked and telemetered frogs that were captured at least twice, we analyzed the weight change between the initial capture and last recapture when they were ≥14 days apart.

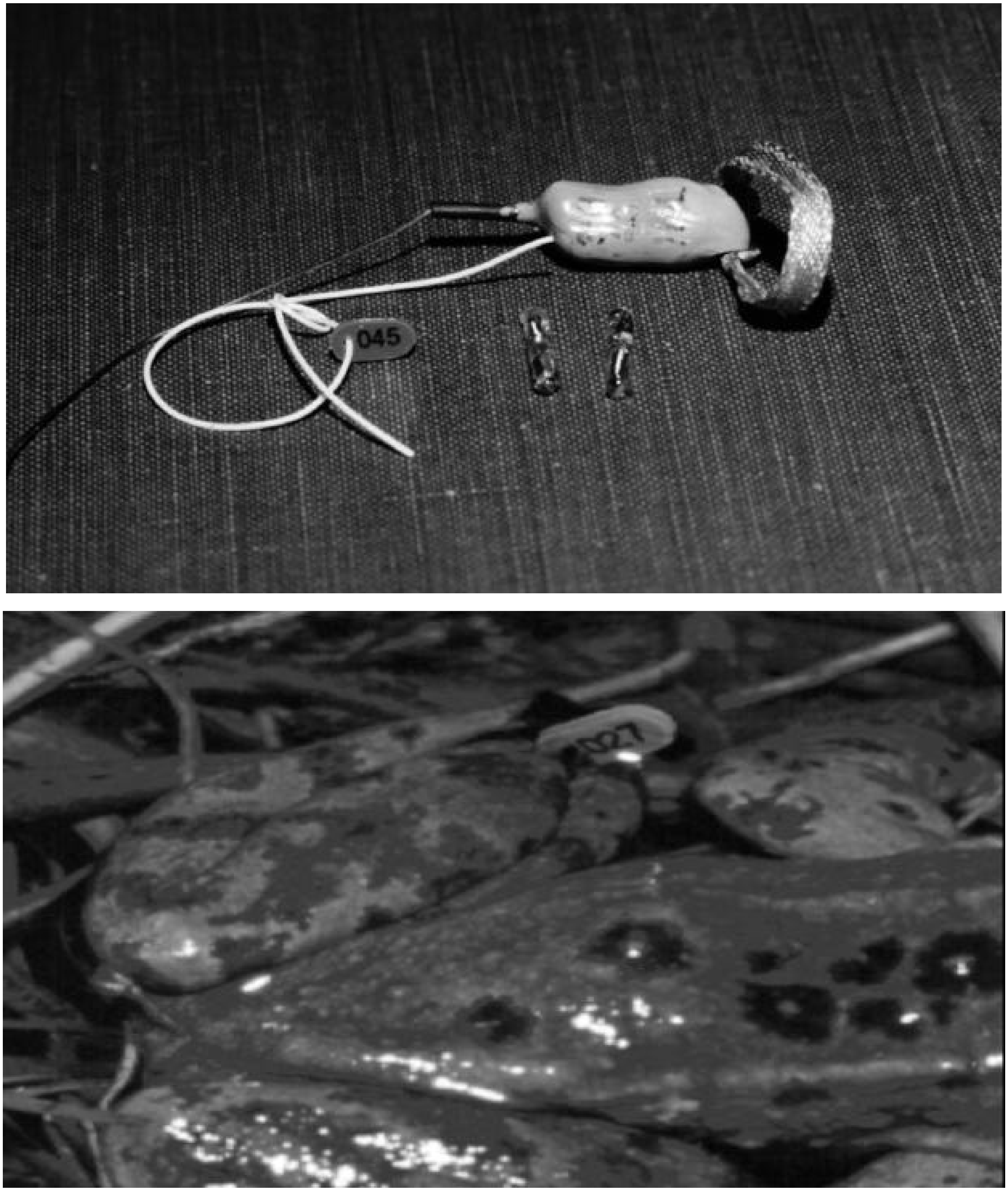


Fig. 1.3. Markers used to monitor Oregon spotted frogs at Dempsey Creek, Washington. (Top) Knee-tag, passive integrated transponders (PIT-tags), and VHF transmitter with nylon attachment belt. (Bottom) Knee-tagged adult male *Rana pretiosa*.

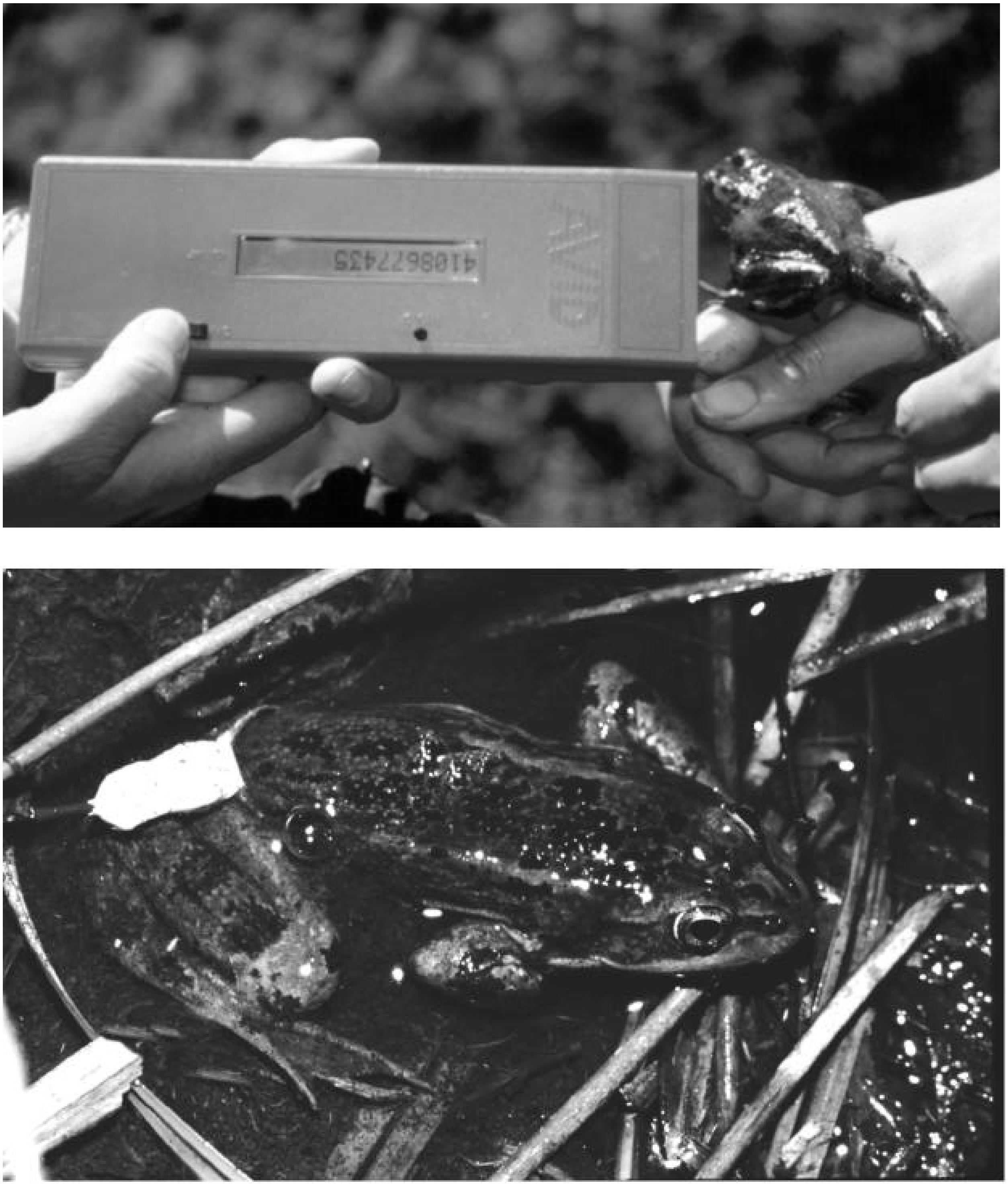


Fig. 1.4. Methods used to identify individual Oregon spotted frogs at Dempsey Creek, Washington. (Top) PIT-tag reader identifying code of tag located subcutaneously in frogs dorsum. (Bottom) VHF transmitter attached to frog's waist with a nylon belt.

Natural fluctuations in weight would be expected throughout the year reflecting prey availability, age-influenced growth potential, and the reproductive cycle (Turner 1960). We assumed adverse effects of markers or transmitters, relative to each other, would be reflected by differences in rates of weight change. Weight changes were classified according to the season that encompassed the first and last capture of each frog: breeding (February through May); dry (June through August); wet (September - January); and annual (1-year beginning in spring or fall). Weight of each animal was not determined at the beginning and end of the entire period and thus rates of weight change reflected the trend and not the absolute rate of weight change during that season. For PIT-tagged and telemetered frogs, we compared mean seasonal weight changes with Student's t-tests. Small samples of knee-tagged frogs precluded quantitative comparisons of weight change with PIT-tagged and telemetered frogs.

RESULTS

Capture and Marking Summary

We identified 568 different frogs during 980 captures from October, 1996 through June, 1999. Males accounted for 49% of 535 frogs for which gender was identified, and females 51%. Because frogs congregated at locations that varied by season, the opportunity to capture frogs was enhanced by knowledge of where to search. Male frogs, in particular, were congregated at breeding pools in February and early March, while females were often congregated at basking pools after March. Capture success was affected by season, and weather. When temperatures were near or below 4°C (40°F), particularly from February through June, frogs typically did not surface. In the spring period, bright sunlight, even for a few minutes, caused frogs to surface *en masse*. We found that slow, calculated steps, followed by a thorough visual scan of the surrounding water and vegetation for surfaced frogs, was a better search technique than constant walking through the search area. Because Oregon spotted frogs generally floated at the water's surface, they were quick to dive and avoid capture when located. Typically, frogs were easily captured by hand during winter in the cool water, but warmer water and greater mobility of frogs in the summer necessitated use of dip nets for capture. Frogs missed on initial capture efforts could many times be captured several minutes later by revisiting the pool.

Thirty-six frogs were knee-tagged in fall, 1996 and spring, 1997. Twelve of these frogs (33%) were seen again after their initial release. In spite of careful application, deep skin and tissue lacerations from the attaching thread were observed on four of 12 knee-tagged frogs that were recaptured. One frog died in captivity, and the lower leg of another was amputated and the frog later released. The other two frogs healed in captivity. We removed knee tags from these frogs, and from six of the remaining eight uninjured frogs, then PIT-tagged and released them. Two of these frogs were recaptured in 1999 and appeared healthy. Knee-tagging was discontinued after March, 1997.

We PIT-tagged 462 frogs that were neither knee-tagged nor telemetered. One hundred eighty-five (40%) of these frogs were captured again after their initial release. No signs of infection were observed on recaptured PIT-tagged frogs; however, subcutaneous PIT-tags had moved ventrally on at least two recaptured frogs with no known effects. The PIT scanner identified these as marked frogs in spite of the fact we did not initially see the tags in the usual location.

Sixty frogs were telemetered and monitored between February, 1997 and January, 1999. Frogs were monitored for an average of 57 days (SE = 10). Fifty-seven of these frogs were also PIT-tagged. Thirty-nine frogs (65%) were telemetered once, and eight of these frogs were not detected again via telemetry after their initial release. Transmitters were deployed more than once on the remaining 21 frogs either prior to expiration of the original transmitter, or after their transmitters had slipped off. This included 13 frogs (22%) that were telemetered twice, five frogs (8%) that were telemetered three times, two frogs (3%) telemetered four times, and one frog (2%) telemetered five times. Of the original 60 transmitters that were deployed, 21 (35%) slipped off of the frogs after transmitting from 1 to 50 days (transmitters were redeployed on four of these frogs that were recaptured). Seventeen (28%) transmitters remained attached to frogs and were replaced prior to expiration of their batteries, 13 (21%) expired prematurely before frogs could be recaptured, five (8%) were recovered on dead frogs, three (5%) were removed from frogs because of belt lacerations, and one (2%) transmitter was removed because of antenna entanglement in vegetation. Death of at least one frog was likely related to ensnarement of the transmitter antenna in thick vegetation. Another telemetered frog was eaten by a common garter snake (*Thamnophis sirtalis*) after the second transmitter deployment. We noted this frog was lethargic upon release, possibly a result of handling. Its death was not believed to have resulted from effects of the transmitter.

Comparative Effects of Marker Type

We detected no difference in survival of frogs marked with knee-tags and PIT-tags. The proportion of frogs that were knee-tagged and recaptured at least once (31% of 36) was not different from frogs that were PIT-tagged (40% of 462; $P = 0.315$). We did not detect intra-seasonal differences in rates of weight change for PIT-tagged frogs and telemetered frogs. In the breeding season there was no difference in the rate of weight gain between PIT-tagged frogs ($n = 23$) and telemetered frogs ($n = 11$; $P = 0.429$). Average rate of weight gain for these 34 frogs was 0.41 g/wk (SE = 0.08) over an average of 43 days (SE = 4). In the dry season there was no difference in the rate of weight gain between PIT-tagged frogs ($n = 7$) and telemetered frogs ($n = 9$; $P = 0.586$). Average rate of weight gain for these 16 frogs was 0.49 g/wk (SE = 0.08) over an average of 139 days (SE = 15). In the wet season there was no difference in the rate of weight gain between PIT-tagged frogs ($n = 7$) and telemetered frogs ($n = 3$; $P = 0.730$). Average rate of weight gain for these 10 frogs was 0.79 g/wk (SE = 0.14) over an average of 38 days (SE = 7). For 37 frogs recaptured 1 year following marking (i.e., $\bar{x}$ days between capture and recapture = 351, SE = 6), average weight gain was 0.07 g/wk (SE = 0.02). Small samples of knee-tagged frogs ($n = 2$) and telemetered frogs ($n = 1$) precluded analysis of differences among frogs marked over 1 year. However, both knee tagged frogs lost weight ($\bar{x} = -0.02$ g/wk, SE = 0.03) as did the telemetered frog ($\bar{x} = -0.08$ g/wk).

DISCUSSION

Intensive capture and marking of Oregon spotted frogs at Dempsey Creek revealed several points that will improve searches and marking techniques in future field studies of this species. First, Oregon spotted frog activity, and hence visibility, were greatly influenced by water conditions (e.g., depth and temperature). Captures were enhanced by taking slow, infrequent steps in search pools, and scanning the surface of the water for floating or resting frogs before proceeding. The escape behavior of this species is to dive immediately and submerge in the nearest water (Licht 1986a). If frogs weren't captured on the surface or immediately after they dove they were infrequently captured since they swam away quickly into concealment cover. Even after locating frogs via radiotelemetry, we were unable to see 52% of them, half of which were in water <20 cm (8 inches) deep (Chapter 3).

Searches also were more productive when temperatures were >4°C (40°F) and under clear skies when frogs surfaced to bask and feed. While the presence of egg masses from February through early April in Washington is a confirmation of frog presence (Leonard 1997, Chapter 2), use of these techniques in summer or fall when egg masses are absent will enhance searches for new populations. On many occasions at Dempsey Creek, searches that lasted several hours and under less than ideal conditions were unproductive. Without knowledge of the existence of the population we could have easily assumed there were no frogs on the study area.

For marking techniques, we found knee-tags attached to frogs with elastic thread to be an unacceptable means of long-term population monitoring of Oregon spotted frogs. Although great care was taken to adjust markers, skin and muscle lacerations resulted on some frogs. Elmberg (1989) was able to eliminate cuts and abrasions on common frogs (*Rana temporaria*) during the second year of marking with knee tags by adjusting the degree of thread tightness. While some Oregon spotted frogs in our study showed no ill-effects from knee-tags up to a year after marking, we recommend against use of this marker, particularly in light of the endangered status of the species, and suggest PIT-tags are much less invasive. PIT-tag injuries were not identified in our study, nor was marker loss detected. Pit-tagging of spotted frogs in Nevada and red-legged frogs (*Rana aurora*) in California resulted in no detectable injuries and high marker retention (J.K. Reaser, N. Scott, pers. comm.). This technique reduces the likelihood of marker loss compared to toe-clipping since toes may regenerate (Turner 1960) or be lost to predators and confused with research marks. Further, PIT-tagging may be useful for population studies (Donnelly et al. 1994, Chapter 2), and for understanding habitat use (Chapter 3).

The other marking technique we used, radio-telemetry, was valuable for understanding movements and home range use of individuals (Chapter 3), but the need to use this technique should be weighed carefully in light of the high rate of loss (35%) and actual or potential injury to frogs (≥10%). Rates of transmitter loss and injury were higher than those experienced in a study of red-legged frogs where beaded chains were used to attach transmitters (i.e., 27% loss and ≤ 5% mortality; Rathbun and Murphey 1996). We considered use of beaded chains but felt that the chain was heavier than nylon ribbon, potentially more abrasive to the skin, and provided too little flexibility in size adjustment.

Chapter 2

POPULATION CHARACTERISTICS

The Oregon spotted frog (*Rana pretiosa*) is a rare and declining amphibian. In Washington, searches of eleven historically documented sites found only one extant population, suggesting extinction of over 90% of historic populations (McAllister et al. 1993). Three populations that were not documented historically have been found in recent years; two in the southern Puget Sound region, and one in the southern Cascade Mountains. Consequently, the Oregon spotted frog is listed as a State Endangered species under Washington State law, and is a candidate for listing under the federal Endangered Species Act. An understanding of the factors that limit populations is critical to conserving existing populations and establishing new populations to recover this species.

The most detailed investigation of the life history and population characteristics of Oregon spotted frogs was conducted by Licht (1974). His study alluded to the effects of rainfall on juvenile recruitment in southwestern British Columbia, and included an assessment of survival rates for eggs, tadpoles, juveniles, and adults. He identified two oviposition habitats with varied survivability of young; a seasonal pond where <1% of eggs survived to metamorphosis due, in part, to death of tadpoles when the pond dried up before tadpoles could metamorphose; and riverine habitat where water was retained year-round and where frogs metamorphosed from an estimated >5% of eggs that were laid. Licht's study, despite the researcher's translocation of egg masses from drying pools to deeper water, showed how Oregon spotted frog reproductive success was linked to rainfall, primarily due to susceptibility of eggs to stranding with dropping water levels.

One of the isolated populations of Oregon spotted frogs in Washington, at Dempsey Creek, was first discovered in 1990 (McAllister et al. 1993). The core of this population resides within a 29-ha area that includes emergent wetland habitat in the floodplain of Dempsey Creek and unnamed seasonal tributaries, all of which flow into the Black River in Thurston County (Fig. 2.1). Upland pastures and ephemeral wetlands are grazed by cows throughout the year.

In spring, 1995, we initiated efforts to determine the distribution and size of the Dempsey Creek Oregon spotted frog population. Searches for oviposition sites were conducted in the ephemeral depressions adjacent to the uplands to count egg masses and provide a measure of reproductive effort. Because individual frogs were rarely encountered incidentally, we recognized that an intensive and methodical approach was needed to evaluate characteristics of this population. We initiated this study to estimate size of the Dempsey Creek Oregon spotted frog population from egg mass counts, mark-recapture trials, and age class data. Here, we compare the estimates of each method and provide an assessment of individual growth rates and longevity of frogs captured over multiple years. We also analyze the association of spring rainfall to juvenile recruitment, and also report on frog malformations and sources of mortality.

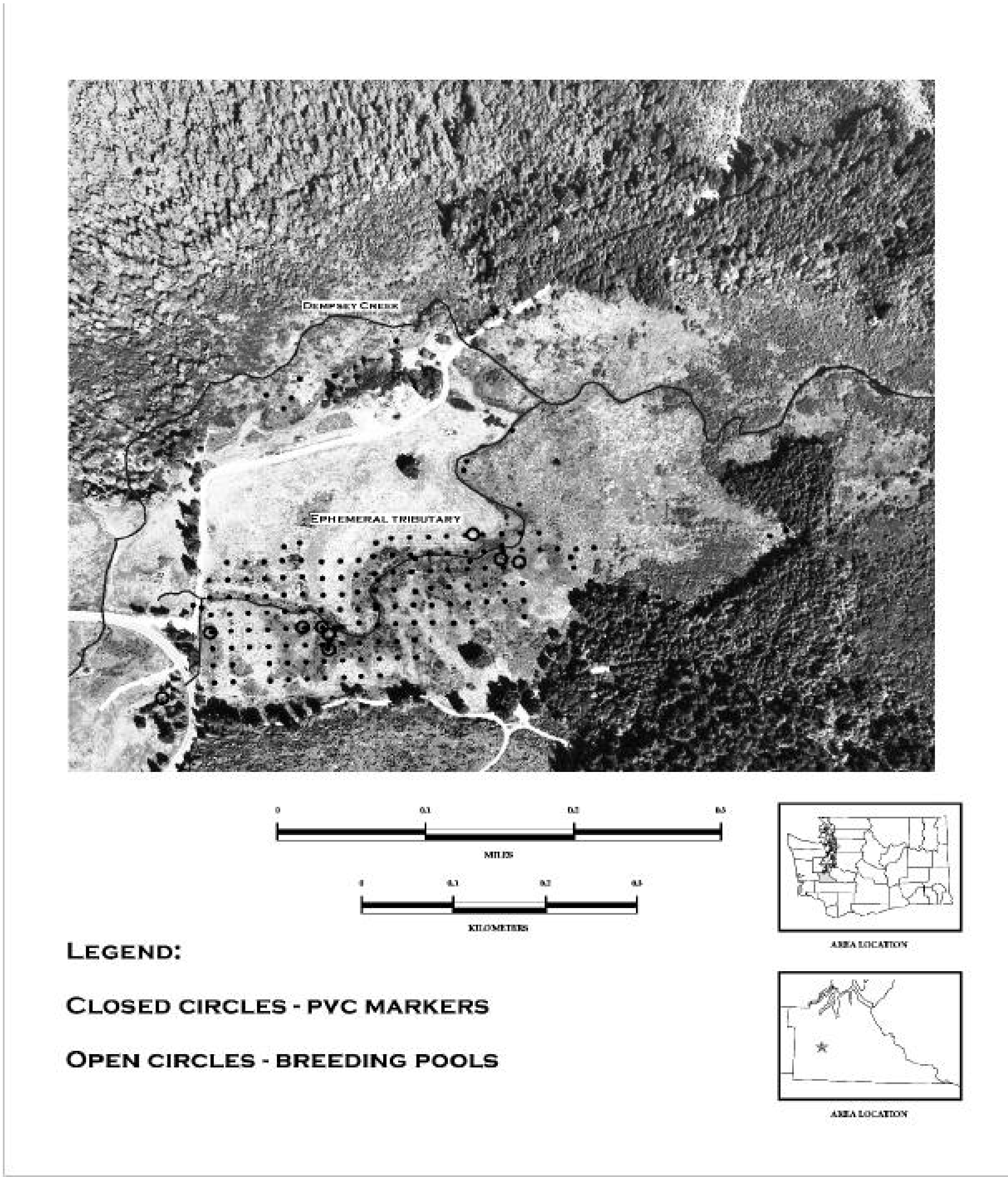


Fig. 2.1. Location of the Oregon spotted frog study area along Dempsey Creek, Washington. Locations of major breeding pools and grid post markers are indicated.

METHODS

Population Estimation

Beginning October 1996, and through March, 1997, we captured frogs opportunistically during non-systematic searches to test marking methods (Chapter 1). All frogs that were captured were marked, except for juveniles <42 mm long (snout-vent length, SVL). Numbered, plastic fingerling tags were used initially but abandoned because they caused severe lacerations on some frogs (Chapter 1). All frogs captured thereafter were marked with Passive Integrated Transponders (PIT-tags) which were inserted beneath the skin via a small (2-3 mm) cut along the dorsum (Chapter 1). Prior to release each frog was measured (SVL) to the nearest millimeter and weighed to the nearest 0.5 gram.

To geographically locate frogs in the study area, we established a 200 x 400 m grid in the core of the study area (Fig. 2.1). Grid posts were located 20 m apart. Additional posts were added at selected points throughout the study area to provide reference locations for frogs located away from the grid area. Coordinates of marker posts were determined using a Trimble Global Positioning System with real-time correction capability. Frog locations were then calculated based on distance and direction from the marker post locations.

We estimated the size of the Dempsey Creek Oregon spotted frog population in three ways. First, the size of the adult population was assessed from mark-recapture surveys in the spring and fall of 1997 and 1998, and winters of 1998 and 1999. Mark and recapture surveys lasted from 0.5 to 8.0 hrs, and most were conducted by four to seven biologists who waded creeks, flooded uplands, and palustrine wetlands. Each survey included biologists that were experienced and inexperienced in capturing Oregon spotted frogs. We avoided searches on days with inclement weather (e.g., <40°F and precipitation) when frogs were unlikely to surface (chapter 1). We excluded dry, upland pastures from most searches. However, one survey day during each of the spring and fall mark-recapture efforts was devoted to searching all accessible habitat within the study area. We assumed that all frogs in the population had an equal probability of capture and that marking had no influence on the probability of capture. Frogs were captured and marked when at least in their second active season (i.e.,$\geq$42 mm SVL), and their history recorded as new or previous capture. For purposes of population estimation, frogs recaptured during testing of marking methods and telemetry studies (i.e., October 1996 - March 1997) and incidental to daily field activities were considered first-time captures during mark-recapture surveys. We included telemetered frogs (Chapter 3) in the recapture sample even though our ability to detect frogs was potentially increased due to transmitters.

Capture and recapture data were analyzed using GLIM (Francis et al. 1993). The GLIM macro developed by Cormack (1985) was used as the basis for deriving all capture-recapture estimates. We selected a multiple recapture model (i.e., M_o per Otis et al. 1978, Schnable 1938) to allow for varying capture probabilities among capture periods. Individual capture days during each winter, spring, and fall were grouped to three periods to minimize the number of empty capture histories, and maintain at least four animals with recaptures as required by the model (Robson and Regier

1964). On average, surveys for a given period were 7 days apart (maximum = 20 days). We considered this period brief enough to negate death/emigration and birth/immigration to the population, and estimated the size of the population each season based on closed population models. We also estimated annual population size and survival using an open population model. Capture data for all seasons were combined for each year, to give 3 sampling periods (i.e., 1997, 1998, and 1999). For seasonal and annual population estimates we did not assume constant sampling effort in each period, and reported estimated parameters for the second period, since those of those of the first and third periods cannot be estimated (Cormack 1985). We report the standard error of the population estimate, but recognize its limited value because estimates of biological parameters have highly skewed distributions (Cormack 1985, Pollock et al. 1990). Variances used to determine standard errors were calculated from the following formula (Chapman 1952):

$$Var(\hat{N}) = \hat{N}^2 \left[\frac{\hat{N}}{\sum_{i=2}^{k} n_i M_i} + 2\frac{\hat{N}^2}{\left(\sum_{i=2}^{k} n_i M_i\right)^2} + 6\frac{\hat{N}^3}{\left(\sum_{i=2}^{k} n_i M_i\right)^3} \right]$$

where n_i = no. of frogs caught in period *i*
M_i = no. of marked frogs available in period *i*
K = no. of capture periods (i.e., K = 3)

We tested the relevance of "catch happy" individuals to 1997 population estimates by examining standardized residuals of the data (Cormack 1985). Potential "catch happy" individuals were identified when standardized residuals were >1.0. Removal of these individuals from calculations did not change population estimates so we included all individuals for the final analyses.

For the second method of population estimation we tallied egg masses in oviposition sites to estimate size of the adult cohort, and the proportion of adult frogs captured and marked during systematic and non-systematic searches in a given year to estimate the subadult cohort. Oviposition sites were surveyed and monitored from 1995-1998. We searched shallow pools and wetland margins to enumerate egg masses. Egg mass counts are a common and time-efficient means of assessing adult frog populations (Olson and Leonard 1997). We assumed a single egg mass was produced by each adult female each year, and that there was a 1:1 sex ratio of adult females to adult males, so the breeding adult segment of the population was twice the number of egg masses. We planned to derive the actual ratio of female numbers to egg masses from mark-recapture estimates, but mark-recapture estimates were too few and variable for that analysis. Because the proportion of adults that did not breed was unknown, the size of the adult cohort was likely underestimated by this method. Classification of captured frogs into adult and subadult age classes was based on snout-vent lengths of the sample of adult frogs found in amplexus. Frogs were classified as subadults if they were smaller than the smallest frog of the same sex captured while in amplexus (i.e., males <49mm, females <62 mm). We assumed there was equal catchability of adult and subadult frogs. The following formula was used to estimate annual population size:

Population size = adult cohort + subadult cohort

where adult cohort = 2 (egg mass count)
subadult cohort = adult cohort (% of subadults in captures / % of adults in captures)

The third method we used to estimate adult population size was based on the number of frogs known to be alive during one season (i.e., 1998), the fact that there was a lack of recruitment of new individuals that same season due to low rainfall, and our knowledge of the proportion of those individuals in the captured population the following season (i.e., 1999). Since recruitment was observed to be negligible in 1998, we assumed that all of the frogs captured in 1999 were alive and large enough to be marked during 1998. The following formula was used to estimate population size:

population size = # individuals captured in 1998 /
proportion of individuals captured in 1999 also captured in 1998

Population Dynamics

We estimated minimum annual survival of the adult population for 1996-98 by calculating the proportion of adults known to be alive in years following capture. We also estimated average annual survival (ϕ) for the second sampling period (i.e., 1998) from mark-recapture data using the GLIM macro (Cormack 1985).

To summarize aspects of population trends, growth, longevity, and rainfall associations to productivity, it was necessary to further identify age classes of captured frogs during different times of the year. Frog searches of irregular frequency and duration occurred annually from 1994-99 (Appendix, Table 1). Searches in 1994 started in May upon discovery of the population's core habitat. Beginning in 1995, searches were conducted throughout the study area, focusing on breeding pools from late February through April and in areas of more permanent wetland habitat from May through October. Visits in 1997 and 1998 increased due to the implementation of habitat and population studies. Three age classes were recognized: hatch-year, second-year, and adults $\geq$3 years. Hatch-year frogs were readily recognizable throughout their first year by their distinctly small size and could be accurately classified to age cohort. Second-year frogs were less easily distinguished from the older age cohorts. To identify second-year frogs, we retrospectively plotted SVL against month and day of capture to track this age class until it merged with 3rd year plus age classes (Fig. 2.2). To reduce the possibility of misclassification of second-year frogs, we used a conservative approach and assigned an age cohort classification only when there was a high probability of accuracy.

To determine if growth rates of adult frogs were correlated with frog size, we calculated growth rates by dividing the increase in SVL (mm) between the first and last capture by the number of days between captures. We regressed growth rates on initial frog length for each sex using linear regression. Predictive modeling was used to estimate the length of frogs at which growth ceased.

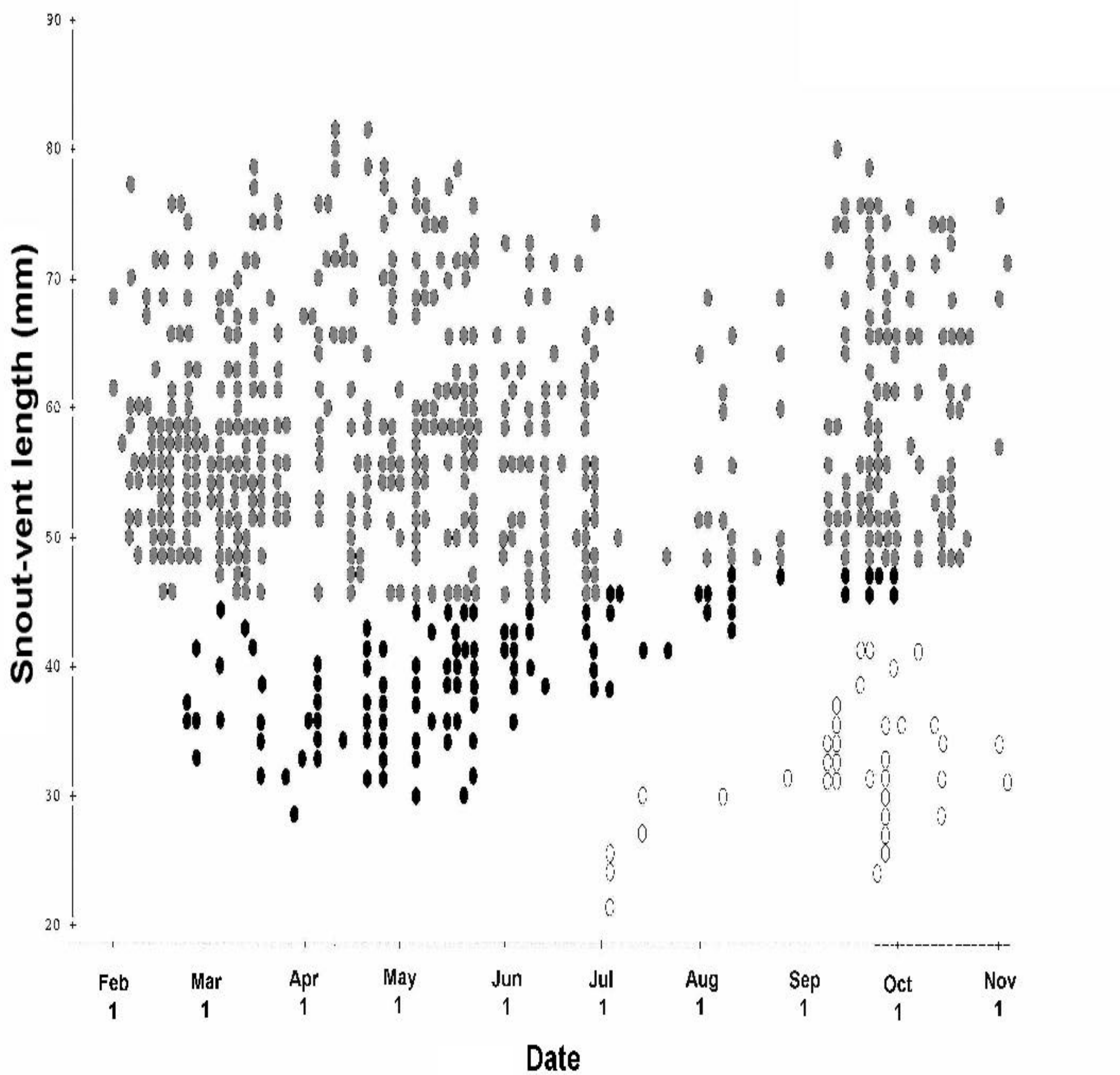


Fig. 2.2. Distribution of snout-vent lengths of Oregon spotted frogs captured and measured at Dempsey Creek, Washington, 1994-99. Open ovals represent hatch-year frogs. Black ovals represent a conservative classification of second-year frogs. Gray ovals are frogs ≥3 years.

Rates at which we encountered hatch-year and second-year juvenile frogs were calculated by dividing numbers of frogs encountered by search time (hrs) during each season. Encounter rates were calculated for each year from 1993 through 1998. For 1994-98 we were able to follow and classify the same cohort through the two juvenile age classes, hatch-year and second-year. Because the study was initiated in May, 1994, observations of hatch-year juveniles were lacking for the 1993 cohort. Observations of numbers of second-year juveniles from the 1998 cohort were terminated at the end of the study period, June 30, 1999. To assess the relationship between rainfall and juvenile recruitment, monthly rainfall totals were obtained for each year from data collected at the Olympia airport, 9 km from the study site. Early spring rainfall (April-May) was subjectively categorized as low (<7.6 cm/mo) or high (>7.6 cm/mo). Juvenile encounter rates were compared for years with high and low early spring rainfall using a Student's t-test.

Mortalities and Malformations

Notes were kept of frogs found dead or exhibiting obvious abnormalities. Freshly dead frogs without an obvious cause of death were submitted to Dr. Michael Garner of Northwest Zoopath who completed a pathology examination and provided a written report.

RESULTS

Population Estimation

From the time we initiated marking in October 1996, through June 1999, 980 captures were recorded for 568 individual frogs ≥42 mm SVL (Table 2.1). The proportion of frogs marked in a prior year increased each year during the study, reaching 40% in 1999 (Table 2.1). Minimum survival in years when substantial numbers of frogs were captured was 28% in 1997, and 16% in 1998.

Table 2.1. Annual summary for Oregon spotted frogs ≥ 42 mm that were captured and marked at Dempsey Creek during incidental surveys and structured mark-recapture surveys, 1996-99.

Year	Total captures	No. newly marked	No. recaptured from a prior year	% marked in prior year[a]	No. captured in succeeding year	Minimum survival to following year (%)[b]
1996	10	10	-	-	4	40
1997	252	176	4	2	50	28
1998	559	300	41	12	61	16
1999	159	82	54	40	-	-
Total	980	568	99		115	

[a]No. recaptured from prior year/(no. recaptured from prior year + no. newly marked) X 100.
[b]No. captured in succeeding year/(no. newly marked + no. recaptured from a prior year) X 100.

During six seasons between 1997-99 we conducted 48 mark-recapture surveys totaling 372 hours (Table 2.2). There was a seasonal gender-bias to capture success (Table 2.2). Female frogs were most often captured in the spring (56% of total captures for combined years), and fall (65%), possibly resulting from their tendency bask and remain higher in the water column where warmer conditions hastened egg development (M. Hayes, pers. comm.). Males were most often captured in the winter (86%). Consequently, we made independent population estimates for males and females at each season of each year to maximize recaptures for each sex and derive the best estimates. Population estimates for both sexes were highly variable across seasons, with no obvious trends (i.e., increase or decrease), and ranged between 52 and 200 females, and 51 to 674 males (Table 2.3). Low and variable capture probabilities among seasons (Table 2.3) decreased precision of population estimates, which was reflected in high and variable standard errors. Standard errors were approximate, because population estimates typically have non-normal distributions (Cormack 1985, Pollock et al. 1990). Because survival was assumed to be high (e.g., $\phi = 1.0$, closed models), this parameter was not a factor influencing precision of seasonal population estimates. With the exception of the estimated population of male frogs in winter, 1999 (i.e., 674), which was a very imprecise estimate (i.e., SE = 883), mark-recapture analyses suggested populations of adult male and female frogs were >50 and <300 animals from 1997-99.

Table 2.2. Summary of sampling effort during mark-recapture surveys for Oregon spotted frogs at Dempsey Creek, 1997-99.

Season and Year	Period	No. Search Days[a]	Search effort (hrs)	No. males (%)	No. females (%)	Total
spring 1997	May 8 - May 23	7	61	12 (32)	26 (68)	38
fall 1997	Sept 10 - Oct 17	12	131	19 (26)	55 (74)	74
winter 1998	Feb 19 - Mar 5	6	44	57 (88)	8 (12)	65
spring 1998	Apr 19 - Jun 2	8	57	50 (48)	54 (52)	104
fall 1998	Sep 22 - Sep 29	5	38	29 (45)	35 (55)	64
winter 1999	Feb 13 - Mar 11	10	41	67 (84)	13 (16)	80
	Total	48	372	234 (55)	191 (45)	425

[a]Search days were consolidated into three periods for each seasonal population estimate.

The annual population estimate for the 2[nd] sampling period (i.e., 1998), based on all captures of both sexes during the 3-years of surveys, was 514 adult frogs (SE = 129.4). Average between year survival was low to moderate (37%), and capture probability high (66%) compared to seasonal estimates.

Population estimates based on egg mass counts were larger than mark-recapture estimates. To validate size of age classes we evaluated characteristics of 27 frogs captured in amplexus,

Table 2.3. Sex-specific population estimates from mark-recapture surveys of Oregon spotted frogs at Dempsey Creek, Washington, 1997-99. Estimates were based on closed population models that assumed unequal capture probabilities among the three capture periods that were used for each seasonal estimate.

		Parameter		
Sex[a]	Sampling year and season	p[b]	N[c]	SE
female	spring 1997	0.17	60.3	35.6
	fall 1997	0.11	199.5	97.3
	winter 1998[d]	n/a	n/a	n/a
	spring 1998	0.24	71.2	22.5
	fall 1998	0.10	149.0	106.2
	winter 1999	0.15	54.8	160.1
male	spring 1997	0.12	50.8	155.7
	fall 1997	0.15	67.8	90.1
	winter 1998	0.09	101.4	29.0
	spring 1998	0.12	157.1	88.6
	fall 1998	0.29	51.9	21.1
	winter 1999	0.05	674.0	882.5

[a]Sex for which seasonal estimate was made.
[a]Probability of observing a marked frog in the sample.
[b]Population estimate.
[d]Too few captures (i.e., 12) for estimate.

including one female grasped by two males. This allowed classification of adult females from 62 to 77 mm (SVL), and males from 49 to 65 mm (SVL). Based on this classification scheme, 60% of the frogs captured during the study (including unmarked frogs <42 mm SVL) were classified as adults (Table 2.4). Adult population estimates based on egg mass counts and a 1:1 adult sex ratio averaged 300 animals (Table 2.4). Total population estimates, based on the sum of estimated numbers of adults and subadults ranged between 410 and 555 individuals for the period 1996-1999, and averaged 496 animals (Table 2.4). When the sex ratio was adjusted to reflect that observed for all captured frogs (n = 568; 52% females and 48% males), the average adult estimate for the 4 years was 288 animals, and total population estimate was 480 individuals.

The third method we used to estimate population size, combining capture summary data and knowledge of recruitment in 1998, resulted in the highest estimate of population size. In 1999, 40% of 136 adult frogs captured through June had been marked in a prior year (Table 2.1). Given that 341 frogs were captured and known to be marked in 1998, the 1999 finding of 40% seen during both years indicated a minimum 1998 population of 853 adult frogs.

Table 2.4. Annual population estimates of Oregon spotted frogs at Dempsey Creek based on egg mass counts, estimated adult numbers (2 X egg count), and proportion of adults captured.

Year	Egg mass count	Adult estimate	Percent adults	Population estimate
1996	172	344	62%	555
1997	125	250	53%	471
1998	119	238	58%	410
1999	183	366	67%	546
Mean	150	300	60%	496

Population Dynamics

Annual Changes in Age Cohorts.-- The annual proportion adults, based on egg mass counts, was variable (Table 2.4). The 1997 and 1998 proportions, 53% and 58% respectively, indicated a healthy subadult component to the population, probably reflective of good spring rainfall in 1996 and 1997 which allowed for high larval survivorship to metamorphosis. In contrast, during 1999, 67% of frogs captured were classed as adults, an indication of poor survival of tadpoles in 1998. In fact, many of the frogs classed as subadults in 1999 were estimated to be 2-year old females produced during the 1997 hatch-year.

Growth Rates and Longevity.-- We measured 47 male frogs that were ≥45 mm long, and 41 females ≥42 mm long, to analyze growth rates of adult frogs. Adult males grew an average of 2.2 mm/yr (SE = 0.4) and females grew an average of 6.1 mm/yr (SE = 0.7). Growth rates of adult frogs relative to initial length were fit to linear models. Both models were significant (males: $F_{1,45} = 28.65$, $P<0.001$; females: $F_{1,39} = 62.00$, $P<0.001$), although female growth rates were more highly correlated to frog size ($r^2 = 0.614$) than males ($r^2 = 0.389$). Predictive modeling suggested male frogs ceased to grow at 57.2 mm SVL (GRATE in mm/day = 0.0572 - 0.001LENGTH in mm), whereas females ceased to grow at 75.9 mm SVL (GRATE = 0.0835 - 0.001LENGTH). We estimated precision of SVL measurements at 2.71 mm (SE = 0.46) based on recaptures and re-measurements of 14 frogs.

One marked frog was captured in all 4 years of surveys. This frog (4112570A79) was one of only 10 frogs marked in 1996 so her capture history is quite remarkable. She was initially captured on 3 October, 1996 as an adult in at least her fourth year (based on her large size; 68 mm SVL). She was recaptured on 23 September ,1997, 24 February, 1998, and 11 March, 1999. This frog, at a minimum, was in her 7th year. Growth of this frog over the four years was negligible as this frog gained only 2 mm in snout-vent length (70 mm on 11 March, 1999).

Associations Between Spring Rainfall and Juvenile Recruitment.-- Retrospective review of snout-vent lengths of all captured frogs at capture time (Fig. 2.2) provided for breakdown of hatch-year, second-year, and older age classes (Table 2.5). During July and August, frogs <39 mm SVL were classified as hatch-year juveniles while those 40 to 48 mm in SVL were classified as second-year juveniles. During September through November, frogs <42 mm SVL were considered hatch-year juveniles while those 42 to 48 mm in SVL were classified as second-year juveniles. During July through November, all frogs >48 mm in SVL were classified as unknown age. Frogs <46 mm in SVL and captured from February through June (spring) were classified as second-year juveniles. Those frogs ≥46 mm during these months were considered to be of unknown age. Hatch-year juveniles did not appear until metamorphosis of tadpoles in July.

Table 2.5. Age classification of Oregon spotted frogs at Dempsey Creek through consideration of size and date based on 980 captures of 568 frogs.

Date	SVL[a] (mm)	Classification
July-August	< 39	Hatch-year juvenile
Sept-Nov	< 42	Hatch-year juvenile
February-June	< 46	Second-year juvenile
July-August	39 to 48	Second-year juvenile
Sept-Nov	42 to 48	Second-year juvenile
February-June	>45	Unknown age/possible 3rd yr +
July-October	>48	Unknown age/possible 3rd yr +

[a]Snout-vent length.

Cohort encounter rates suggested low recruitment in 1994, 1995, and 1998, and higher recruitment in 1993, 1996, and 1997 (Table 2.6). Rainfall data (Appendix, Table 2) showed that April/May rainfall levels, when eggs and tadpoles were most vulnerable to death from low water, followed this same grouping of years (Fig. 2.3). Mean rainfall in April/May of dry years (1994, 1995, and 1998) was 4.4 cm/month (SE = 0.6) and in wet years (1993, 1996, and 1997) was 12.7 cm/month (SE = 1.9). Encounter rates were not found to be statistically different ($t = 1.802$, $df = 4$, $P = 0.146$) in low spring rainfall years versus high rainfall years, but this difference translated into an actual difference of encountering >1 adult frog more/survey-hour in high rainfall years; a difference that was biologically important.

Mortalities and Malformations

Observed mortalities and malformations in metamorphosed frogs were relatively unusual. The more common observations of dead embryos in eggs (frequently caused by freezing) or tadpoles killed by desiccation were not consistently recorded and are not summarized here. Six frogs died while equipped with transmitters (Table 2.7, Chapter 1). Two cases were apparent predation, involving a common garter snake (*Thamnophis sirtalis*) and a mammal. The common garter snake, one of three species of garter snake known to inhabit the study area, was confirmed to

Table 2.6. Summary of search effort and encounter rates for hatch-year and second-year juvenile Oregon spotted frogs at Dempsey Creek.

Hatch-year cohort year	Hatch-year search time (hrs)	Second-year search time (hrs)	Overall search time (hrs)	Juvenile encounters (frogs)	Encounter rate (frogs/hr)
1993	0	8.4	8.4	21	2.50
1994	3.0	15.0	18.0	2	0.11
1995	1.5	40.5	42.0	5	0.12
1996	10.5	141.8	152.3	82	0.55
1997	53.9	125.7	179.6	117	0.65
1998	35.6	56.0	91.6	4	0.04

have taken a telemetered adult female and a recent metapmorph frog. Mink (*Mustela vison*) were seen on the study area and may have eaten a telemetered frog and an unmarked frog found partially eaten on 25 February, 1999. In the first instance, the frog had been completely eaten but the nylon ribbon, transmitter, and PIT-tag had been discarded. In the second, the frog's head and one forelimb were consumed. One telemetered frog was found dead on 22 July, 1997 with no obvious cause of death. A pathology examination concluded that a fungal infection of the skin was likely the proximal cause of death. Three telemetered frogs found dead in early May on the Wilson dairy property east of the main study area, but were too decomposed for a meaningful pathology examination. There were two occasions where unexpanded (i.e., non-laid) ranid frog eggs were found at the bases of fence posts in the pasture near the breeding pools. Bird feathers and pellets composed of rodent hair and bones in the same vicinity suggested that the posts were used by raptors, likely hawks or owls. It was obvious that female ranid frogs had been killed and eaten, probably by a raptor that carried the frog to the post to eat. We could not determine the species of ranid (*aurora* or *pretiosa*).

DISCUSSION

We chose a variety of methods to estimate the population size of Oregon spotted frogs at Dempsey Creek because no one method, either statistically or practically based, was ideally suited to study this elusive ranid. Mark-recapture analyses resulted in the lowest population estimates of all methods for most seasonal periods, but we believe they were negatively biased relative to other estimates. The most likely source of bias for mark-recapture estimates was heterogeneity of capture probabilities between marked and unmarked frogs. If the average capture probability of marked frogs was greater than unmarked frogs, we overestimated the true proportion of marked frogs in the population leading to a negative population bias (Pollock et al. 1990). We did not find a high degree of trap-happiness of specific marked frogs that might have inflated average capture probability. It is more likely that a population segment in the study area was unavailable for capture at certain seasons, either due to due to their location or behavior, so we tended to

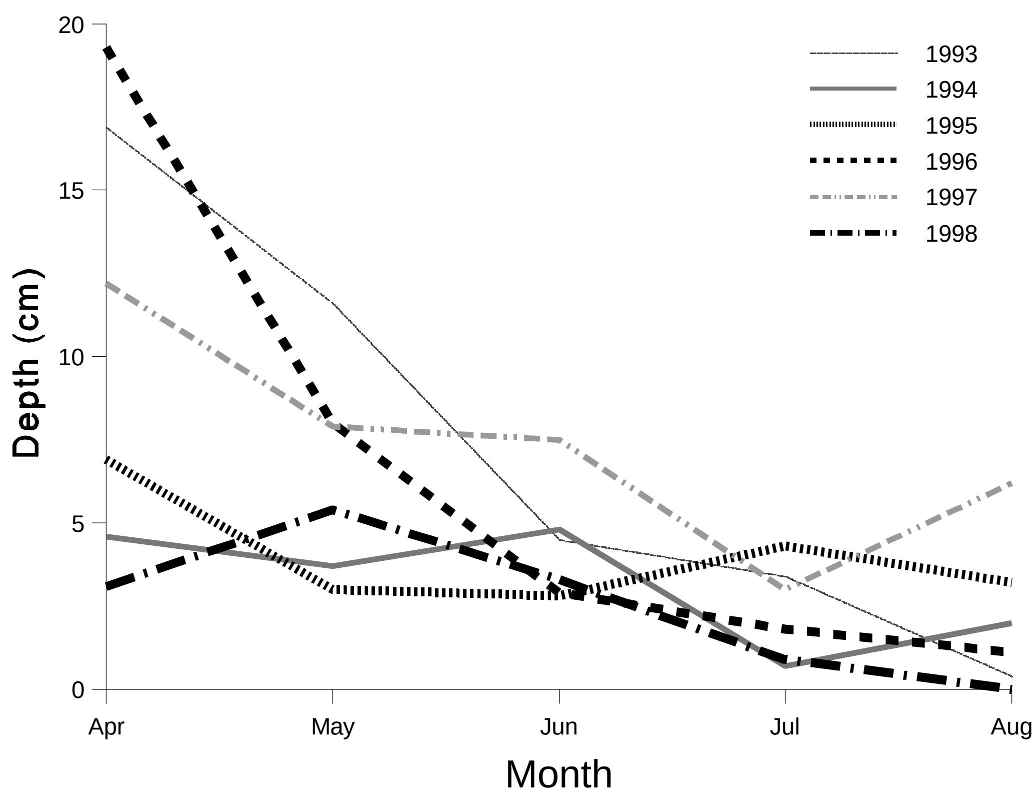


Fig. 2.3. Rainfall recorded at the Olympia airport, 9 km east of the Dempsey Creek study area.

Table 2.7. Mortalities and malformations of Oregon spotted frogs at Dempsey Creek, Washington, 1993-99.

Date	PIT-tag no.	Type	Comment
9/25/96	None	Dead	28mm SVL metamorph disgorged from 202mm SVL Common Garter Snake (*Thamnophis sirtalis*)
3/24/97	Knee Tag 064	Dead	Severely lacerated skin from knee tag, died in handling.
6/12/97	41087D2240	Dead	Telemetered frog eaten by 552mm SVL Common Garter Snake
7/22/97	411266485B	Dead	Telemetered frog died of fungal dermatitus (pathology report)
2/23/98	410A1F5A64	Dead	Died soon after initial capture. Ruptured ovum and oviduct hemorrhage (pathology report)
3/26/98	414F08613A	Dead	Telemetered frog eaten, apparently, by a mammalian predator
5/1/98	414F082060	Dead	Telemetered frog found dead in pool on Wilson dairy property
5/4/98	414F052F64	Dead	Telemetered frog found dead in pool on Wilson dairy property
5/4/98	41126C610D	Dead	Telemetered frog found dead in pool on Wilson dairy property
2/2/99	None	Dead	Dead male frog, in poor condition, margin of Parking Lot pool
2/25/99	None	Dead	Dead male frog, head and forelimb chewed off, possibly by mink
11/3/97	507B6F3053	Malformed	Female with extra right forelimb, small and poorly formed
5/20/98	None	Malformed	Juvenile (30mm SVL) frog with missing eye

resample a subpopulation with increased numbers of marked frogs. We surveyed the main study area as completely as possible, but acknowledge limited access to some areas with dense emergent vegetation. It is unlikely that a *large* population segment resided in these habitats based on the fact that frogs avoided dense habitats and preferred moderately vegetated stands (Chapter 3). More likely, we failed to detect *small* pockets of frogs outside the periphery of our study area that were unavailable for capture during mark-recapture surveys. The dramatic increase of several hundred animals for the winter 1999 population estimate, compared to previous estimates, illustrates the point (Table 2.2). There was a known minimum population of 341 marked adults in 1998, which would have accounted for the entire population according to prior mark-recapture estimates, so there was either: 1) a dramatic loss of marked individuals over the winter of 1998; and/or 2) an influx of new, unmarked adults into the sampled population. We discounted widespread marker loss (Chapter 1) or a massive die-off of marked individuals since we recorded the highest egg mass count in 1999. It is more likely there was a sudden influx of unmarked males from the 1997 class, which was a very good year for metamorph production, but it was unclear where these frogs might been located to have avoided prior capture.

The most reliable population estimate from mark-recapture surveys was the annual estimate of 514 adult frogs for 1998, based on the more realistic standard error and greater relative precision of the estimate compared to seasonal estimates. Interestingly, this annual estimate for all adults was approximately twice the maximum seasonal estimates for males and females (i.e., 200 frogs). Theoretically the greatest precision of the population estimate is achieved when average survival is 1.0 and average recapture probability is 1.0 (Pollock et al. 1990). Our recapture probability of 0.66 over 3 years of surveys was less than ideal, but still surprisingly high considering the difficulty of surveying and capturing this species (Chapter 1).

Estimates of population size from egg mass counts were approximately twice that of mark-recapture estimates and were consistent among the 4 years of study. An advantage of this method was the relative ease of locating and counting egg masses, which provided an index of female abundance. Because oviposition sites of Oregon spotted frogs were in shallow, ephemeral pools, that were relatively easy to locate, we believe most egg masses were counted each year. However, the unknown components of this population estimate, the relationship of egg mass numbers to adult females, and the ratio of adult males to females in the population, limited the precision of these estimates. The latter ratio, females:males, was derived from sex ratios of the entire population of captured frogs, and was probably a realistic reflection of the actual sex ratios because it was based on several seasonal captures over several years. Licht (1974) also found the Little Campbell River population of Oregon spotted frogs weighted toward females (64% in 1968, 73% in 1969) and suggested it was because of greater mortality of males during the breeding season when they were more conspicuous to predators for a longer time. The greater unknowns were the number of females that did *not* oviposit in a given year, and whether one egg mass was laid by each female. If each female laid more than one egg mass, then we overestimated the population. We don't believe this to be the case. In the Little Campbell River study area of southwest British Columbia, Licht (1975) collected and dissected females, counted the ova, and found that they correlated well with the number of eggs per mass in situ. Females bred annually and laid one egg mass, in contrast to Columbia spotted frogs in higher, colder elevations in Wyoming (Turner 1960), where adult females had delayed sexual maturity and did not breed every year. The elevation and climate at Dempsey Creek is similar to that in Licht's study area. If more adult females were present than laid eggs, then we underestimated population size. We believe this was the overriding unknown factor limiting the precision of our population estimates from egg mass counts, and suggest that our estimates represent minimum adult frog numbers (i.e., 500) that might be projected upward if the proportion of non-gravid adult females could be determined in the population.

The last method of estimating the Dempsey Creek Oregon spotted frog population, using the number of known adults to project population size from subsequent recapture ratios, was the simplest method, but perhaps yielded the most realistic population estimates. The fact that 341 marked, adult frogs were known to be alive in 1998, and those frogs accounted for only 38% of frogs caught in 1999, suggested a larger population existed (853 frogs) than indicated by the other population estimation methods we used. The possibility of an influx of unmarked individuals to the winter 1999 population, most likely the large cohort of recruits from the 1997 class, potentially inflated this estimate, and so 853 is a reasonable upper estimate of the Dempsey Creek population. We conclude that based on this estimate, and the most reliable estimates from the mark-recapture study (e.g., 514), and egg mass counts (e.g., 500), between 500 and 850 adult frogs occupied the 38.5 ac of wetlands at Dempsey Creek (Chapter 4) during the study period.

Minimal known annual survival of adult frogs at Dempsey Creek was low for 1997 (16%) and 1998 (28%). The 1999 estimate would have changed had we been able to survey with greater intensity, and for the entire year of 1999 (our study ended 1 July). Average annual survival estimated from mark-recaptures was slightly higher (37%), but low relative to the 64% minimal survival for frogs on the Little Campbell River (Licht 1974) and 61% for Columbia spotted frogs in Wyoming (Turner 1960). Licht's estimates may not be directly comparable to ours since it was unclear if he accounted for new adults recruited into the population. Neither population was subject to introduced bullfrogs (bullfrogs were observed in the last year of Licht's work), a factor that might be expected to reduce survival rates. Predation on Oregon spotted frogs at Dempsey Creek appeared to be only by endemic reptiles, and mammals. Avian predation, confirmed twice by indirect evidence, was probably greater since avian predators (e.g., great blue heron [*Ardea herodias*] and American bittern [*Ixobrychus exilis*]) were common on the study area. Avian predators could quickly carry predated frogs outside the study area. The sudden cessation of radio-signals that we experienced from some telemetered frogs may have resulted from birds carrying predated frogs with transmitters out of the range of our receiver.

Adult Oregon spotted frogs at Dempsey Creek experienced growth well after their 3rd year from between 2mm/yr (males) and 6 mm/year (females), and modeling suggested growth was negligible after frogs attained lengths of 57 mm (males) and 76 mm (females). The only frog for which we confirmed growth rates was the female that ceased to grow after reaching 70 mm. Projecting these growth rates to adult frogs at minimum length (>48 mm) suggested 3 year-old adults at Dempsey Creek would continue to grow another 4 to 5 years before attaining maximum size (i.e., 7 to 8 years of age). These growth rates and maximum adult sizes were between those identified for Oregon spotted frogs in British Columbia (Licht 1975) and Columbia spotted frogs in Wyoming (Turner 1960). The former study found frogs did not grow or at most 1 mm/yr after the 3rd year season when they attained a maximum size of 45 mm (males) and 62 mm (females). In contrast, frogs in the latter study took up to 10 years to attain maximum sizes which for males was 57 mm, and females 70 mm. As Licht (1975) suggested, some of these differences in growth rates relate to elevation and hence temperature differences at study areas. We suspect there is also a strong nutritional relationship underlying these differences.

Our observation, that larval survival and success of Oregon spotted frog recruitment survival was closely related to rainfall, was similar to that of Licht (1974). However, in that study, losses were attributed to low rainfall during the embryonic development period rather than during larval rearing even though the chronology of breeding events was similar (Licht 1971). During our study period, losses during embryonic development were relatively low, partly due to researcher intervention. There were two instances when researchers intervened to protect developing eggs. The first was on 1 March, 1995 when 49 egg masses were moved to deeper water when dropping water levels left them exposed to freezing conditions. The second was on 22 February, 1997 when foam rubber pads were placed on top of 60 egg masses during a night when the water level was down and the temperature dropped below freezing. There was inadequate follow-up to determine how our moving of egg masses might have affected survival to metamorphosis in 1995. However, foam rubber pads appeared effective in protecting egg masses since ice formed in the breeding pool but no eggs were freeze-damaged. At our study latitude, Oregon spotted frogs laid eggs in late February and early March, and hatched in April. Tadpoles appeared in breeding pools just when drying conditions began to eliminate outflow water to permanent waters, where metamorphosis was completed from July through August. A difference of 8 cm of rainfall in April and May was enough to eliminate these outflow routes and resulted in nearly a total loss of the annual recruitment. Based on larval rearing requirements, June rainfall may have been important though this relationship was not apparent. Most important, however, is the realization that only three to four seasons of spring drought could seriously affect new adult recruitment into the population, thereby reducing population size and future reproduction.

Of the mortalities identified during this study, the three telemetered frogs that died in the breeding pool on the Wilson dairy property were the most intriguing. For at least one of the frogs, the transmitter's antenna was ensnared in vegetation, possibly drowning the frog. This conclusion, though, was not entirely satisfactory given the chronic problems we had with frogs slipping out of their transmitter belts (Chapter 1). A frog with its antenna caught in any way might be expected to simply wriggle free of the entire apparatus. Another possibility, supported by low recaptures of marked frogs from this pool, is that the pool was a death trap created by artificial flow conditions regardless of whether frogs were telemetered. Of 47 individual spotted frogs captured in this breeding pool during 1998, only three were seen after the pool dried up. We caught 282 individual frogs after this breeding pool dried up so there was ample opportunity to recapture a good proportion of these frogs. This pool was unique in that it was separated from the main body of the study area by Delphi Road, a two-lane rural, county road. Unlike most of the breeding pools at Dempsey Creek, which dried up in relative synchrony with the water courses that lead to permanent water, the breeding pool on the Wilson dairy property held water until after its immediate surroundings were totally dry. The culvert that drained under Delphi Road maintained deeper conditions than found in other breeding pools. It's conceivable that, by the time the frogs detected the impending loss of water, they were land-locked and reluctant to move overland. They became more vulnerable to predators or lethal conditions associated with high temperatures and low dissolved oxygen. The water was inhospitably warm (e.g., 21-23° C surface temperature on 1 May) and heavily vegetated when known mortalities occurred.

Alternatively, the frogs in the breeding pool on the Wilson property may have represented a separate sub-population that over-summered in areas that we searched infrequently, or not at all. Of 47 frogs observed in the Wilson dairy breeding pool, 13 were originally in the main study area, so there was some interchange of frogs into the main study area. Regardless of the fate of the frogs that were present in this pool when it dried out in 1998, only one spotted frog egg mass was laid in this pool the following year, an indication that the site was not a traditional location for concentrated breeding activity. This site, and perhaps others like it, may contribute only occasionally to adult recruitment.

MANAGEMENT IMPLICATIONS

Population estimates, particularly those derived from egg mass counts, indicated the Dempsey

Creek Oregon spotted frog population was reproductively stable during our brief (i.e., 4-year) study, even with apparently low to moderate adult survival (38%), and in spite of an absence of introduced predators. We spent considerable time and effort deriving a reasonable population estimate (e.g., 500-850 animals), and yet still desired greater precision. Without refinement of the methods we used to estimate the frog population, future surveys at this or other study sites are likely to be limited because of costs and effort. Because mark-recapture studies were limited by our inability to ensure a complete search of the study area, use of capture methods that reduce seasonal and sexual capture bias, such as funnel traps, might improve estimates. Such traps would also require fewer field personnel during capture periods. Whereas mark-recapture studies may derive a reliable estimate of population size, we believe long-term monitoring of Oregon spotted frog populations can be best accomplished and with less labor investment by counting egg-masses. Precision of egg mass counts for estimating and monitoring frog numbers could be improved with further studies of fecundity that determine the proportion of adult females that oviposit each year, and thus the number of adult females *not* represented by egg masses.

The critical link between spring rainfall and juvenile survival for Oregon spotted frogs was reinforced through our study, and suggests drought conditions could be a serious bottleneck for remnant frog populations if experienced over several years. Alternatives to allowing dessication of egg masses or death of larva in drying pools may include moving of egg masses or tadpoles, or covering egg masses, which we found to be effective. The potential for drought conditions over several years also emphasizes the need to for experimentation to see if breeding and larval habitat for Oregon spotted frogs can be created, and what criteria (e.g., depth, location, etc.) would be needed for these pools to remain viable through the summer months. In order to develop life tables for Oregon spotted frogs, and better understand the relevance of the survival rate of adult frogs at Dempsey Creek to population dynamics, more information is needed on frog longevity . Continued marking studies over several years at Dempsey Creek may provide this important information.

Chapter 3

HOME RANGE, MOVEMENTS, AND HABITAT SELECTION

The Oregon spotted frog (*Rana pretiosa*) ranges from extreme southwestern British Columbia through Puget Sound, south-central Washington, and the Oregon Cascades (Green et al. 1997). This species was only recently recognized as distinct from the Columbia spotted frog (*R. luteiventris*), which ranges more widely from southwestern Yukon southward to Nevada (Green et al. 1997). The Oregon spotted frog is a candidate for federal listing, and in 1997 was listed as a state endangered species in Washington. The primary impetus for listing was a reduction in historic range, estimated to be >90%; only four populations are known in Washington (Hayes et al. 1997), including a recently identified population on Beaver Creek in southwest Washington (Chapter 4). This ranid is highly aquatic (Licht 1986a), and suggested reasons for population declines include altered hydrology, predation by exotic fish and amphibians, and physiologic effects from changes in water chemistry and ultraviolet radiation (Hayes et al. 1997). Recent examination of 24 relict populations suggests inadequate habitat (most sites ≤25 ha) may be contributing to population declines of this species (Hayes et al. 1997).

Much of what is known about Oregon spotted frog ecology including life history, breeding, feeding, and escape behavior, was established from research conducted in British Columbia (Licht 1969, 1971, 1975, 1986a, 1986b). Little is known about spotted frog movements and fidelity to breeding sites, but this information is important to assess the potential for recolonization where the species has been extirpated (Hayes 1997). Proper management of the remaining isolated frog populations is critical to perpetuate this species, and requires site-specific knowledge of vegetation characteristics, home range, and seasonal changes in hydrology that may affect movements.

One of the Oregon spotted frog populations in west-central Washington is on Dempsey Creek, a tributary of the Black River. This population was discovered in 1990 (McAllister et al. 1993). It is one of two populations in Washington occupying habitat that is grazed by cattle throughout the year, both of which appear to be reproductively healthy (McAllister and Leonard 1997). In response to the interest of the landowners to better manage and protect the habitat for Oregon spotted frogs, we initiated a cooperative study in 1996. Our objectives were to: 1) describe home ranges and movement patterns of Oregon spotted frogs; and 2) determine micro- and macro-scale habitat use patterns of the spotted frog population.

STUDY AREA

The study area was located on approximately 70 acres, south of Black Lake, in Thurston County, Washington (Fig. 3.1). Dempsey Creek flowed from west to east through the study area. An unnamed, ephemeral creek flowed from west to east through the southern half of the study area. These creeks fed a permanent, emergent palustrine wetland, referred to as the basin, on the east

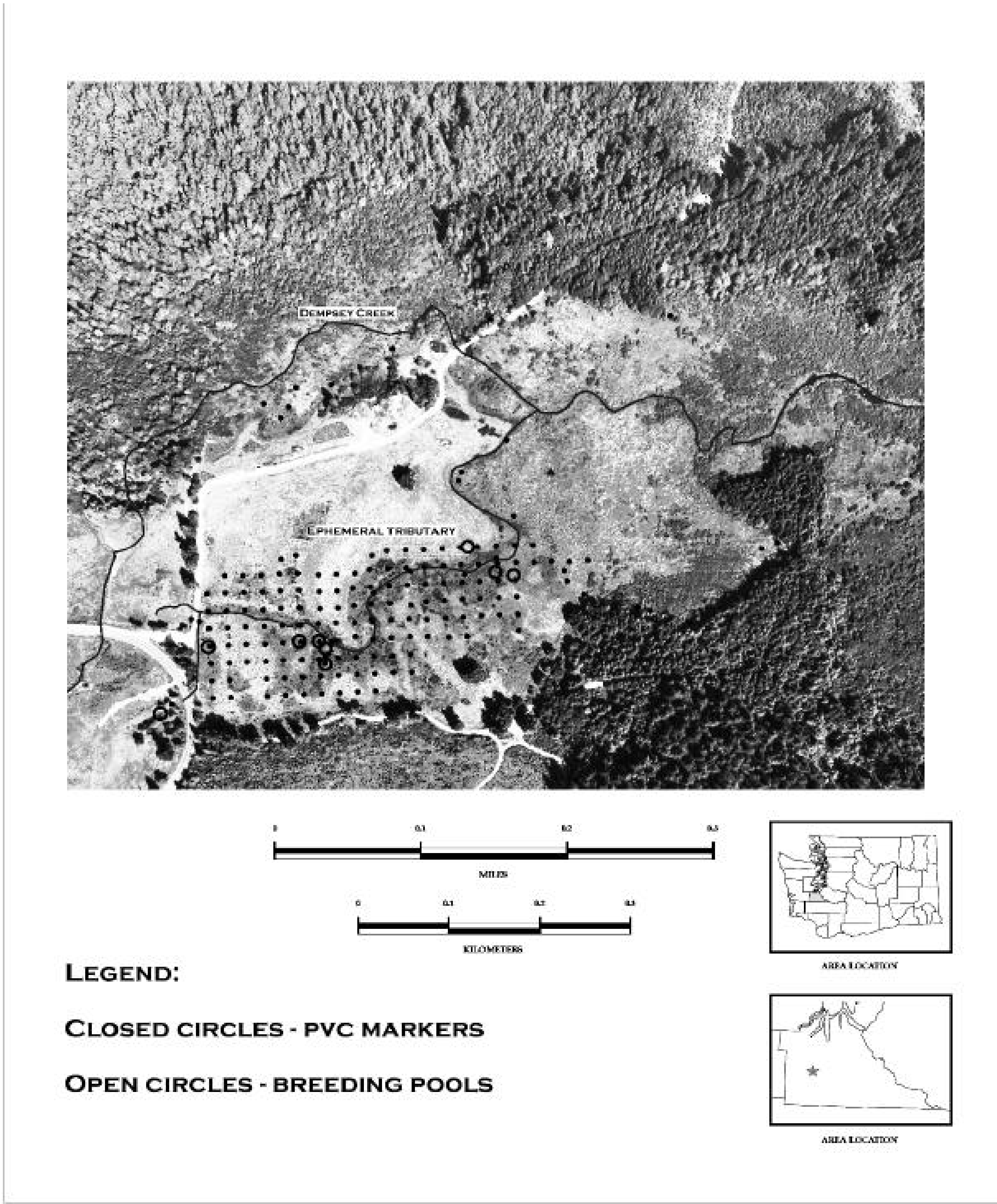


Fig. 3.1. Location of the Oregon spotted frog study area along Dempsey Creek, Washington. Locations of major breeding pools and grid post markers are indicated.

side of the study area. This wetland was vegetated predominantly with reed canary-grass (*Phalaris arundinacea*), hardhack (*Spiraea douglasii*), slough sedge (*Carex obnupta*), beaked sedge (*C. utriculata*), willow (*Salix* sp.), cattail (*Typha latifolia*), and mannagrass (*Glyceria* sp.). A floating mat of vegetation, up to 0.5 m thick, underpinned most reed canary-grass beds in the permanent wetland. Breaks in the reed canary-grass mat provided open water pools, often associated with water-starwort (*Callitriche stagnalis*), and false loosestrife (*Ludwigia palustris*), the principle submergent plants in the study area. The primary breeding areas were shallow depressions along the margins of the ephemeral creek. Most of the ephemeral wetlands, including the breeding pools and margins of the permanent wetland, supported soft rush (*Juncus effusus*) and slough sedge, in addition to low-growing forbs like creeping buttercup (*Ranunculus repens*) and small bedstraw (*Galium trifidum*).

Water levels in the ephemeral creek decreased beginning in April, and stagnated by June. Consequently, the backwater areas and spillover pools in the floodplain, adjacent to the creek and in the basin, became increasingly drier and fewer in number from June through August. Pasture grasses (*Poa* sp.), Himalayan blackberry (*Rubus discolor*), and red alder (*Alnus rubra*) were at the margins of the spillover pools where elevation began to increase away from the floodplain. Douglas-fir (*Pseudotsuga menziesii*) predominated the upland forests.

About 20 cows grazed the property throughout the year and regularly accessed the ephemeral creek and spillover areas, although they avoided areas of permanent water, including the main basin, except during very dry periods. Common garter snakes (*Thamnophis sirtalis*) were commonly seen and were confirmed predators of juvenile and adult spotted frogs on the study area. Bullfrogs (*Rana catesbeiana*), another potential predator (Hayes and Jennings 1986), were not observed on the study area, but were seen on the Black River drainage, as close as 4 km away.

METHODS

Capture, Marking, and Radiotelemetry

Beginning October, 1996, frogs >42 mm (snout-vent length, SVL) were captured by hand and with dip nets. We captured frogs during population sampling (Chapter 2), when we deployed or replaced transmitters for monitoring activities, and incidentally to other field activities. Frogs were marked with numeric-coded tags attached over the knee of frogs with elastic thread (Elmberg 1989), or with 12 mm PIT-tags (Donnelly et al. 1994). PIT-tags were read by scanning with a portable reader (Fig. 1.4).

In spring, 1997, through winter, 1998, we attached BD-2 and BD-2G transmitters from *Holohil Systems, Ltd.* to adult male ($\geq$20 g) and adult female ($\geq$30g) frogs with nylon ribbon waistbelts. BD-2 transmitters weighed between 0.9 and 1.2 g, had an expected life of 7 weeks, and were affixed to male frogs. BD-2G transmitters weighed from 1.2 to 2.0 g, had an expected life of 17 weeks, and were affixed to females. Additional details of capture, marking, and radiotelemetry are found in Chapter 1.

Home Range and Movements

Primary assessment of home range and individual movements was from telemetered individuals. We attempted to locate telemetered frogs twice each week ($\bar{x}$ interval = 4 days, SE = 1). Signal reception was obtained up to 400 m, but was subject to the effects of frog depth and vegetation density. We believe this range of signal reception allowed us to successfully locate telemetered frogs throughout the study area when transmitters were functioning. However, frog movement outside the search area, particularly at the northern and eastern-most extremes of the study area (Fig. 3.1), may have contributed to our occasional inability to locate them. In 1997, for example, 6% of attempts to locate frogs were unsuccessful due to weak or non-existent signals possibly a result of frogs being too distant, in unusually deep water or dense hardhack cover, or having transmitters that failed prematurely.

To geographically describe frog locations, we measured the distance and determined the direction of frogs from marker posts that we established throughout the study area. Marker posts were located 20 m apart on a 200 x 400 m grid surrounding the primary breeding habitat with additional markers away from the grid (Fig. 3.1). Coordinates of posts were determined using a Trimble Global Positioning System with real-time correction capability.

We analyzed frog locations and range use at different scales. Locations for all frogs for the entire study period were pooled to present the distribution of the frog population at Dempsey Creek (i.e., population range). We determined the population range independently from telemetry locations and capture locations to show the contrast of population range size and location as interpreted from the two data sets. We also presented the population range of telemetered frogs for 1997 and 1998 to show annual variation in distribution. Secondly, we summarized range characteristics of telemetered frogs for periods of the year (i.e., seasonal ranges) by pooling their locations into different periods based on general hydrologic conditions: breeding season (February-May); dry season (June-August); and wet season (September-January). Seasonal ranges showed general range use changes of the population over the study area throughout the year. Thirdly, we determined ranges of individuals (i.e., individual ranges) for all telemetered frogs for the duration of the period they were monitored. Because transmitters were short-lived relative to the length of these seasons, and frogs sometimes slipped from transmitter belts (Chapter 1), most frog ranges were monitored ranges only within one season. For frogs monitored via telemetry for $\geq$50 days duration and with $\geq$10 locations, we averaged their range sizes and determined their average minimum rate of movement (m/day) within seasons. This allowed us to compare average individual range size and movements among seasons. We arbitrarily assigned this minimum sampling interval and intensity which likely underestimated the actual range sizes. For frogs with a lesser duration and intensity of monitoring we reported range size and rate of movement, but did not include these in average individual estimates. Finally, for the few individuals that were monitored during all three seasons (i.e., breeding, dry, wet) we estimated year-long individual ranges (i.e., home ranges) to show how individuals used the study area throughout the year.

We estimated sizes of 100% minimum convex polygons (100% MCP) with program HOME RANGE (Ackerman et al. 1989). This software also calculated distance moved between locations from which we derived minimum rates of movement (m/day). We also estimated sizes of 100% fixed kernels for frogs with $\geq$10 locations using THE HOME RANGER (Hovey 1999). This provided a non-parametric home range estimate. We used the automatic smoothing parameter which was based on the smallest least-squares cross-validation, and a 70 x 70 grid resolution. For range analysis, we considered locations to be independent (White and Garrott 1990) since frogs were capable of traveling the diameter of the average home range (i.e., 150 m) in the minimum sampling interval of 1 day.

We compared rates of frog movement between seasons, sexual differences in rates of movement, and rates of pool use, with Student's t-tests. Rate of pool use was determined by viewing movement plots of each animal and counting the number of main pools visited each season.

Habitat Selection

Identification and quantification of coarse-scale (macro) habitats throughout the Dempsey Creek study area were accomplished by interpreting spectral reflectance images from a custom air photo taken during August, 1997. This photo provided for interpretation of habitats during the driest time of the year and revealed maximum plant coverage. We designated the limits of the study area based on locations of wetland edges that encompassed all frog locations. Classes of spectral reflectance were matched to nine wetland types that were verified in the field (Fig. 3.2). These types included reed canary-grass, sedge/rush, alder/willow, hardhack/reed canary-grass, hardhack, sedge/reed canary-grass, deep water, reed canary-grass/sedge/cattail, and reed canary/manna grass. Availability of macrohabitats was estimated by calculating proportions of each type relative to the entire study area. Use of macrohabitats was summarized by calculating percentages of telemetry locations in each type for the entire year. Macrohabitat use was also summarized from capture locations to compare whether interpretation of selection was different using telemetry or capture data (chi-square contingency test) and to identify potential biases of basing habitat analysis on capture locations. Selection or avoidance of macrohabitats was evaluated by determining confidence intervals for the proportion of occurrence of frog locations in each type (i.e., use), and comparing them to the expected occurrence based on availability (Neu et al. 1974). Macrohabitat use was evaluated at three temporal scales: annual, seasonal (breeding, dry, wet), and inter-annual (1997 vs. 1998). We compared seasonal and annual habitat use by evaluating independence of their distributions (chi-square contingency tests), and then determined selection or avoidance of each habitat type within the season or year for comparisons. Where necessary, to minimize small samples, we combined habitat types for selection analyses. We did not establish models to assess habitat availability as a function of water depth, but evaluated selection of water depth by frogs independently for microhabitats.

Use of microhabitats by the Dempsey Creek Oregon spotted frog population was assessed by measuring habitat features $\leq$0.28 m (0.25 m^2) from locations of telemetered frogs and comparing them with features at randomly selected locations. When telemetered frogs were located, we recorded observation type (visual, no visual); distance to the nearest grid post (m); direction to

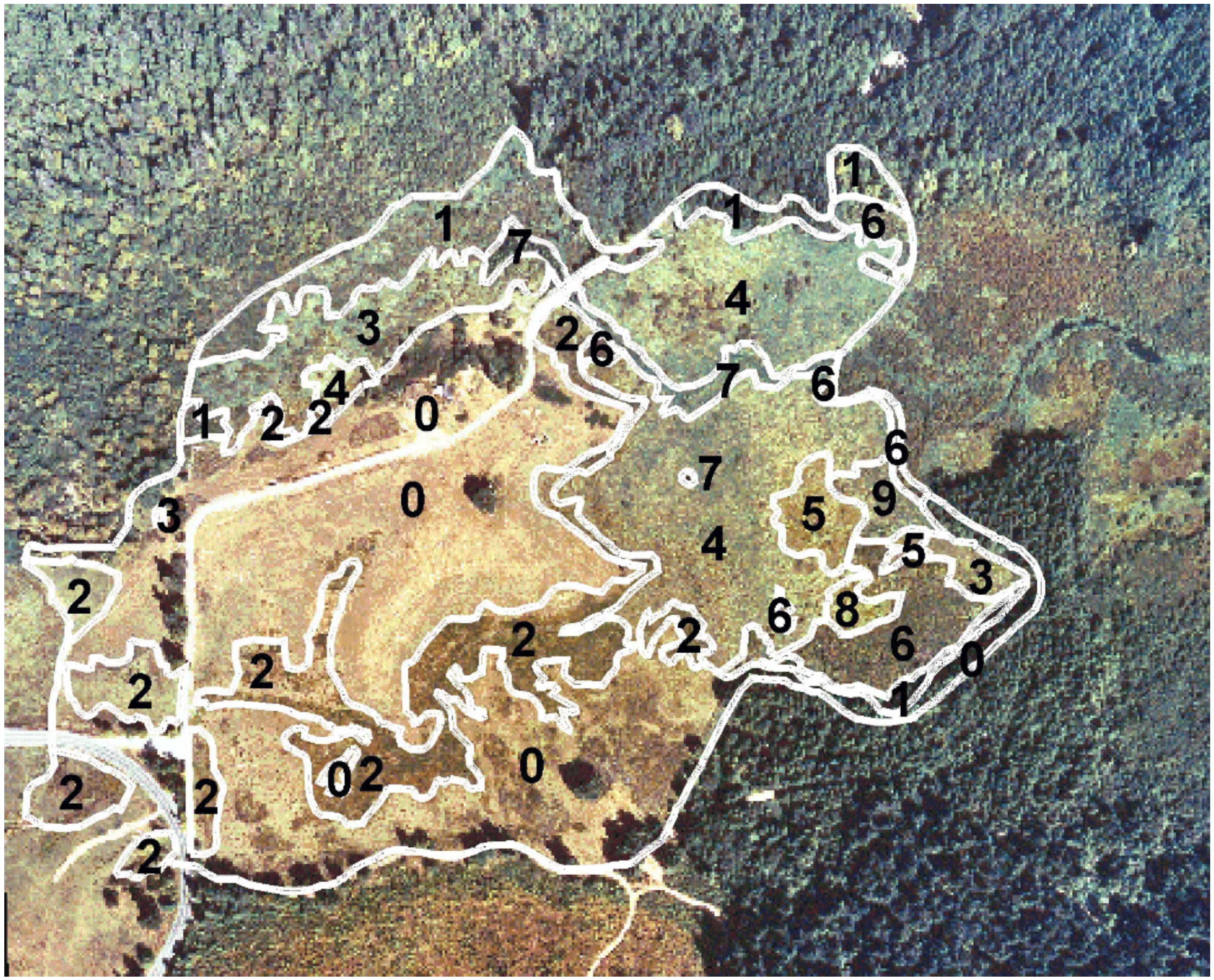


Fig. 3.2. Major vegetation types at the Dempsey Creek Oregon spotted frog study area, including uplands (0); alder/willow (1); sedge/rush (2); hardhack/reed canary-grass (3); reed-canary-grass (4); sedge/reed canary-grass (5); hardhack (6); deep water (7); reed-canary grass/manna grass (8); and reed canary-grass/sedge/cattail (9). Map scale is 1:4,875.

the nearest grid post (compass bearing); distance of the frog to the water surface (cm); depth of water where the frog was located (cm); water surface, and bottom temperatures (°C). Non-visual locations provided a frog's location (via peak signal strength and directionality) but not depth of frog below the water's surface. Frog depth was the only microhabitat variable with biased sampling because of visibility (i.e., more likely to see frogs closer to the surface). We overlayed the frog location with a 0.25 m^2 gridded disk, centered at the location, to estimate vegetative cover characteristics. We recorded the % of the grid accounted for by open water, rush, reed canary-grass, grass, and other emergent plants at the water surface. We also categorized subsurface habitats including submergent vegetation in the same grid. To measure the amount of concealment cover provided by vegetation, we also recorded the % cover from an overview of the grid. This variable provided a more complete picture of frog hiding cover than the estimate based on the plane of the water's surface, since emergent vegetation not growing within the grid sometimes extended into the grid.

Determining selection of vegetation types, structural characteristics, and water conditions by spotted frogs required measurement of habitat characteristics at random locations. To assess availability of these characteristics, we measured the distance the frog moved from the previous location, which was recorded $\geq$2 days earlier. This distance was the radius of the area within which frogs selected habitat. A random location was determined by multiplying this distance by the square root of a random proportion between 0 and 1, and calculating a random bearing (Skalski 1987).

We used paired t-tests of actual and random locations to test habitat selection with respect to water depth, surface temperature, and subsurface temperature at the substrate. Student's t-test was used to investigate differences in water temperature for frogs at or below the surface. To see if individual frogs were distributed in the water column based on temperature, we conducted chi-square contingency tests to compare the proportion of frogs among classes of surface to subsurface temperature differentials: class 1 = -3 to 0°C; class 2 = 0.1 to 3°C; class 3 = 3.1 to 6°C; class 4 = >6°C. Selection or avoidance of surface microhabitats (i.e., 15 plant species in addition to open water, mud, dirt, and wood) and subsurface microhabitats (i.e., eight submergent plant species in addition to layer of herbs/detritus/sediment) was determined with paired t-tests that compared proportions of each habitat found within 0.25 m^2 for actual and random frog locations. We tested the need for arcsine transformation of proportions since proportions tend to form a binomial, rather than normal distribution (Zar 1984). Transformation resulted in little or no difference in actual proportions, and no differences in statistical outcomes. For each cover class that frogs selected or avoided, we categorized the number of actual and random locations for that type among four classes (class 1 = 0 to 25%; class 2 = 26 to 50%; class 3 = 51 to 75%; and class 4 >75%). Chi-square contingency tests were used to evaluate differences in proportions among actual and random locations to identify significant classes.

Grazing

The relationship of cattle grazing to habitat characteristics and frog use was evaluated by chi-square contingency analysis that compared evidence of grazing (i.e., yes or no; plant clipping, hoofprints, dung piles) with the percentage of total emergent plant cover in four classes (class 1 = 0 to 25%; class 2 = 26 to 50%; class 3 = 51 to 75%; and class 4 >75%). To test whether macrohabitat use by frogs was independent of grazing, we conducted a chi-square test of independence of grazing sign and habitat types. To document plant groups grazed or avoided by cows, in spring, 1997, we established three, 3 m x 3 m exclosures in the southwestern quarter of the study area that was accessed by cows throughout the year. Exclosures were located in plots dominated by three main plant groups including pasture grass, rush interspersed with pasture grasses, and hardhack. Photo history of exclosed vegetation was recorded in spring and fall, 1997. By 1998, cows had intruded into the three exclosures as a result of inadequate fencing and small exclosure size. We noted no obvious qualitative differences in plant groups from the surrounding grazed areas, but in recognition of the lengthy time span required to identify these differences, and the fact that cows violated the exclosure areas, we abandoned the exclosure study.

RESULTS

Ranges and Movements

Population Range.--Between February, 1997, and January, 1999, we monitored the movements of 39 telemetered adult female frogs, and 21 adult male frogs. Because of transmitter belt slippage, difficulties in recapturing individuals before batteries expired, and mortalities (Chapter 1), only 21 of the 60 frogs (35%) received >1 transmitter. On average, telemetered frogs were monitored for 57 days (SE = 10 days). Forty-six telemetered frogs (77%) were followed during one season; 14 frogs (13%) were monitored multiple seasons including three frogs that were followed portions of both years. The population range of the 60 telemetered animals, that defined the extent of the area used by Oregon spotted frogs at Dempsey Creek, encompassed <75 ac (n = 654 locations; 100% FK = 68.83 ac; 100% MCP = 71.90 ac) (Fig. 3.3). The population range, based on 938 capture locations of 510 frogs for which we recorded coordinates, was <55 ac, and was contained within the range defined by telemetry locations (100% FK = 47.66 ac; 100% MCP = 53.48 ac) (Fig. 3.4).

The population range of telemetered frogs in 1997 (100% FK = 37.07 ac; 100% MCP = 51.11 ac; n = 333 locations; Fig. 3.5) was smaller than in 1998 (100% FK = 63.43 ac; 100% MCP = 67.62 ac; n = 321 locations; Fig. 3.6). In 1998 frog locations were more prevalent on the west and north sides of the study area, particularly during the wet and dry seasons. Although average rainfall was >5 cm/mo more in 1997 than 1998, interpretation of these distributional differences based on rainfall variation was confounded by the fact that we telemetered several more animals in the western and northern pools in 1998. In other words, in 1998 initial capture points for telemetered frogs were more widely separated as were their subsequent telemetry locations.

Home Ranges.--We were unable to monitor any individual for an entire year. Monitoring telemetered frogs through the winter was particularly difficult. Transmitters tended to slip off of most frogs in late October or November, probably due to normal fall weight loss or the long

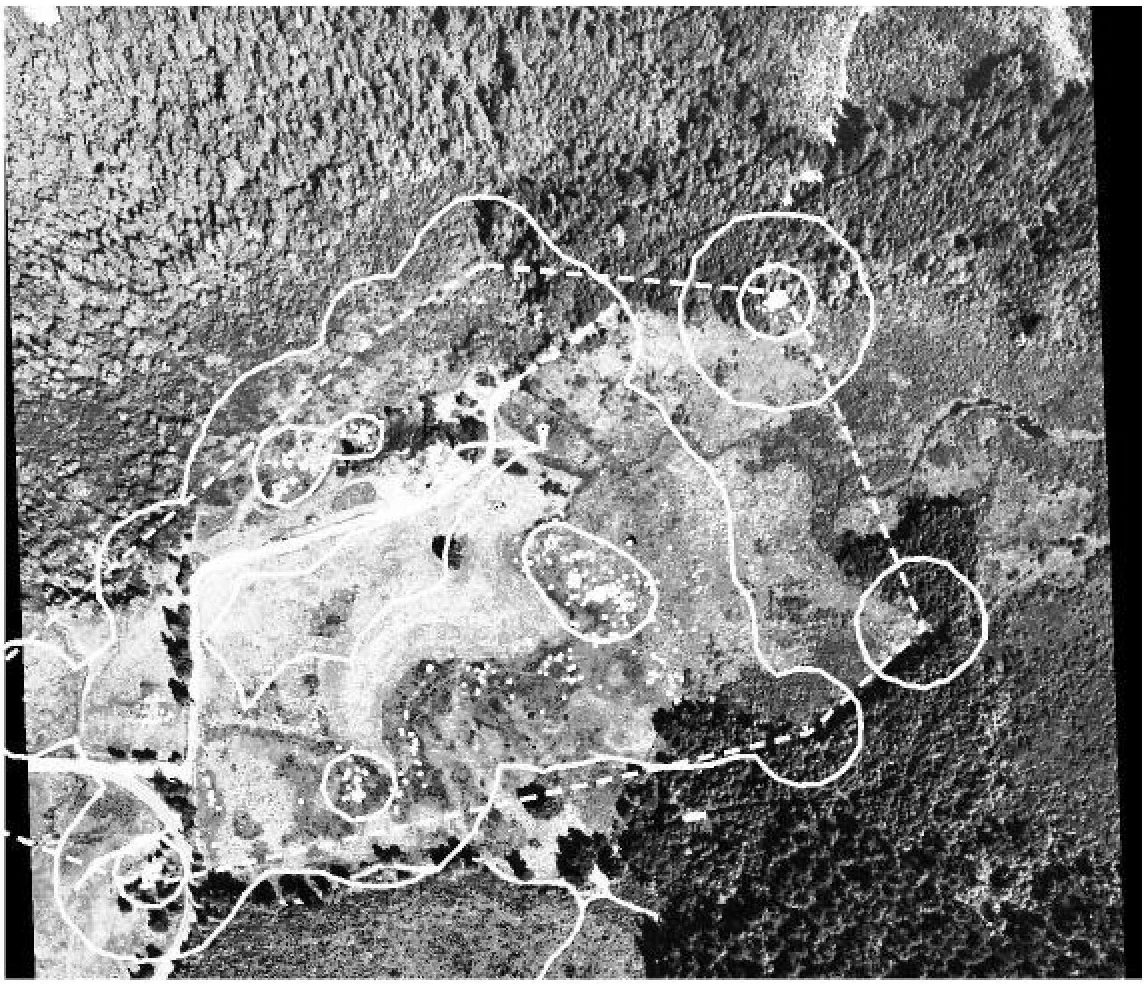


Fig. 3.3. Population range of Oregon spotted frogs at Dempsey Creek based on pooled locations (*n* = 654) of 60 telemetered animals in 1997 and 1998. Solid lines identify the 100% fixed kernel (outer contours, 68.83 ac) and 50% fixed kernels (inner contours, 5.51 ac). The dashed line identifies the 100% minimum convex polygon (71.90 ac). White dots are frog locations. Map scale is 1:4,875.

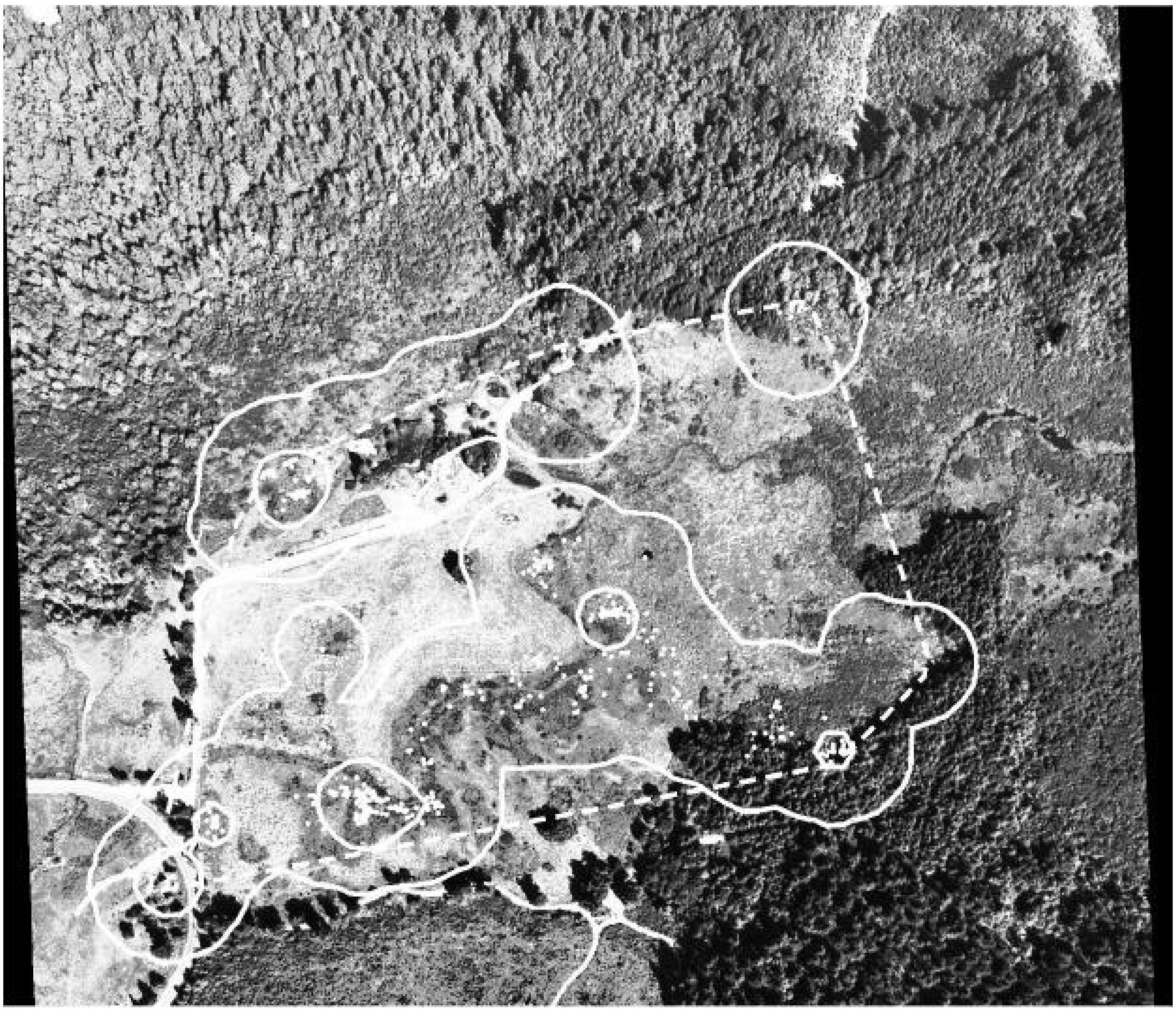


Fig. 3.4. Population range of Oregon spotted frogs at Dempsey Creek based on capture and recapture locations (*n* = 938) of 510 frogs in 1997 and 1998. Solid lines identify the 100% fixed kernel (outer contours, 47.66 ac) and 50% fixed kernels (inner contours, 3.67 ac). The dashed line identifies the 100% minimum convex polygon (53.48 ac). White dots are frog locations. Map scale is 1:4,875.

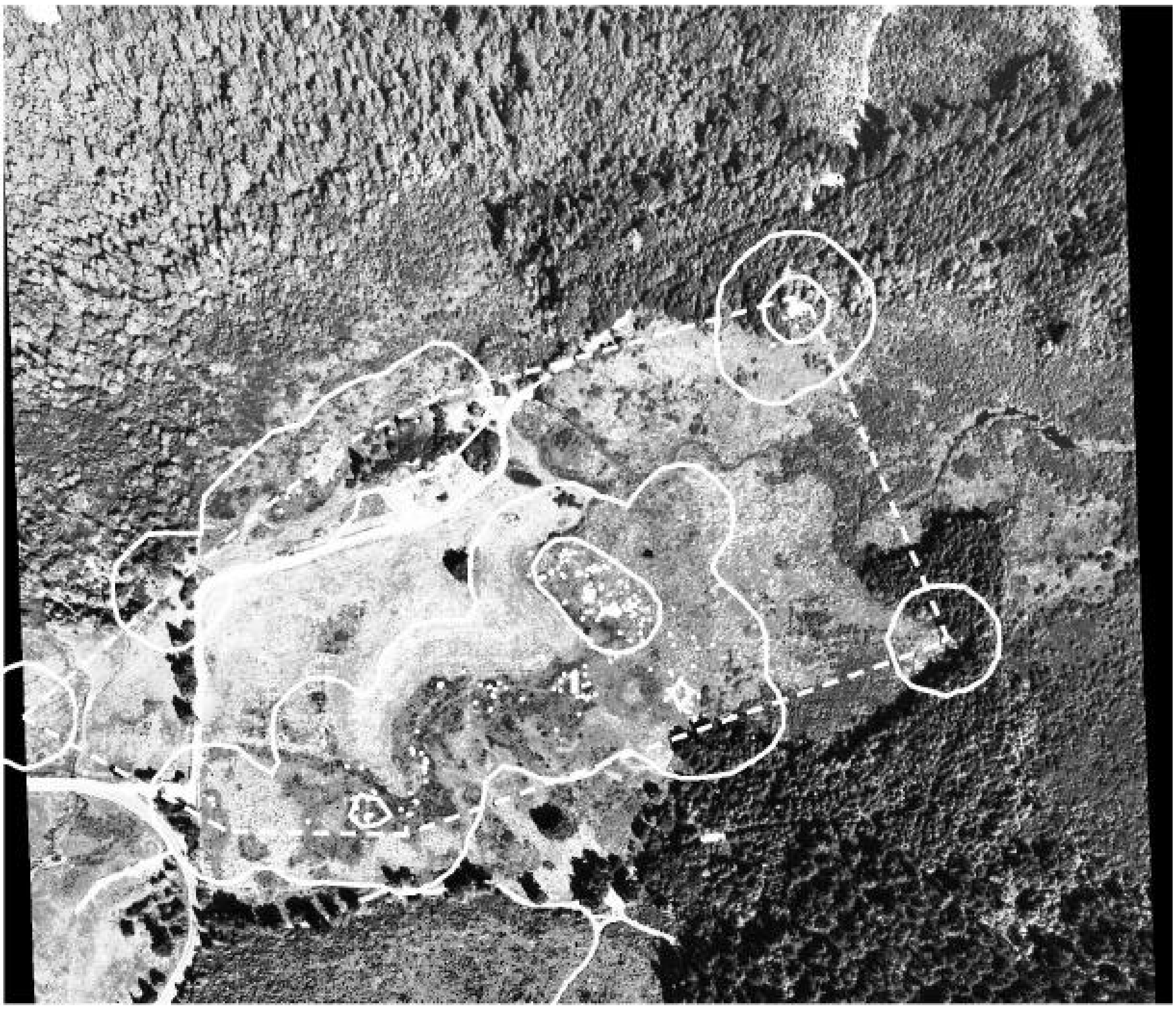


Fig. 3.5. Population range from pooled locations (*n* = 333) of 60 telemetered Oregon spotted frogs at Dempsey Creek in 1997. Solid lines identify the 100% fixed kernel (outer contours, 37.07 ac) and 50% fixed kernels (inner contours, 2.73 ac). The dashed line identifies the 100% minimum convex polygon (51.11 ac). White dots are frog locations. Map scale is 1:4,875.

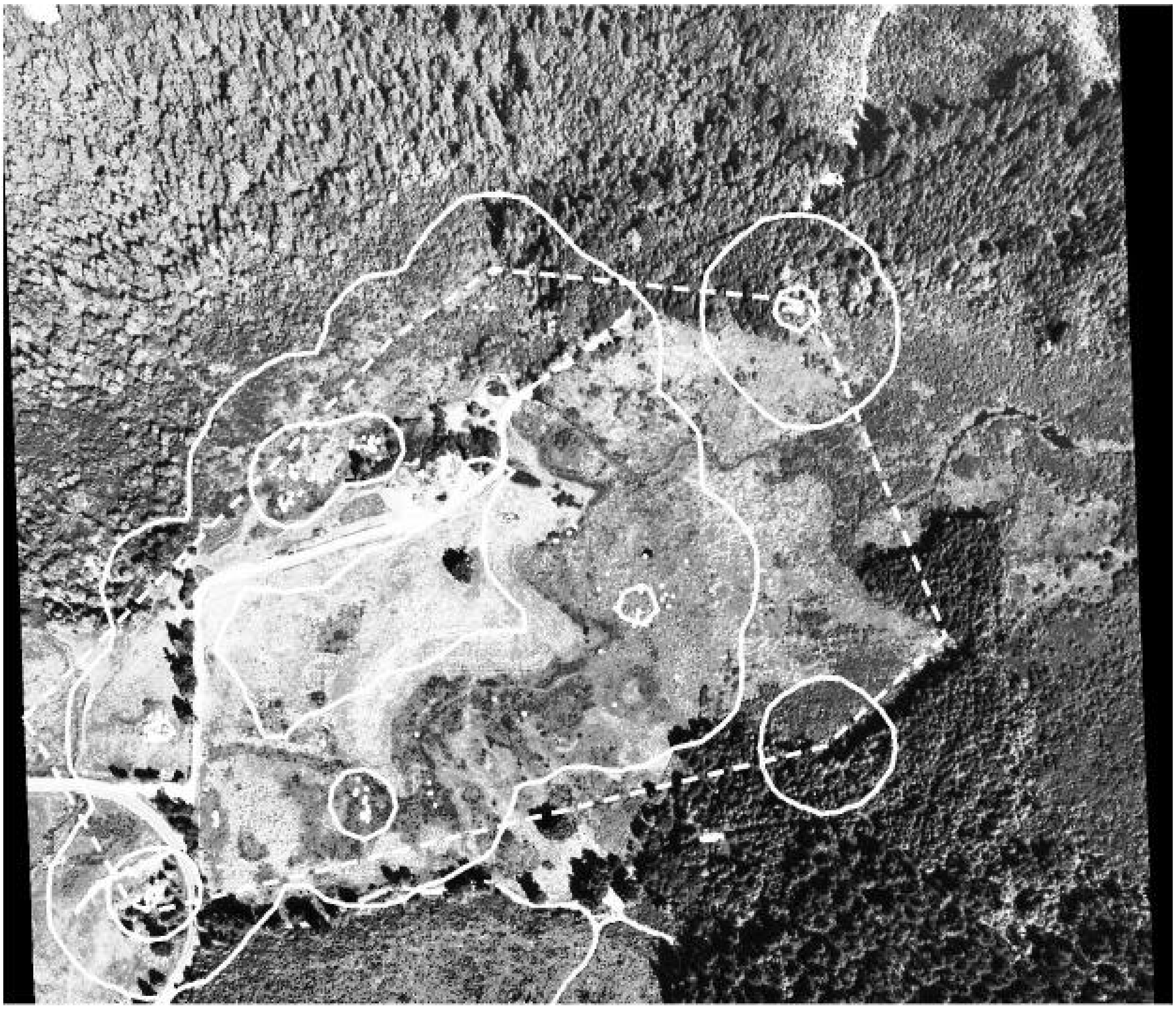


Fig. 3.6. Population range from pooled locations (n = 321) of 60 telemetered Oregon spotted frogs at Dempsey Creek in 1998. Solid lines identify the 100% fixed kernel (outer contours, 63.43 ac) and 50% fixed kernels (inner contours, 4.28 ac). The dashed line identifies the 100% minimum convex polygon (67.62 ac). White dots are frog locations. Map scale is 1:4,875.

distance movements during this period. However, five adult female and one male frog were monitored via telemetry for 147 to 225 days and at 25 to 47 locations (Appendix, Table 3), including one female monitored during 2 years. The best estimate of home range size was from four frogs (PIT No's. 410861757D, 41086F2651, 41086E1A64, and 41095C571A) that were monitored a substantial portion of each of the three seasons (i.e., breeding, dry, wet) in 1997 (Table 3.1). These frogs moved between three to five major pools throughout the year. Their ranges overlapped, and on average occupied 8% to 9% of the population range of all telemetered frogs. Minimum convex polygons for these animals provided a poorer representation of range size than did fixed kernels since polygons often included uplands between pools that were not used (Fig. 3.7 to Fig. 3.10). The female with the largest home range (PIT 41086E1A64) occupied three general areas that were widely separated (Fig. 3.9). Her daily rate of movement (6.8 m/day) was similar to that of another female (PIT 4180861757D; 6.6 m/day) although her 100% FK home range was four times larger (i.e., 12.42 ac vs. 3.32 ac). Movement patterns of these two frogs typified the extreme types of annual movements exhibited by frogs; infrequent, long-distance movements between widely separated pools, or frequent movement between pools in closer proximity (Fig. 3.11). The only male frog (PIT 414F112E27) monitored with a similar intensity to these four females (i.e., 147 days, 25 locations) occupied a similar-sized area (i.e., 100% FK = 6.04 ac) (Fig. 3.12) and moved at a similar rate (i.e., 4.4 m/day). He was not monitored during the wet season (September-December), a period when frogs normally exhibited long-distance movements (Table 3.1).

Table 3.1. Summary characteristics (mean ± standard error) of individual Oregon spotted frog ranges and movements during different seasons at Dempsey Creek, Washington, 1997-98.

Range Type[a]	No. Frogs	No. Days Monitored	No. Locations	Range Size (ac)[b] 100% FK	100% MCP	Movement[c] (m/day)
Home range	4	203 ± 14	44 ± 2	5.40 ± 2.48	6.41 ± 4.85	5 ± 1
Breeding	9	72 ± 4	14 ± 1	4.49 ± 1.55	1.69 ± 0.48	7 ± 2
Dry	9	75 ± 5	17 ± 2	0.50 ± 0.21	0.45 ± 0.23	3 ± 1
Wet	4	98 ± 23	15 ± 3	4.70 ± 0.71	2.17 ± 0.40	6 ± 1

[a] Home range includes the entire year from the Breeding Season through the Wet Season; Breeding Range = February through May; Dry Season Range = June through August; Wet Season Range = September through January.

[b] 100% Minimum Convex Polygon, 100% Fixed Kernel. A minimum of 10 locations gathered over a minimum of 50 days was used to estimate range size.

[c] Movement distance and movement rates were minimums since they were based on locations gathered twice/week.

Breeding Season Range.--Forty-two frogs were monitored during the breeding season (February-May) of 1997 or 1998 (Appendix, Table 3). The breeding range from pooled locations of these frogs (Fig. 3.13; 100% FK = 34.04 ac; 100% MCP = 46.31 ac; n = 292 locations) occupied 50% to 64% of the population range that encompassed all telemetered frog locations

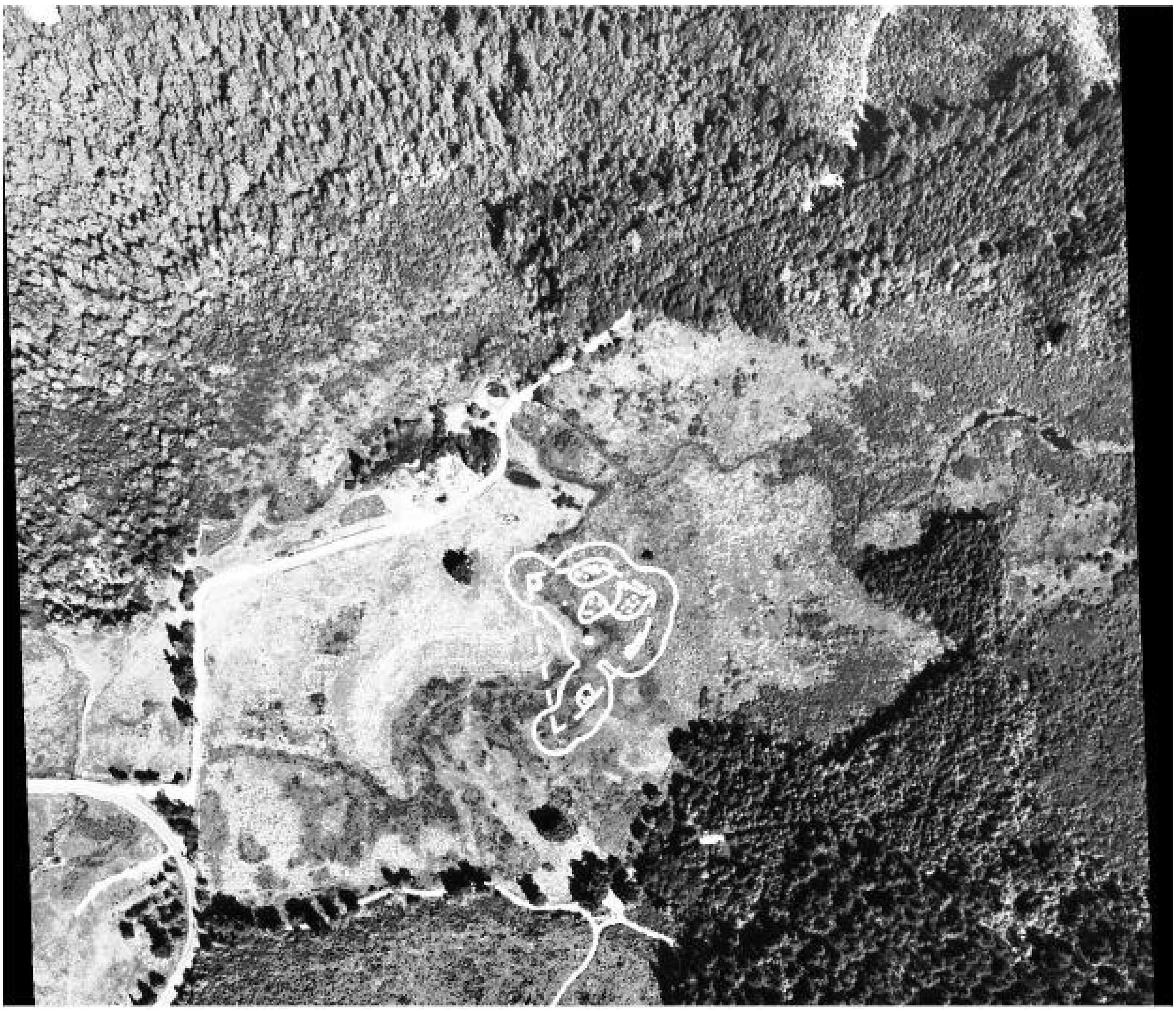


Fig. 3.7. Home range of adult female Oregon spotted frog 410861757D, occupied from 3/20/97 to 10/31/97 at Dempsey Creek, Washington. Solid lines identify the 100% fixed kernel (outer contours, 3.32 ac), and 50% fixed kernels (inner contours, 0.50 ac). The dashed line identifies the 100% minimum convex polygon (2.28 ac). White dots are frog locations (*n* = 47). Map scale is 1:4,875.

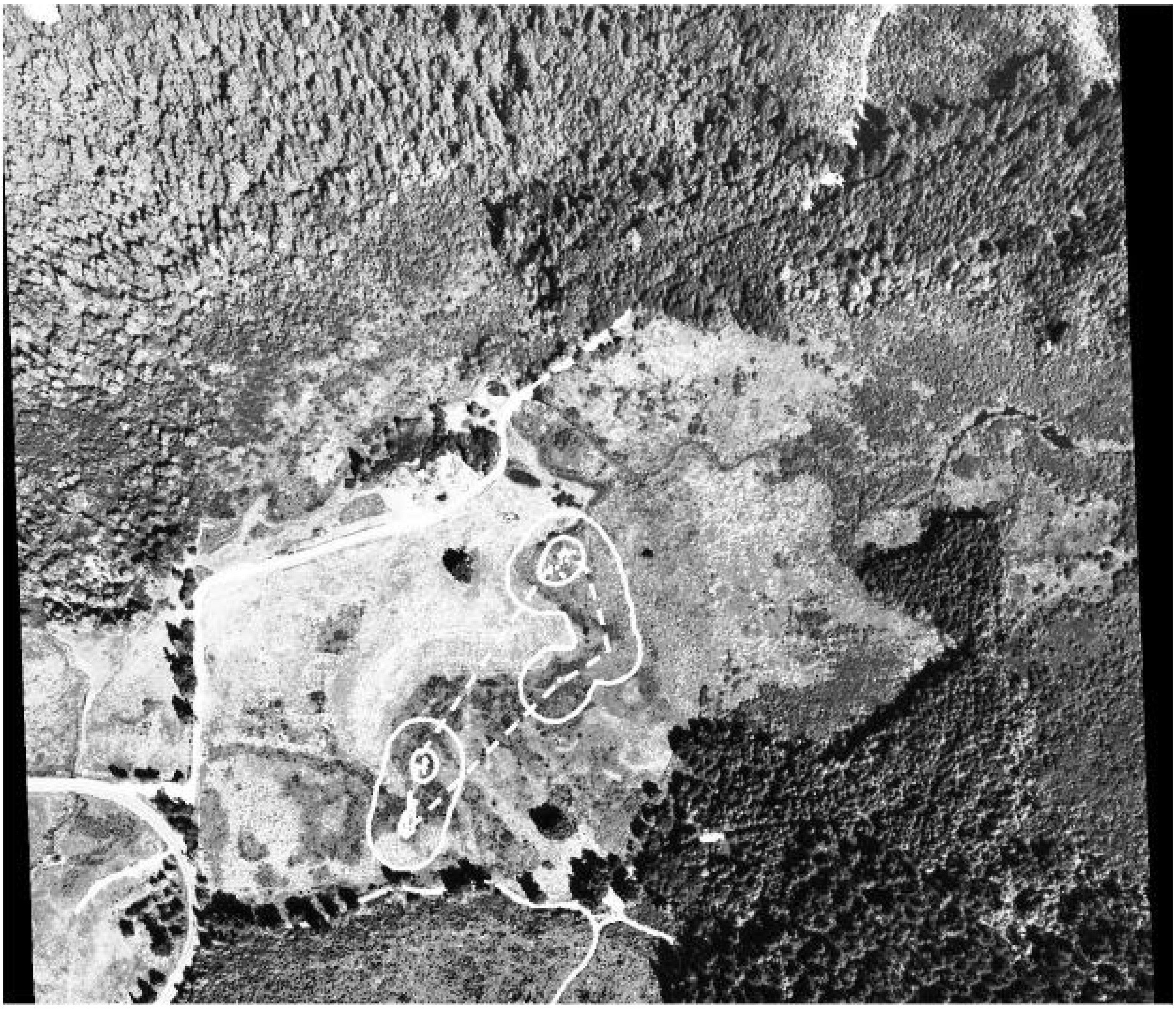


Fig. 3.8. Home range of adult female Oregon spotted frog 41086F2651, occupied from 3/24/97 to 10/10/97 at Dempsey Creek, Washington. Solid lines identify the 100% fixed kernel (outer contours, 4.92 ac), and 50% fixed kernels (inner contours, 0.43 ac). The dashed line identifies the 100% minimum convex polygon (3.51 ac). White dots are frog locations (*n* = 47). Map scale is 1:4,875.

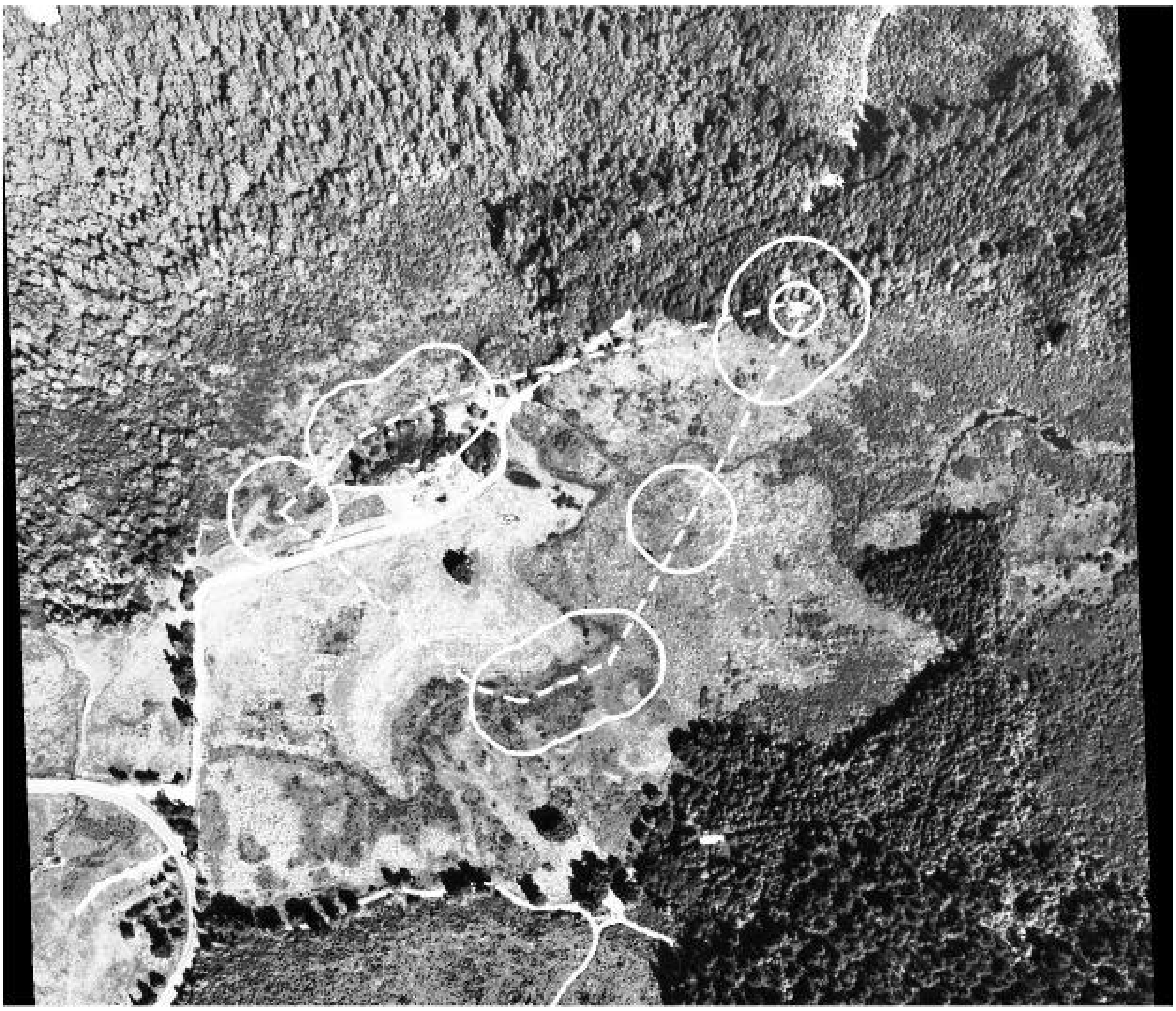


Fig. 3.9. Home range of adult female Oregon spotted frog 41086E1A64, occupied from 3/24/97 to 10/31/97 at Dempsey Creek, Washington. Solid lines identify the 100% fixed kernel (outer contours, 12.42 ac), and 50% fixed kernels (inner contours, 0.38 ac). The dashed line identifies the 100% minimum convex polygon (18.49 ac). White dots are frog locations (n = 42). Map scale is 1:4,875.

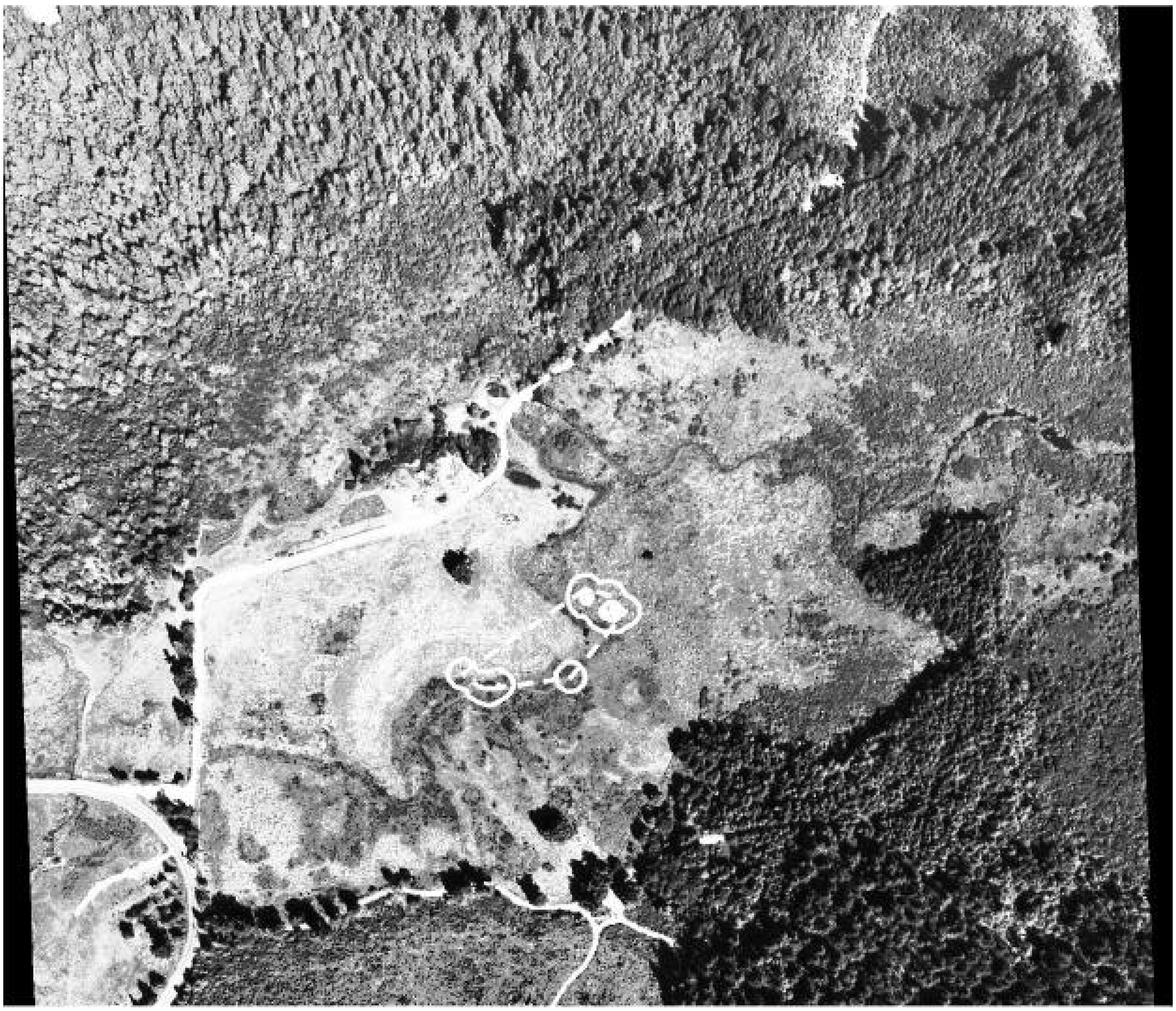


Fig. 3.10. Home range of adult female Oregon spotted frog 41095C571A, occupied from 5/12/97 to 10/23/97 at Dempsey Creek, Washington. Solid lines identify the 100% fixed kernel (outer contours, 0.93 ac), and 50% fixed kernels (inner contours, 0.08 ac). The dashed line identifies the 100% minimum convex polygon (1.36 ac). White dots are frog locations (*n* = 39). Map scale is 1:4,875.

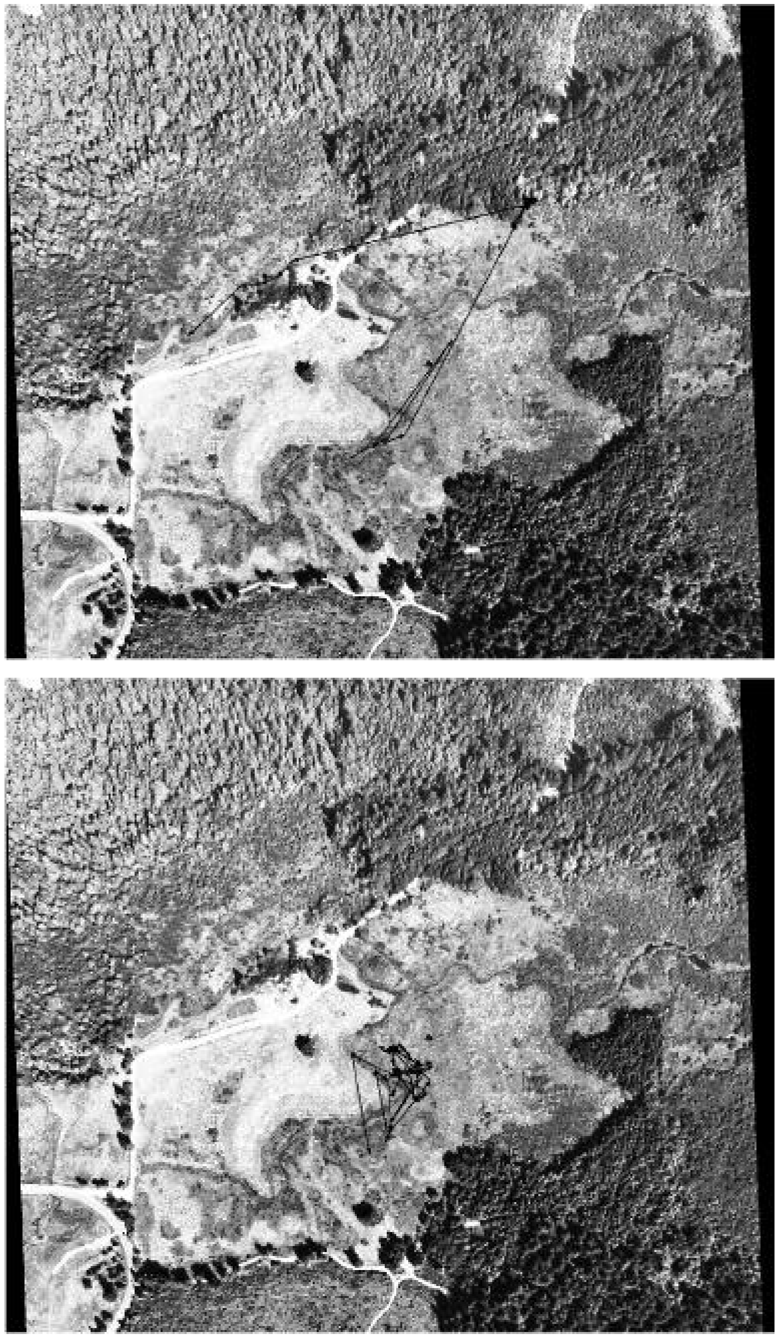


Fig. 3.11. Annual movement patterns exhibited by adult female Oregon spotted frogs showing (top) infrequent movement between extant pools (frog 41086E1A64; 6.8 m/day for 221 days, n = 42 locations) and (bottom) frequent movement between pools in closer proximity (frog 410861757D; 6.6 m/day for 225 days, n = 47 locations). Map scale is 1:3,413.

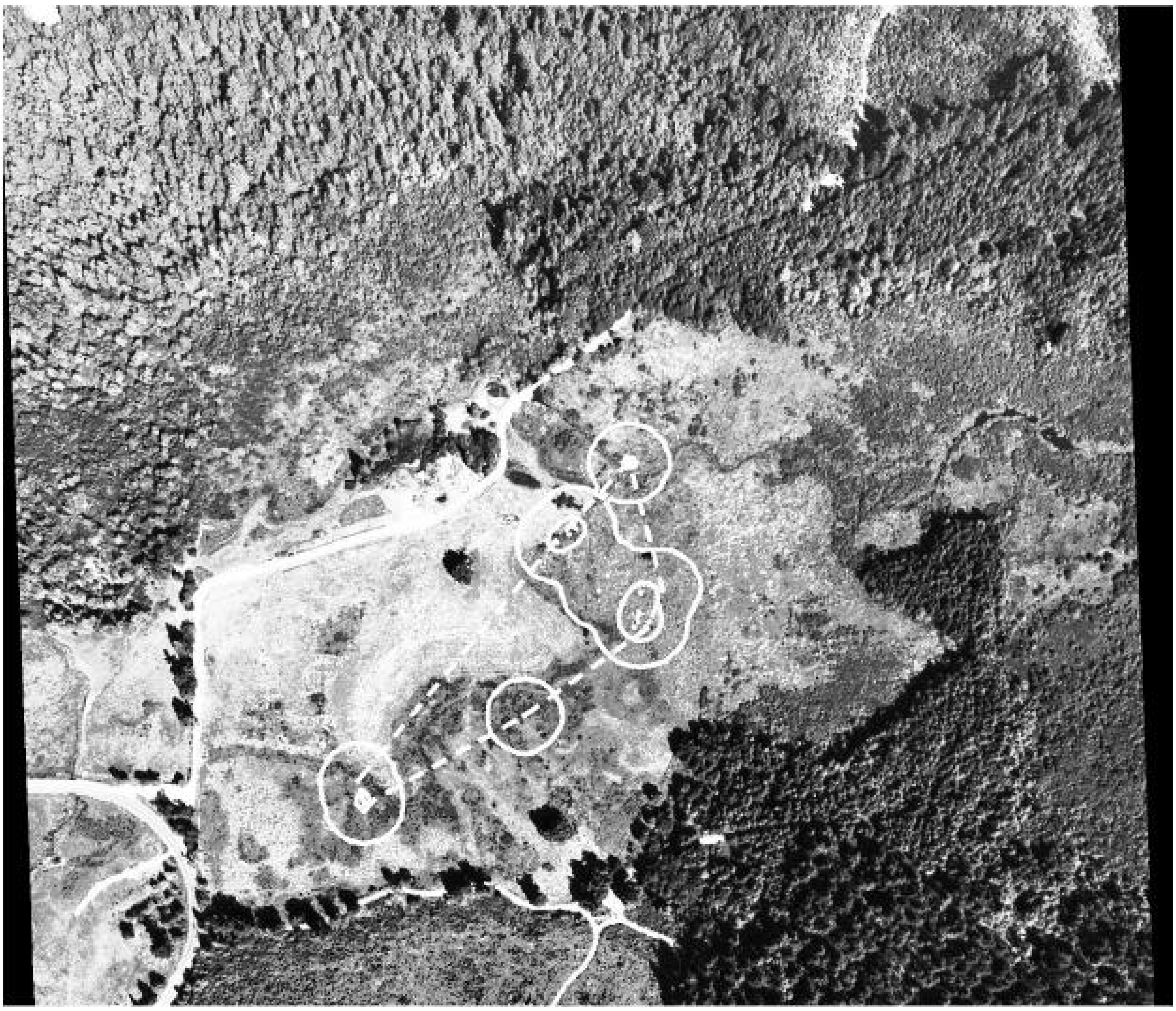


Fig. 3.12. Home range of adult male Oregon spotted frog 414F112E27, occupied from 2/24/98 to 7/21/98 at Dempsey Creek, Washington. Solid lines identify the 100% fixed kernel (outer contours, 6.04 ac), and 50% fixed kernels (inner contours, 0.56 ac). The dashed line identifies the 100% minimum convex polygon (5.93 ac). White dots are frog locations (n = 25). Map scale is 1:4,875.

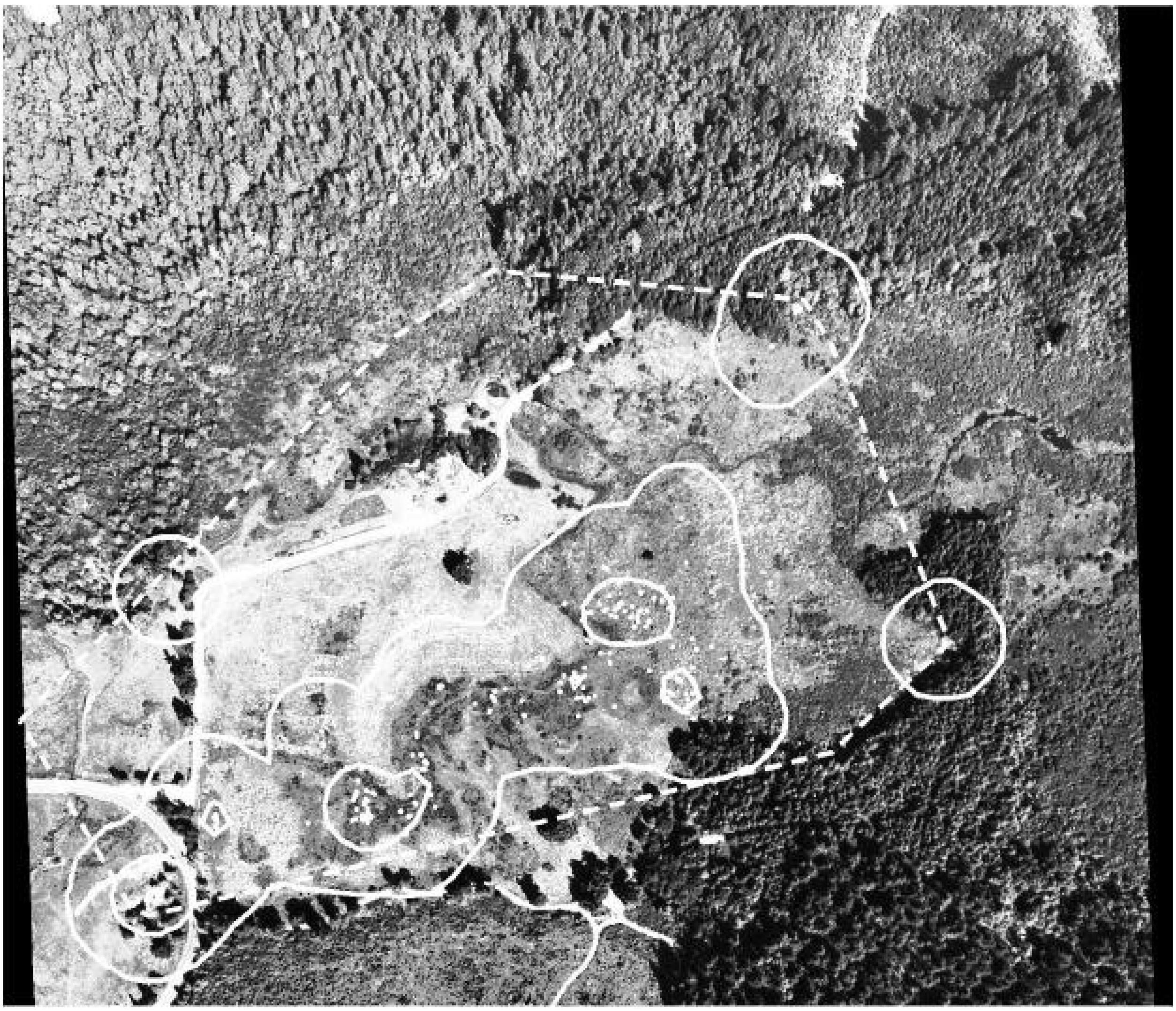


Fig. 3.13. Breeding range of Oregon spotted frogs at Dempsey Creek based on pooled locations of 42 telemetered animals in 1997 and 1998. Solid lines identify the 100% fixed kernel(outer contours, 34.04 ac), and 50% fixed kernels (inner contours, 3.30 ac). The dashed line identifies the 100% minimum convex polygon (46.31 ac). White dots are frog locations (*n* = 295). Map scale is 1:4,875.

throughout the year. The most significant area not included in the breeding range that was used by telemetered frogs at other times of the year was at the northern portion of the study area where Dempsey Creek left its channel and flowed broadly through dense woody and emergent vegetation. The water at this location was typically flowing and deep during the breeding season. Late in the breeding periods of 1998 and 1999 we identified a single egg mass of Oregon spotted frogs in this northern area, suggesting some minimal use of the area during breeding. Thus, while most egg-laying on the study site was communal and frog distribution during the breeding season was clustered near the main breeding pools, there was occasional breeding activity away from communal oviposition sites and closer to permanent, and usually deeper water.

Nine frogs provided the best estimate of an individual's breeding season range size (i.e., frogs monitored $\geq$50 days and with $\geq$10 locations). The average individual breeding range was similar in size to that used in the wet season, but over four times larger than in the dry season (Table 3.1). Similarly, average movement rates during the breeding season were similar to those in the wet season, but twice as great as movements in the dry season (Table 3.1). Exceptional rates of movement were also characteristic of this season; seven frogs (6 females, 1 male) moved at a rate between 32 and 111 m/day for 2-18 days (Appendix, Table 3). We did not find sexual differences in rates of movement (P = 0.595) or the rate of pool use (i.e., no. pools/days observed; P = 0.290) for 38 frogs during the breeding season. On average, during the breeding season, frogs of both sexes moved to a different pool every 22 days (SE = 2); this included return to use of previously used pools.

Thirty-five frogs recaptured in successive years (including one captured 2-years apart) during the breeding season provided a measure of breeding range fidelity ($\bar{x}$ separation of Julian capture dates = 28 days, SE = 4; $\bar{x}$ distance of location separation = 137 m, SE = 24). Breeding range fidelity, which we defined as recaptures $\leq$150 m from previous locations, or the diameter of the average breeding range area (4.5 ac), was exhibited by 22 (63%) of the frogs. Eight (23%) of 35 frogs were recaptured $\leq$15 m from the previous year's location, in the same pool or an associated channel, including one frog at the exact location.

Small samples precluded statistical comparisons of site fidelity during breeding to other seasons. However, during the dry season, five of seven (71%) frogs were recaptured in successive years $\leq$150 m from previous locations ($\bar{x}$ separation of Julian capture dates = 63 days, SE = 13; $\bar{x}$ distance separated = 65 m, SE = 28), including one frog at the exact location. Similarly, five of seven (71%) frogs were recaptured successive years during the wet season $\leq$150 m from previous locations ($\bar{x}$ separation of Julian capture dates = 16 days, SE = 1; $\bar{x}$ distance separated = 93 m, SE = 43), including two frogs at the exact location. One telemetered frog (i.e., PIT 41086E1A64, Appendix, Table 3) provided site fidelity information in successive years during the same season. For the periods of 5/4/97 to 9/23/97, and 5/4/98 to 9/17/98, this frog occupied the same pool, but used a smaller area in 1997 (100% MCP = 0.07 ac vs. 0.26 ac in 1998). Distance moved and rate of movement were similar both years (207 m at 2 m/day in 1997; 260 m at 2 m/day in 1998) although the frog was monitored 6 fewer days in 1997.

Observations of overland movement of frogs during the breeding season or at other times of the year were rare. Once, we observed a telemetered frog moving upslope into a patch of Himalayan blackberry. Evidence that Oregon spotted frogs traveled by water was found at one breeding pool that was separated from the main study area by a two-lane road (Fig. 3.1). This breeding pool was heavily used in 1998 and 47 adults were captured in this pool. The only water route connection to the pool was provided by a culvert under the road. An Oregon spotted frog was observed on the road during an evening rain, but we did not find road-killed Oregon spotted frogs throughout the study. In contrast, we found several road-killed red-legged frogs (*Rana aurora*) and dozens of road-killed Pacific treefrogs (*Hyla regilla*).

Dry Season Range.--Eighteen frogs were monitored during the dry season from June through August (Appendix, Table 2). The pooled range for these frogs (Fig. 3.14; 100% FK = 30.64 ac, 100% MCP = 53.73 ac; n = 205 locations) occupied 45% to 75% of the population range that encompassed all telemetered frog locations throughout the year. The western side of the study area, which was occupied at other times of the year, was the most significant area not used by frogs in the dry season. Except for Dempsey Creek, which flowed in an incised channel at this location, the area was devoid of standing water by August.

Individual ranges during the dry season were the smallest of all seasonal ranges (Table 3.1). During the dry season, frogs were located in remnant pools in the main basin, or in pools along the forest margin, where they were often seen basking in the warm days of summer. Frogs were considerably less mobile during the dry season than at other times of the year (Table 3.1) but were not stationary. Movements of a female frog between two remnant pools in early June and late August (i.e., PIT 41095C571A) illustrated the confined activity of some frogs during the dry season (Fig. 3.15). Inexplicably, we had difficulty relocating male frogs during the dry season and hence only one male was represented in the telemetry sample during this period. It was unclear whether this was caused by behavioral differences that made males more difficult to capture, unique habitat use by male frogs that we did not identify, or for some other reason.

Wet Season Range.--Twenty-one frogs were monitored during the wet season from September through January (Appendix, Table 3). The pooled, wet season range for these frogs (Fig. 3.16; 100% FK = 41.15 ac, 100% MCP = 46.85 ac; n = 154 locations) occupied 60% to 65% of the population range that encompassed all telemetered frog locations throughout the year. During the wet season frogs made distinct up-drainage movements and redistributed themselves throughout the study area. Thus, the range of frogs during the wet season tended to overlap the breeding range to include the main breeding pools, but also included the western-most portion of the study area where frogs were found in the coldest periods of the wet season.

Four frogs provided quality location information for determining individual range size in the wet season (Table 3.1). Average range size of these frogs was similar to that of frogs during the breeding season, as were rates of frog movement, which increased during the wet season (Table 3.1). Increased rates of movement corresponded with increased precipitation, rising water levels, and increased mobility. Observations of three frogs late into the wet season indicated they

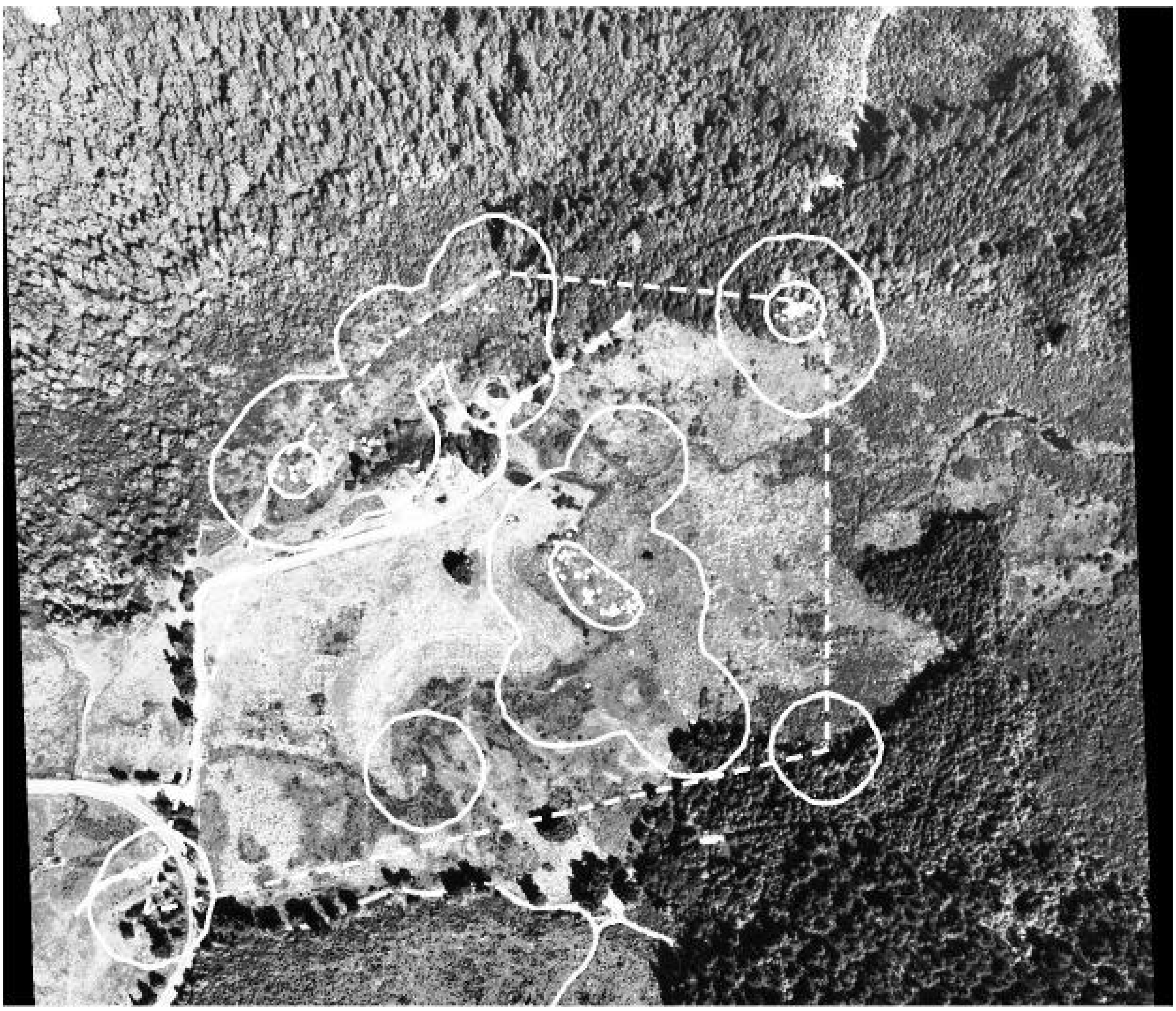


Fig. 3.14. Dry season range of Oregon spotted frogs at Dempsey Creek based on pooled locations of 18 telemetered animals in 1997 and 1998. Solid lines identify the 100% fixed kernel(outer contours, 30.64 ac), and 50% fixed kernels (inner contours, 1.71 ac). The dashed line identifies the 100% minimum convex polygon (53.73 ac). White dots are frog locations (*n* = 205). Map scale is 1:4,875.

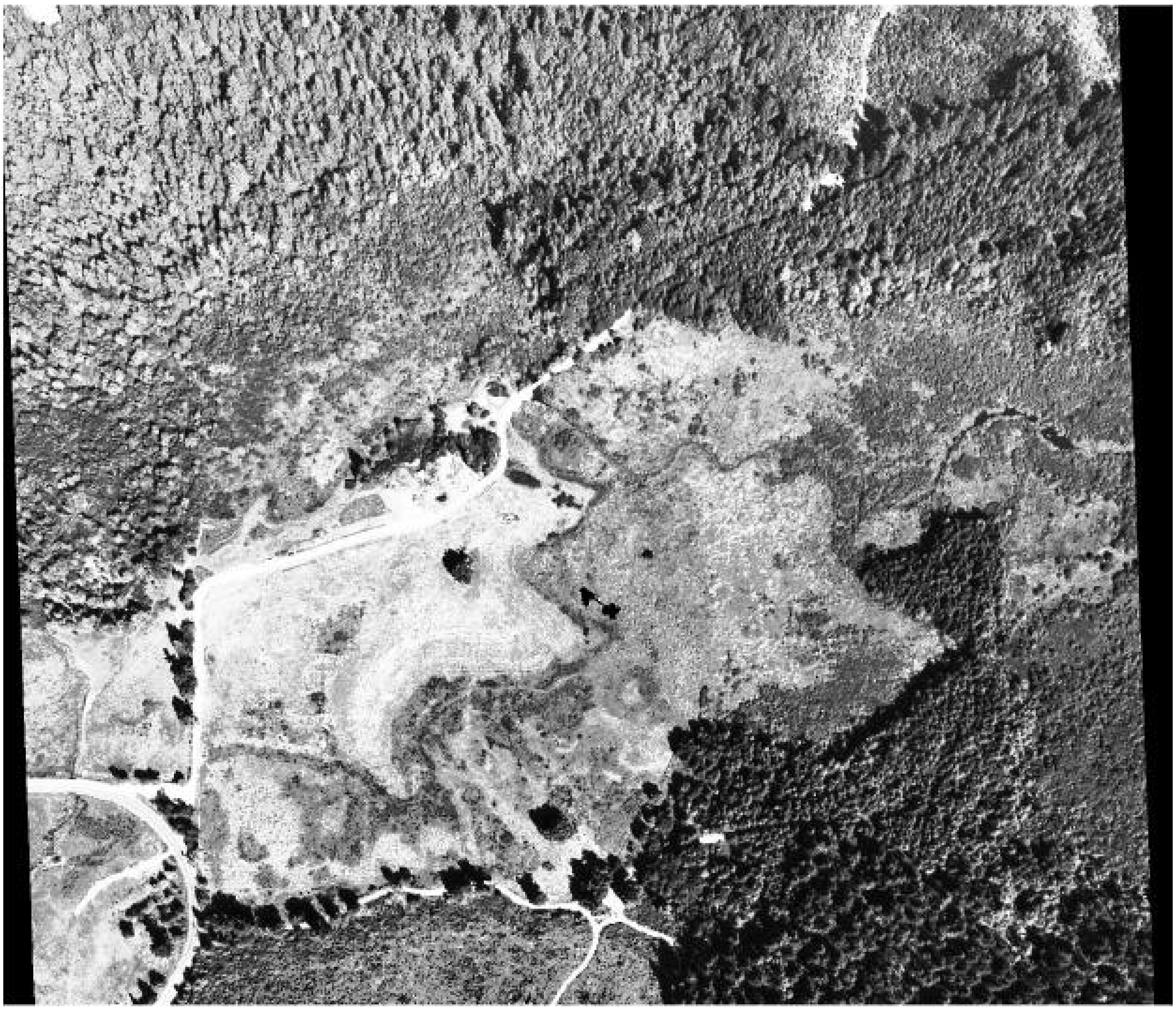


Fig. 3.15. Example of the confined, localized movement of Oregon spotted frogs at Dempsey Creek during the dry season. Movement is from an adult female frog (41095C571A) between early June and late August (88 days, n = 22 locations). Map scale is 1:3,413.

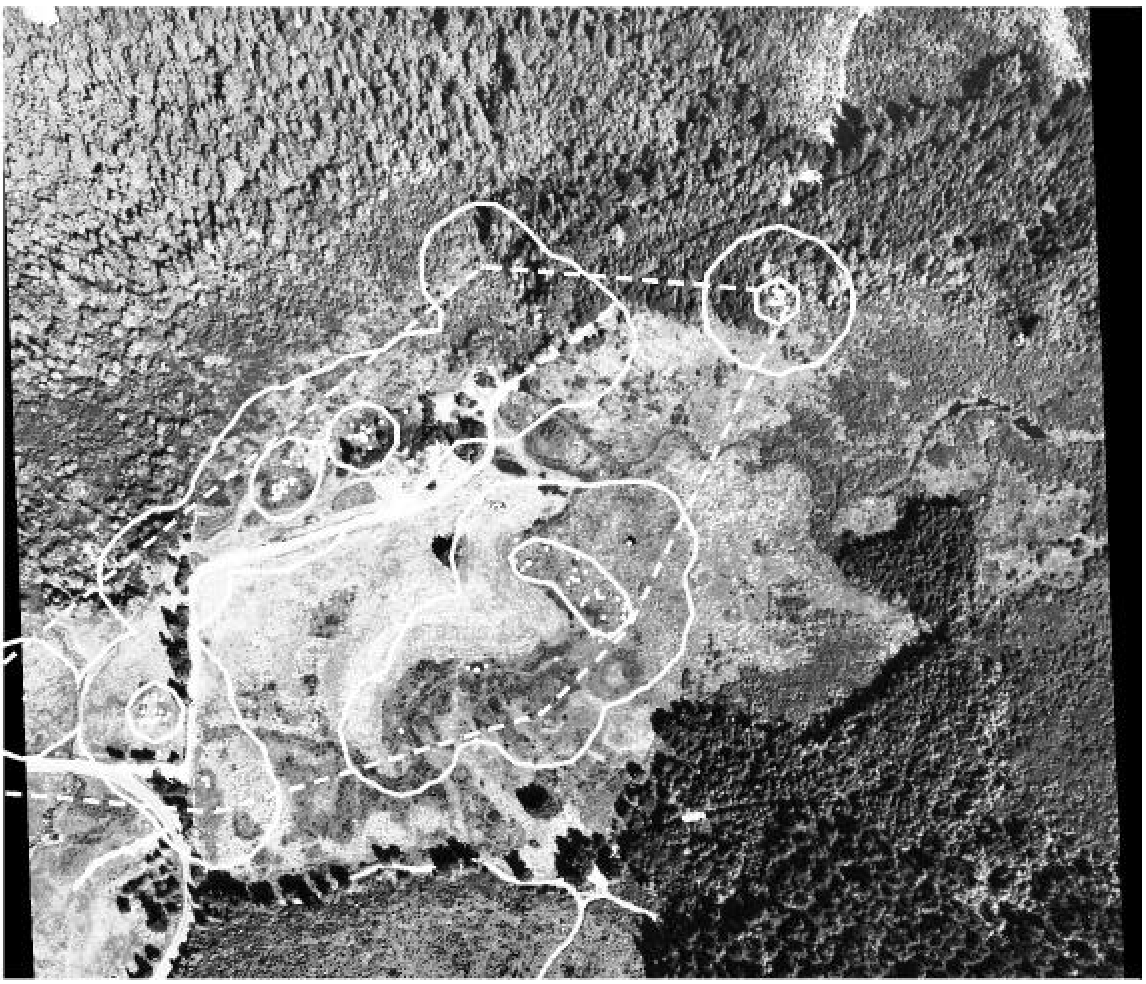


Fig. 3.16. Wet season range of Oregon spotted frogs at Dempsey Creek based on pooled locations of 21 telemetered animals in 1997 and 1998. Solid lines identify the 100% fixed kernel(outer contours, 41.15 ac), and 50% fixed kernels (inner contours, 3.26 ac). The dashed line identifies the 100% minimum convex polygon (46.85 ac). White dots are frog locations (n = 154). Map scale is 1:4,875.

continued to move westward to pastureland, until mid-winter (i.e., late December) when mobility ceased. One frog was last located in a ditch margin adjacent to pasture on 28 November. The other two frogs remained in shallow water on pastureland and buried themselves at the base of inundated clumps of soft rush. From mid-December to January these frogs remained immobile, buried in dense vegetation that was submerged in shallow water and for a time under $\leq$5 cm of ice. The last locations of these frogs indicated they moved a few meters by the time the ice was reduced to a thin layer.

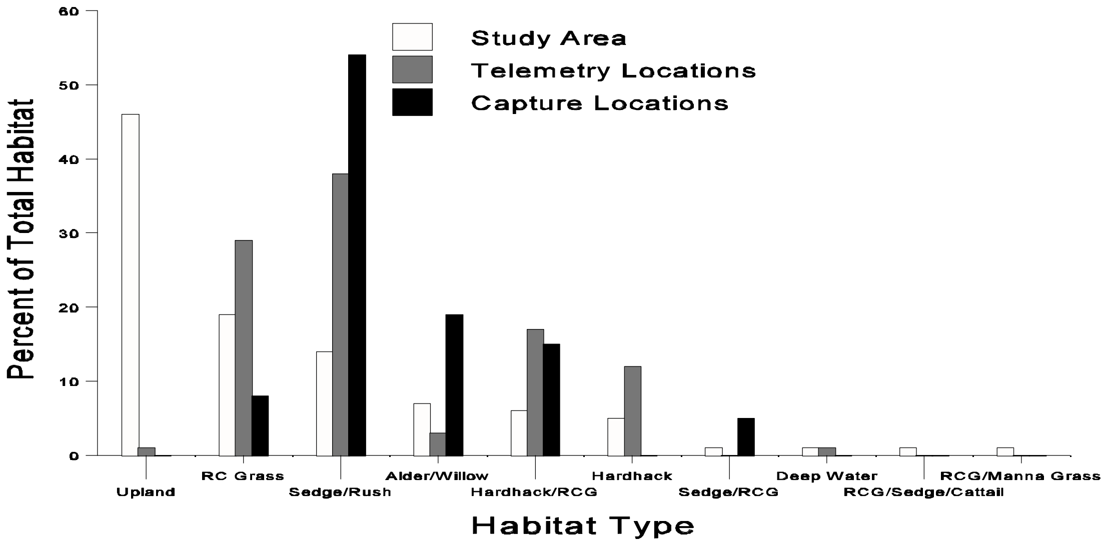
Habitat Selection

Macrohabitat Characteristics.--The boundary which encompassed frog locations, and within which we classified reflectance imagery to assess habitat availability, was 71 ac in size. Forty-six percent of this area (32.5 ac) was upland, and 54% wetland (38.5 ac) (Fig. 3.17a). Wetlands were predominated by reed canary-grass (35%) and sedge/rush (26%). Alder/willow (12%), hardhack/reed canary-grass (10%), and hardhack (9%) were less common, and there were smaller areas of sedge/reed canary-grass (3%), deep water (3%), reed canary-grass/sedge/cattail (2%) and reed canary-grass/manna grass (1%). Upland habitat was avoided by frogs relative to wetland habitats based on interpretation of 654 telemetry locations from 60 telemetered frogs (χ^2 goodness-of-fit = 360.32, 1 df, $P < 0.001$) and based on 938 capture locations of 546 frogs (χ^2 goodness-of-fit = 538.90, 1 df, $P < 0.001$). Thus, we excluded upland habitat from all further habitat analyses and concentrated our comparisons of use among wetland types.

Distribution of telemetry locations and capture locations among the major wetland habitat types (Fig. 3.17a) was different (χ^2 = 413.14, 6 df, $P < 0.001$). For telemetry locations, frogs selected sedge- and hardhack-dominated types, and avoided reed canary-grass types, alder/willow, and deep water (Table 3.2). Although reed canary-grass types were used less than other habitats based on availability, 30% of all telemetry locations were in reed-canary grass habitats, showing this habitat was used conditionally in the study area. Habitat selection based on capture locations was different from that based on telemetry locations; frogs selected for alder/willow and avoided hardhack-dominated types (Table 3.3). These differences reflected the bias in capture locations particularly in the dry season; frogs located in hardhack were difficult to capture, but those in the tree-dominated wetlands of alder and willow were easier to capture. We used telemetry locations as the basis for the remaining habitat selection analyses to avoid bias of capture locations due to differential capture success.

Oregon spotted frogs used habitats differently throughout the year based on the distribution of telemetry points during the breeding, dry, and wet seasons (Fig. 3.17b; χ^2 = 319.70, 8 df, $P < 0.001$). During the breeding season, frogs preferred sedge-dominated habitats, particularly the sedge/rush type found in association with oviposition sites (Table 3.4). The sedge/rush community was usually found along margins of permanent water and in depressions where seasonal waters were present during the breeding season and for a few weeks into the dry season. Hardhack types and alder/willow were in deep waters during the breeding season, when they were avoided by frogs. Avoidance of reed canary-grass reflected the fact that much of this habitat was inaccessible to frogs, particularly in the dry season of 1998, when low rainfall caused drying

(a)



(b)

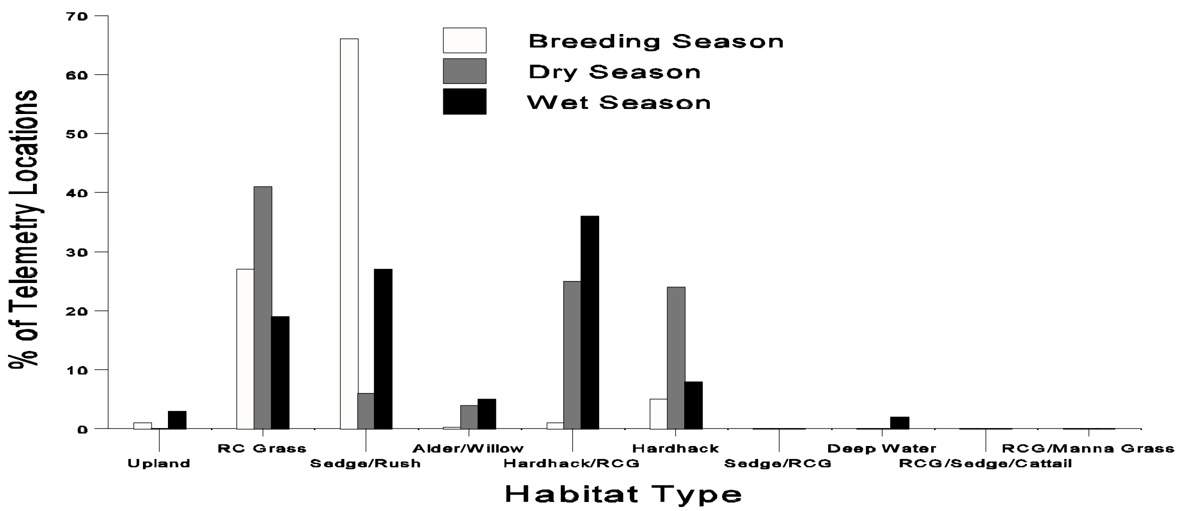


Fig. 3.17. Habitats used by Oregon spotted frogs at Dempsey Creek, Washington, 1997-98. Types were classified from interpretation of reflectance imagery from air photos. (a) Habitats defined by proportion of surface area within the study area (71 ac), by locations of telemetered frogs (*n* = 654), and frog capture locations (*n* = 938). (b) Seasonal habitat use by frogs defined by telemetry locations for the breeding season (February to May, *n* = 295 locations), dry season (June to August, *n* = 205 locations), and the wet season (September through January, *n* = 154 locations).

Table 3.2. Habitat selection of 60 telemetered Oregon spotted frogs based on 646 relocations among wetland habitat types at Dempsey Creek Washington, 1997-98.

Habitat	Acreage (proportion)		No. telemetry points (proportion)		90% family confidence interval[a]	Selection[b]
RC-grass dominant[c]	14.5	(0.376)	192	(0.297)	0.254 - 0.340	-
sedge dominant[d]	11.0	(0.286)	249	(0.385)	0.339 - 0.431	+
alder/willow	4.8	(0.124)	17	(0.026)	0.011 - 0.041	-
hardhack/RC-grass	3.9	(0.102)	109	(0.169)	0.134 - 0.204	+
hardhack	3.3	(0.086)	76	(0.118)	0.088 - 0.148	+
deep water	1.0	(0.027)	3	(0.005)	0.000 - 0.012	-
Total	38.5		646			

[a]Interval for proportion of occurrence of telemetry locations among habitat types.
[b]- = avoidance; 0 = no selection; + = preference.
[c]reed canary-grass (13.4 ac), reed canary-grass/sedge/cattail (0.7 ac), and reed canary/manna grass (0.4 ac).
[d]sedge/rush (10.0 ac) and sedge/reed canary-grass (1.0 ac).

Table 3.3. Habitat selection of Oregon spotted frogs based on 933 capture locations of 546 frogs among wetland habitat types at Dempsey Creek Washington, 1997-98.

Habitat	Acreage (proportion)		No. capture locations (proportion)		90% family confidence interval[a]	Selection[b]
RC-grass dominant[c]	14.5	(0.376)	72	(0.077)	0.056 - 0.098	-
sedge/rush	10.0	(0.259)	504	(0.540)	0.501 - 0.579	+
sedge/RC-grass	1.0	(0.027)	44	(0.047)	0.030 - 0.064	+
alder/willow	4.8	(0.124)	174	(0.187)	0.156 - 0.218	+
hardhack dominant[d]	7.2	(0.188)	138	(0.148)	0.120 - 0.176	-
deep water	1.0	(0.027)	1	(0.001)	0.000 - 0.003	-
Total	38.5		933			

[a]Interval for proportion of occurrence of capture locations among habitat types.
[b]- = avoidance; 0 = no selection; + = preference.
[c]reed canary-grass (13.4 ac), reed canary-grass/sedge/cattail (0.7 ac), and reed canary/manna grass (0.4 ac).
[d]hardhack (3.3 ac) and hardhack/reed canary-grass (3.9 ac).

Table 3.4. Seasonal habitat selection of Oregon spotted frogs based on 643 telemetry locations of 60 frogs at Dempsey Creek Washington, 1997-98. Analysis was based on 292 locations during the breeding season (February to May), 204 locations during the dry season (June to August), and 149 locations during the wet season (September to January).

Habitat	Season[a]	Acreage (proportion)[b]	No. telemetry locations (proportion)		90% family confidence interval[c]	Selection[d]
RC-grass dominant[e]	B	14.5 (0.387)	78	(0.270)	0.210 - 0.330	-
	D		84	(0.410)	0.331 - 0.489	0
	W		30	(0.201)	0.126 - 0.276)	-
sedge-dominated[f]	B	11.0 (0.293)	194	(0.671)	0.643 - 0.699	+
	D		12	(0.059)	0.021 - 0.097	-
	W		43	(0.289)	0.204 - 0.374	0
alder/willow	B	4.8 (0.128)	1	(0.004)	0.000 - 0.013	-
	D		8	(0.039)	0.008 - 0.070	-
	W		8	(0.054)	0.012 - 0.096	-
hardhack/RCG	B	3.9 (0.104)	3	(0.010)	0.000 - 0.023	-
	D		51	(0.249)	0.180 - 0.318	+
	W		56	(0.376)	0.285 - 0.467	+
hardhack	B	3.3 (0.088)	13	(0.045)	0.017 - 0.073	-
	D		50	(0.243)	0.174 - 0.312	+
	W		12	(0.080)	0.029 - 0.131	0
Total		37.5	643			

[a]B = breeding season; D = dry season; W = wet season.
[b]Available acreage based on interpretation of reflectance imagery from air photo taken in August, 1997.
[c]Interval for proportion of occurrence of telemetry locations points among habitat types.
[d]- = avoidance; 0 = no selection; + = preference.
[e]reed canary-grass (13.4 ac), reed canary-grass/sedge/cattail (0.7 ac), and reed canary/manna grass (0.4 ac).
[f]sedge/rush (10.0 ac) and sedge/reed canary-grass (1.0 ac).

of pools within this vegetation type. Instead, frogs selected hardhack-dominated habitats in the dry season (Table 3.4). Although hardhack was found over the deepest waters throughout the year, it provided shade that prevented the establishment of impenetrable grass cover, and when waters receded during the dry season frogs occupied the remnant pools of open water under the shrub canopy. Avoidance of sedge-dominated types in the dry season was a consequence of frogs moving away from oviposition sites, where sedge-dominated habitats were found, to deeper pools.

Habitat use was transitional during the wet season when frogs moved back into the breeding range (Table 3.4). Frogs continued to use hardhack and preferred hardhack/reed canary-grass, but also used sedge-dominated types in proportion to availability as they reoccupied shallower water areas.

Use of wetland macrohabitats by telemetered frogs was different in 1997 (n = 328 locations) than 1998 (n = 315 locations) (Fig. 3.18; χ^2 = 207.20, 4 df, $P < 0.001$). Except for alder/willow, which was avoided both years, selection between years was different for every major type (Table 3.5). In 1997, which was a wet year (chapter 2), frogs showed a preference for reed canary-grass types and hardhack, in part related to the higher water levels during breeding and summer, which allowed frogs to occupy pools which developed on top of or at breaks in the reed canary-grass matrix. Notably, at lower water levels, reed canary-grass covered what would otherwise have been open water, floating as a mat on the water's surface. In 1998, a dry year, pools within the the reed canary-grass matrix dried up and frogs more often associated with sedge/rush habitat or hardhack cover in reed canary-grass stands that provided open water. Additionally, in 1998 we telemetered more frogs on the north and west sides of the study area where there was more sedge/rush habitat.

Table 3.5. Annual habitat selection of Oregon spotted frogs based on telemetry locations of 60 frogs at Dempsey Creek Washington, 1997-98. Analysis was from 328 locations in 1997, and 315 locations in 1998.

Habitat	Year[a]	Acreage (proportion)[b]	No. telemetry locations (proportion)	90% family confidence interval[c]	Selection[d]
RC-grass dominant[e]	97	14.5 (0.387)	160 (0.488)	0.425 - 0.551	+
	98		32 (0.102)	0.064 - 0.140	-
sedge dominant[f]	97	11.0 (0.293)	101 (0.308)	0.250 - 0.366	0
	98		148 (0.470)	0.406 - 0.534	+
alder/willow	97	4.8 (0.128)	1 (0.003)	0.000 - 0.010	-
	98		16 (0.051)	0.023 - 0.079	-
hardhack/RCG	97	3.9 (0.104)	12 (0.037)	0.013 - 0.061	-
	98		97 (0.308)	0.248 - 0.368	+
hardhack	97	3.3 (0.088)	54 (0.165)	0.118 - 0.212	+
	98		22 (0.070)	0.032 - 0.108	0
Total		37.5	643		

[a]97 = 1997; 98 = 1998.
[b]Available acreage based on interpretation of reflectance imagery from air photo taken in August, 1997.
[c]Interval for proportion of occurrence of telemetry locations points among habitat types.
[d]- = avoidance; 0 = no selection; + = preference.
[e]reed canary-grass (13.4 ac), reed canary-grass/sedge/cattail (0.7 ac), and reed canary/manna grass (0.4 ac).
[f]sedge/rush (10.0 ac) and sedge/reed canary-grass (1.0 ac).

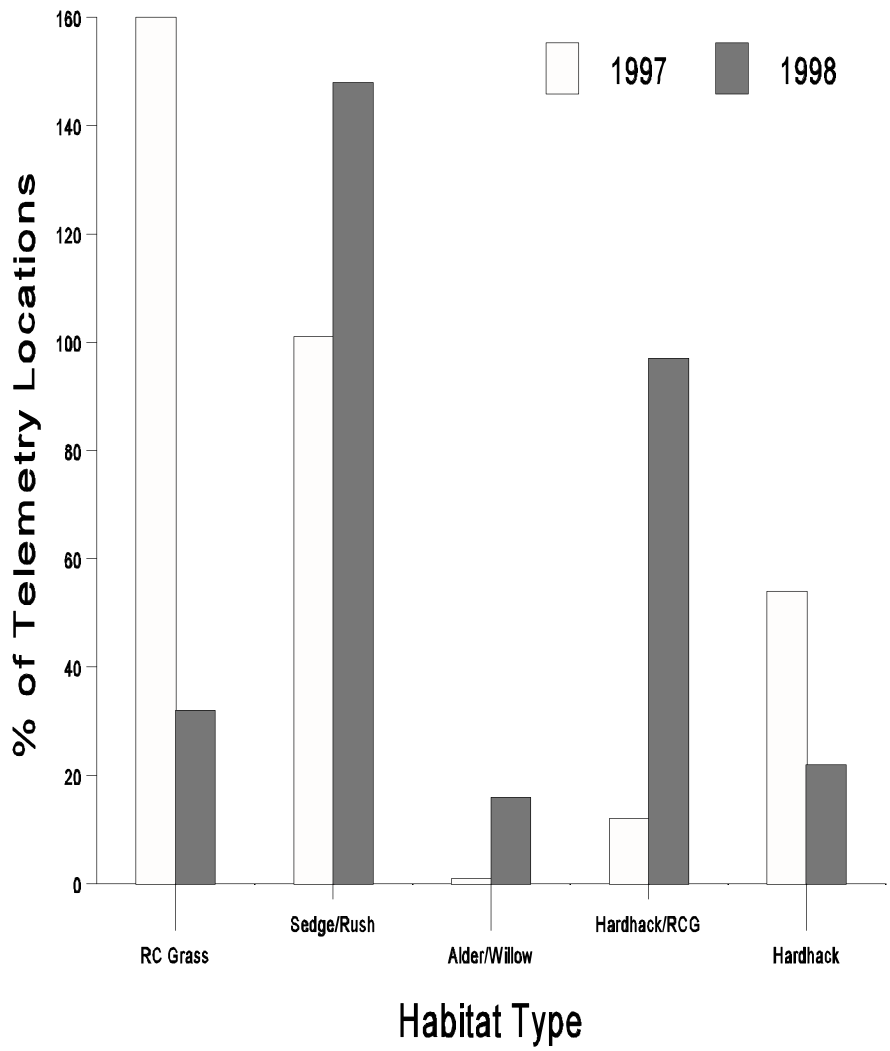


Fig. 3.18. Habitats used by Oregon spotted frogs at Dempsey Creek, Washington in 1997 (n = 328) and 1998 (n = 315). Types were identified from interpretation of reflectance imagery from air photos and ground-truthed.

Microhabitat Characteristics.-- The 60 telemetered frogs were recorded at 654 locations (n = 333 locations in 1997, and 321 in 1998). There was measurable water (i.e., >1 and <86 cm deep) at 99% (n = 645) of all frog locations. On average, frogs were located in water that was 19.0 cm deep (SE = 0.5), and selected water that was 3.3 cm (SE = 0.7) deeper than at random locations (paired-t = 4.89, $P < 0.001$). Mean monthly depths of water in which frogs were found fell within a relatively narrow range between 8.4 cm and 27.5 cm during both years (Fig. 3.19). The most notable difference in mean depths in 1997 and 1998 was a 10.2 cm drop in the mean depth of water where frogs were located during late spring (i.e., April/May) of 1998 (Fig. 3.19). This corresponded with a period of low rainfall, drying of larval-rearing pools, and poor recruitment. Overall, Oregon spotted frogs were located at the shallowest depths in March, deepest waters in the mid-summer dry season, and moderate depths in late fall.

We visually confirmed the geographic location of 351 frogs, and were able to determine the exact depth of frogs in the water column at 334 (51%) of 654 locations. Eighty-eight percent of these frogs (n = 293 locations) were at the water's surface or atop mud or dense vegetation at the water's surface (e.g., depth = 0 cm). Water temperature affected vertical position of frogs in the water column. There was a difference ($\chi^2 = 13.936$, 3 df, $P = 0.003$) between the proportion of frogs in a shallow location (≤10 cm from the surface) and a deep location (>10 cm) relative to the surface-to-subsurface temperature differential (i.e., surface - subsurface temperature in °C; class 1 = -3 to 0; class 2 = 0.1 to 3; class 3 = 3.1 to 6; class 4 = >6). There was a greater than expected proportion of frogs in a deep location for class 1; that is, frogs selected a deeper location (>10 cm) when the surface temperature was 0 to 3 °C colder than the subsurface temperature, accounting for 69% of the chi-square value. Thus, frogs tended not to surface when subsurface waters were the same temperature or warmer. When surface temperatures warmed to 0 to 3 °C above subsurface temperatures (class 2), frogs moved to the surface, resulting in fewer than expected proportions of frogs were at deeper depths, and accounting for 27% of the chi-square value. Ninety-six percent of frogs were at the water surface when the surface to subsurface temperature gradient was >3 °C.

The tendency for frogs to remain deeper in the water column was greater during the months of the breeding season (February to May) when 0% to 23% of the frogs were >10 cm below the surface, than during months in the dry and wet seasons (0% to 3%). Cool, overcast days during the breeding season reduced radiant heat and surface warming from the sun. Later in the year, especially during the dry season, warmer ambient temperatures resulted in comparatively higher water surface temperatures and frogs often surfaced. The trend at all frog locations during both years was for the lowest surface and subsurface temperatures prior to and during the breeding season, increasing to peak mean temperatures from May through July (Fig. 3.19). Annual surface temperatures at frog locations where water was ≥1 cm deep averaged 14.7 °C (SE = 0.2; range = 1.4 to 41.0) and subsurface temperatures 13.4 °C (SE = 0.2; range = 2.0 to 28.2). There was no difference in surface temperatures between frog and random locations ($P = 0.938$) or between subsurface temperatures at frog and random locations ($P = 0.720$).

Surface microhabitat≤0.28 m (0.25 m^2) from 654 frog locations was predominantly open water

(a)

(b)

(c)

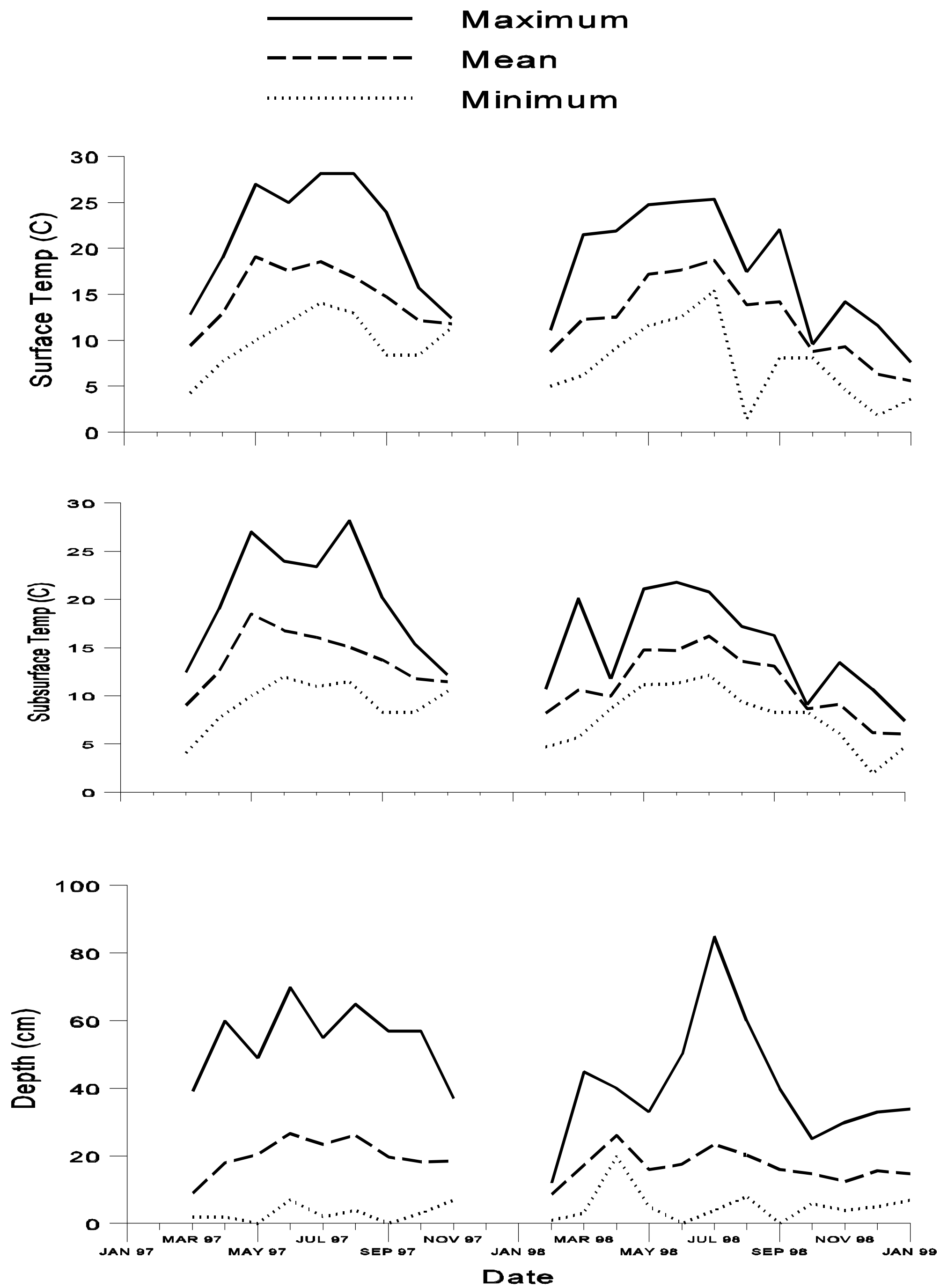


Fig. 3.19. Monthly changes in (a) water surface temperature, (b) water temperature at the substrate, and (c) water depth at 654 Oregon spotted frog locations at Dempsey Creek Washington, 1997-98.

(66%) and three emergent plant types (28%) including soft rush, reed canary-grass, and other grasses (primarily *Poa* sp.) (Fig. 3.20). Mud, hardhack, water pepper (*Polygonum* sp.), and water parsley (*Oenanthe sarmentosa*) accounted for 0.5% to 2% of all surface habitat types, with traces (<0.2%) of willow, sword fern (*Polystichum munitum*), Himalayan blackberry, cattail, water-starwort, wood, buttercup (*Ranunculus* sp.), bedstraw (*Gallium* sp.), skunk cabbage (*Lysichiton americanum*), and soil. Frogs selected areas with higher proportions of open water and lower proportions of reed canary-grass and other grasses (Table. 3.6). Based on the comparison of four percentage classes for actual and random locations (class 1 = 0-25%; class 2 = 26-50%; class 3 = 51-75%; and class 4 >75%), frogs avoided areas with class 1 surface water, which accounted for 81% of the chi-square value, but selected class 3 surface water, which accounted for an additional 13% of the chi-square value ($\chi^2 = 87.063$, 3 df, $P = 0.001$). Frogs avoided classes 3 and 4 reed canary-grass, which together accounted for 94% of the chi-square value ($\chi^2 = 16.56$, 3 df, $P = 0.001$). Frogs avoided class 4 other grass which accounted for 96% of the chi-square value ($\chi^2 = 18.02$, 3 df, $P = 0.001$). Thus, in their immediate proximity, frogs avoided the densest vegetation and the most open water, preferring locations that were moderately open (50 to 75% water).

Table 3.6. Sample means and standard errors of major surface habitats (%) within 0.25 m^2 of 654 Oregon spotted frog locations, and paired random sites, at Dempsey Creek, Washington, 1997-98.

Type	Actual		Random		Paired-t	*P*
	$\bar{x}$	SE	$\bar{x}$	SE		
Water	66.20	0.96	52.92	1.36	8.24	<0.001
Soft rush	13.63	0.86	13.71	0.97	0.17	0.907
Reed canary-grass	9.28	0.65	12.19	0.90	2.75	0.006
Misc. grass	4.56	0.43	7.82	0.79	3.76	<0.001
Mud	1.70	0.38	2.85	0.51	1.80	0.073
Water pepper	1.47	0.19	1.72	0.26	0.73	0.464
Hardhack	1.60	0.29	0.94	0.25	1.79	0.074

We found no difference in the absence or presence of cattle grazing (e.g., clipped/trampled vegetation, hoofprints, dungpiles) between actual and random frog locations ($P = 0.652$). This, in part, reflected the fact that random locations were derived from frog locations and had a similar distribution relative to grazed and ungrazed areas. At frog locations the absence or presence of cattle grazing was distributed disproportionately among four classes of total vegetative surface cover (class 1 = 0 to 25%; class 2 = 26 to 50%; class 3 = 51 to 75%; and class 4 >75%) ($\chi^2 = 10.13$, 3 df, $P = 0.017$). There was a greater proportion of frog locations with, than without, grazing sign where cover was 0-25% (41% of chi-square value) and a lower proportion with grazing sign where cover was >75% (58% of chi-square value). Thus, grazing was associated with reduced cover of emergent vegetation at the most open frog locations, and an absence of grazing was associated with the most densely vegetated sites. Where water depth was <10 cm and thus did not exclude use by cows, frog use of the five main wetland habitats was not

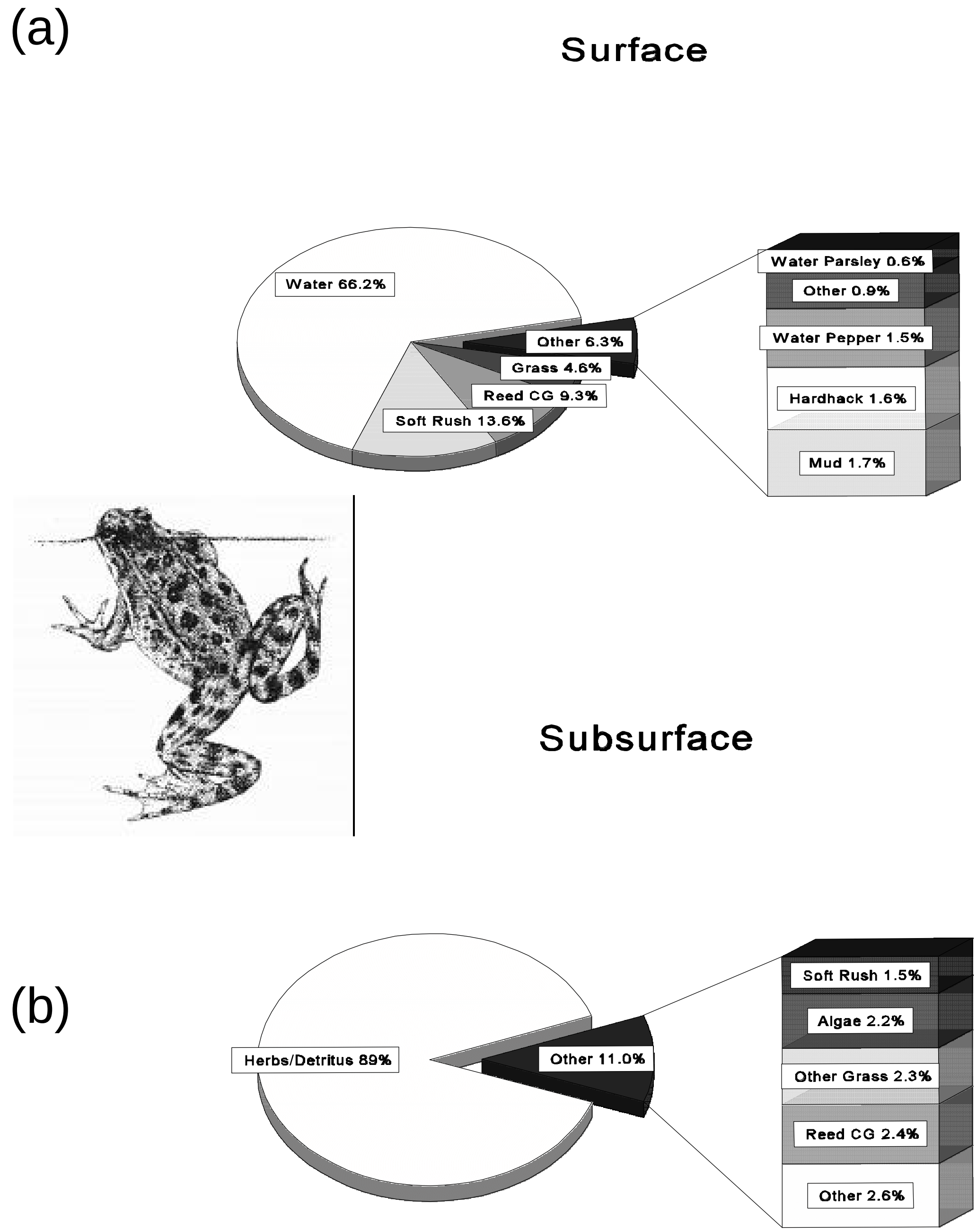


Fig. 3.20. Vegetation at (a) the surface and (b) within the water column $\leq$ 0.25 m^2 from 654 Oregon spotted frog locations at Dempsey Creek, Washington.

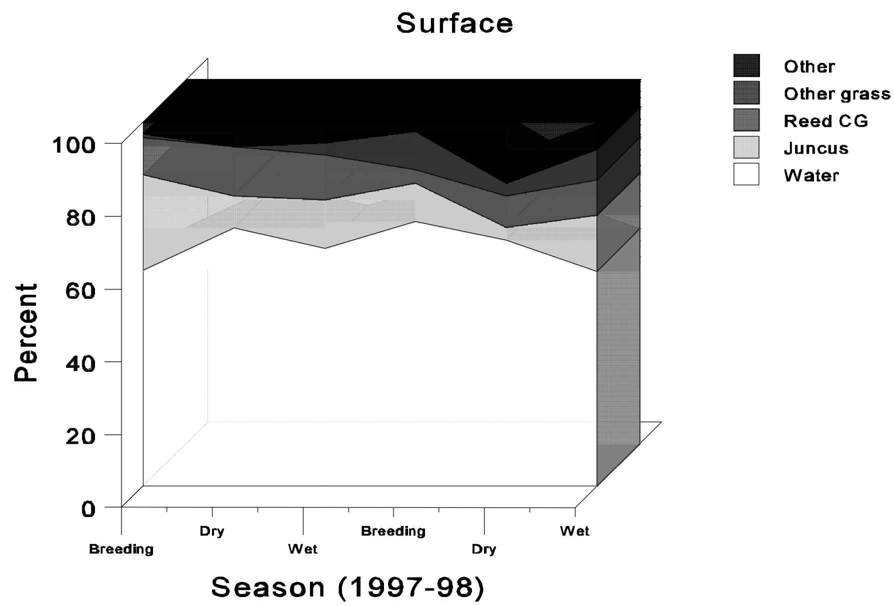
independent of grazing sign (χ^2 = 85.38, 5df, P < 0.001). Habitat at 78% of locations had signs of grazing. Hardhack was less likely to be grazed relative to other types (46% of chi-square value), sedge/rush was more likely to be grazed than other types (27% of chi-square value), and reed canary-grass was about equally likely to be grazed or ungrazed (10% of chi-square value).

Frogs exhibited seasonal changes in habitat use among the four major surface habitat types (Fig. 3.21). During the breeding season, frogs selected areas with a higher proportion of open water and avoided grasses other than reed canary-grass which was used according to its availability (Table 3.7). In the dry season, when percentages of water at random sites were the lowest of any season, frogs selected for open water and avoided all grasses (Table 3.7). During the dry year of 1998, proportions of the three major emergent types decreased at frog locations during the dry season (Fig. 3.21) but there was a significant increase (paired-t = 3.43, P <0.001) in the percent of hardhack at frog locations ($\bar{x}$ = 9.77, SE = 1.82) compared to random locations ($\bar{x}$ = 2.56, SE = 1.12). During the dry season of 1998, pools that remained tended to be at the bases of hardhack which shaded out the mat of reed canary-grass and provided relatively open pools. During the wet season frogs again selected for open water (Table 3.7).

Table 3.7. Sample means and standard errors of the major surface habitats (%) used seasonally within 0.25 m^2 of Oregon spotted frog locations, and paired random sites, at Dempsey Creek, Washington, 1997-98. Breeding season was from February through May (n = 292 locations), dry season from June through August (n = 205 locations), and wet season from September through January (n = 157 locations).

Season	Type	Actual		Random		Paired-t	*P*
		$\bar{x}$	SE	$\bar{x}$	SE		
Breeding	Water	66.16	1.47	54.15	2.10	4.97	<0.001
	Soft rush	18.17	1.56	16.36	1.62	0.15	0.387
	Reed CG	6.95	0.84	6.99	1.03	0.04	0.966
	Misc. grass	5.86	0.66	10.74	1.41	3.16	0.002
Dry	Water	69.52	1.66	50.00	2.41	6.54	<0.001
	Soft rush	6.57	0.95	9.22	1.32	1.61	0.110
	Reed CG	11.28	1.27	20.29	1.97	3.87	<0.001
	Misc. grass	1.56	0.51	4.29	1.00	2.63	0.009
Wet	Water	61.96	1.93	54.45	2.61	2.45	0.015
	Soft rush	14.40	1.56	14.65	2.02	0.21	0.833
	Reed CG	11.02	1.45	11.26	1.74	0.13	0.897
	Misc. grass	6.03	1.08	7.00	1.42	0.53	0.600

(a)



(b)

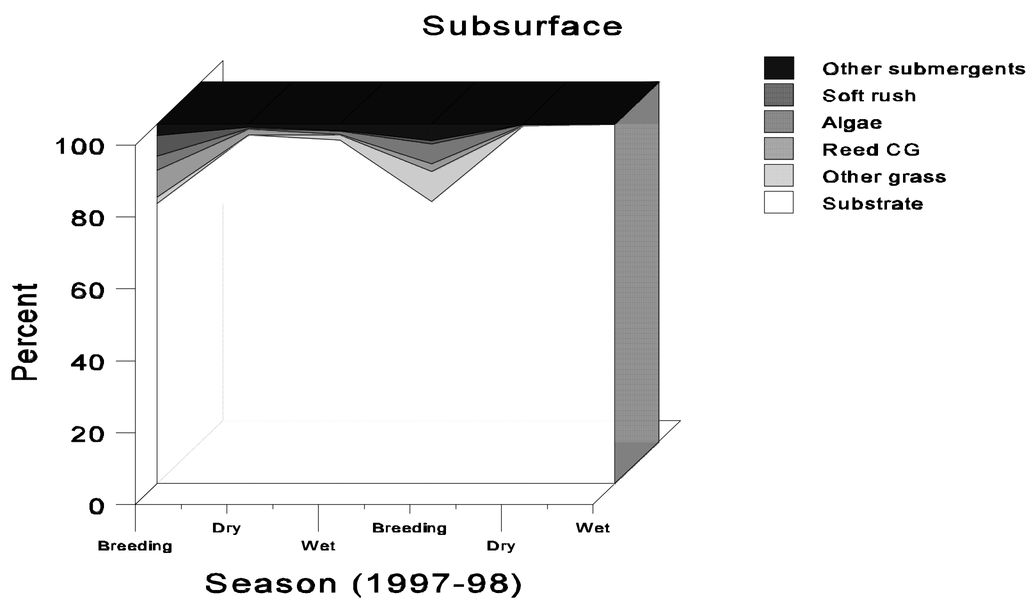


Fig. 3.21. Seasonal changes in habitats (a) above and (b) below water level within 0.25 m^2 of 654 Oregon spotted frog locations at Dempsey Creek, Washington.

Subsurface aquatic habitat $\leq$0.28 m (i.e., within a 0.25 m^2 area) from 654 frog locations was 89% open water above herbs/detritus/sediment at the bottom of the water column, and the remainder largely (8%) submergent soft rush, reed canary-grass, other grasses, and algae within the water column (Fig. 3.20). False loosestrife, water pepper, bedstraw, and wood fiber each accounted for <1% of the remaining area. Percentages of three of four major submergent plants were the same at actual and random sites (grass, P = 0.210; soft rush, P = 0.230; reed canary-grass, P = 0.130). Frogs locations had higher percentages of submerged algae (2.2%, SE = 0.3) than did random locations (1.3%, SE = 0.3) (paired-t = 2.24, P = 0.025). Substrate types at the bottom of the water column were categorized more specifically among the 654 locations as moist compact soil/herbs (51%), moist mat (27%), and moist mulch (22%). There was no selection for these substrate types based on comparisons to random locations (χ^2 = 3.54, 2 df, P = 0.171).

Live, submergent vegetation in the water column constituted <20% of the subsurface habitat during the breeding seasons of 1997 and 1998, but was essentially absent in the dry and wet seasons of both 1997 and 1998 (Fig. 3.21).

DISCUSSION

The population of Oregon spotted frogs at Dempsey Creek appears to be reproductively stable (Chapter 2). Thus, the quantity and juxtaposition of habitats are adequate, although perhaps not ideal, to meet the life cycle requirements of Oregon spotted frogs. While our study identified specific features frogs preferred, the overriding condition for continued frog presence at Dempsey Creek is in part the combination of vegetation types, hydrology, and topography that has become increasingly rare in surrounding areas and throughout western Washington: a large expanse of meadow/wetland with a continuum of vegetation densities along edges and in pools; gradual topographic relief that results in a shallow, slow-moving stream that branches and provides shallow side-pools for oviposition; channels that allow aquatic travel corridors to deeper pools that provide refugia during the dry season, and to shallow water habitats that don't freeze up in the winter; and a lack of introduced predators that have affected populations elsewhere (Hayes and Jennings 1986, Hayes et al. 1997). Although these features that we studied were found at the heart of the 38.5-acre wetland that defined the extent of frog use at Dempsey Creek, other factors that influence habitat quality reside well beyond the wetland to an undefined boundary. Those factors can potentially alter the hydrology (e.g., siltation, damming, construction etc.), fauna (e.g., introduced bullfrogs), or water quality (e.g., spills, runoff, livestock), of the Dempsey Creek study area. Unfortunately, these factors may be difficult to identify and manage but are important to the long-term maintenance of the Oregon spotted frog population. According to Hayes et al. (1997), the 38.5 acre wetland area occupied by frogs at Dempsey Creek is similar to other remnant populations, 58% of which reside on 10 to 63 acres.

Within the acreage actively used by Oregon spotted frogs at Dempsey Creek, spatial use of habitat was closely related to seasonal behaviors and changing surface water conditions. During breeding, frogs selected shallow, backwater pools for oviposition sites rather than deepwater areas. Abundant water allowed frogs uninhibited and exceptional movements. During the breeding season frogs collectively occupied $\geq$50% of the population range, and individuals occupied an average of >80% of their home ranges. In contrast, in the dry season, shallow pools disappeared and frogs were forced to move into remnant pools, which tended to be deeper and away from the breeding sites. Individuals often basked at or near the water surface, exhibited significantly reduced movements, and occupied an average of <10% of their home ranges. These deep pools were important refugia during the late summer, when frogs collectively occupied about 50% of the population range. During the wet season frogs again exhibited exceptional movements and reoccupied the breeding area and peripheral shallow areas, accounting for over 60% of the population range. Shallow water that inundated dense vegetation during the wet season allowed frogs to bury themselves at the base of plants and remain dormant during the coldest season without subsurface freezing during the winter. Similarly, Patla and Peterson (1997) found that Columbia spotted frogs also wintered where water did not freeze. This evidence leads us to conclude that different life stages of Oregon spotted frogs have different critical seasons associated with aquatic needs: adequate water levels for egg and tadpole survival are most important in the breeding season; deep pools are most critical for survival of juveniles and adults in the dry season; and adequate water levels over emergent vegetation are important for survival of all age classes during the wet season and coldest time of the year.

It is not known if the hydrology of the Dempsey Creek study area is unique for Oregon spotted frog populations that necessitates frogs moving from shallow-water breeding sites to deeper pools in the driest time of year. However, based on the selection frogs exhibited, we believe a topographic gradient, with overall gradual relief, may be a necessary characteristic of spotted frog habitat that provides for both needs during the annual cycle. The delicate balance between water levels and topography was evidenced by the fact that a decline in April and May rainfall of 9-15 cm/month between 1997 to 1998 caused nearly total reproductive failure in 1998 when oviposition sites dried up. Interestingly, frog reproduction in 1999 was similar to that in 1998 when record numbers of egg masses and larvae dried out in oviposition pools, but larval survival appeared higher due to the fact that a few solitary egg masses were laid in deeper, outlying pools which survived summer drought (chapter 2). These peripheral pools may be the only source of recruitment in years of drought. A lack of overland movement by Oregon spotted frogs suggests that ideally these two types of seasonal pools (i.e., oviposition and deep-water) must be connected by water, at least through late spring and again in the fall, for frogs to access them. Disjunct, land-locked, shallow breeding pools and deep-water pools do not provide year-round needs of Oregon spotted frogs. Thus, features such as highways or berms that bisect frog habitat may seriously affect populations size and distribution. We found evidence that indicated Oregon spotted frogs crossed the only known water access to a major breeding pool: a 24-inch culvert under the highway. Based on recaptures of adult frogs, some returned to the main basin during the dry season evidently through the same culvert, but tadpoles in the pool perished due to dessication, perhaps in part a result of unnatural water flow caused by the culvert. The drastic effects of a highway that bisected the Yellowstone population of Columbia spotted frogs was one important factor that reduced the population dramatically from the 1950's (Patla and Peterson 1997).

Based on the exceptional frog movements that we observed, Oregon spotted frogs are capable of distant dispersal that would allow recolonization of new sites if not limited by altered flow of the main channel (in this case Dempsey Creek) or the availability of connecting, shallow channels between habitats. It is noteworthy that during the summer of 1999, several unmarked adult frogs and recent metamorphs were found in an area several hundred meters southwest of the core of the study area. These frogs were in a grazed pasture along Stony Creek, very near its confluence with Dempsey Creek (Chapter 4). Dempsey Creek provided an aquatic connection to Stony Creek, which may have allowed some level of interaction between these frogs and those of the study area. However, none of the frogs found in this area were marked. We observed considerable individual variability in frog's spatial use of the study area (long, infrequent movements vs. short, frequent movements) and different degrees of seasonal fidelity within the study area. It is unclear how these characteristics might relate to the potential for some individuals, such as those which are less site-tenacious and wider ranging, to naturally colonize unoccupied habitats. It is also unclear whether or not frog dispersal (distance and number) might be greater in wet versus dry years. Reasons for individual variability in range of movement and fidelity are unknown and merit further study (Hayes et al. 1997).

In addition to water depth and flow characteristics, a moderate to high degree of water surface exposure (i.e., 50% to 75% water), or conversely, a low to moderate degree of emergent vegetation (i.e., 25% to 50%), was a most important feature of microhabitat use by Oregon spotted frogs. Emergent vegetation had the obvious benefit of concealment cover, served as a resting platform for surfaced frogs, and in the hottest part of the dry season shaded and maintained the remnant pools (e.g., hardhack and willow). Seasonal selection for open water locations was in part related to temporal ecological needs: open sites necessary for egg mass deposition and larval rearing during breeding, and deep remnant pools necessary in the dry season when standing water was no longer present surrounding most emergent vegetation. Frogs avoided microhabitats with dense emergent vegetation (≤25% surface water), especially those with dense grass (≥50%). Deep emergent cover hindered movement of frogs seeking deeper water when we tried to capture them. Underwater stems of dense grass presumably reduced mobility of frogs as well.

Plant structure within habitat communities, particularly as influenced by grazing, were key influences on frog distribution and habitat use at Dempsey Creek. Unexpectedly, the sedge/rush community was identified as an important coarse scale habitat during the breeding season, yet microhabitat analysis identified soft rush as the only plant associated with frog locations. The sedge/rush community was closely associated with shallow and ephemeral waters, and experienced a higher degree of grazing at frog locations relative to other types. Presumably this was directed at the sedge, since some sedges are palatable to cows but soft rush is unpalatable (C. Perry, pers. comm.). Thus, frogs were likely selecting this vegetation type because of its association with a particular hydrologic condition (e.g., shallow water), and perhaps, because of a preference for the cover provided by rushes. It is also possible that the accessibility of this vegetation type to the cows produced a grazed condition that was selected by the frogs, showing their preference for shallow water and sparse or short grass cover for breeding.
Evidence suggested that moderate levels of grazing created useable habitat in reed canary-grass communities that would otherwise have been a heavy thatch over shallow water or muck. Within

the reed canary-grass dominated vegetation class, telemetry locations were concentrated near the upland pasture margin (Fig. 3.3). In this area, reed canary-grass existed less as a floating mat and more as broken patches of grass, interspersed with pools containing aquatic vegetation like pond water starwort and false loosestrife. These areas met the frogs' preferences for moderately open water with an emergent vegetation component. We hypothesize that these open pools were maintained when cows entered the wetland along its margins, breaking up the entwined roots of the reed canary-grass, grazing preferentially on the plants, and allowing other species to flourish. When the pasture margin received considerable run-off water, resultant water depths were unsuitable for promoting growth of reed canary-grass. Too much grazing may have had the opposite effect, and resulted in reduced Oregon spotted frog use. Open sites with 0% to 25% cover also had the highest sign of grazing, and this class of surface water was avoided by frogs. Thus, ungrazed and heavily grazed areas of reed canary-grass were unsuitable to frogs, yet a moderate degree of grazing created habitats that were otherwise unsuitable.

While cattle grazing in areas of reed canary-grass may benefit Oregon spotted frogs, other forms of disturbance, such as caused by fire, wandering stream courses, and beaver (*Castor canadensis*), may also maintain conditions in wetland environments conducive to frog use. These forms of disturbance, which were likely more pervasive historically, create early successional conditions, including shallow open water and low, sparse herbaceous vegetation that are optimal frog habitat. Whether reed canary-grass was part of this ecological scenario historically is unknown, as the status of this plant species as an exotic is debated (Bill Leonard pers. comm.). An observation in support of natural disturbance factors and their relationship to Oregon spotted frog breeding habitat comes from Beaver Creek (15 km from Dempsey Creek) where a recently discovered Oregon spotted frog oviposition site was located in a shallow pool where beaver had clipped the willow and trampled the remaining vegetation.

Frogs showed little selection for subsurface habitats at Dempsey Creek. However, that didn't imply that subsurface conditions were irrelevant to frog behavior. The relatively open layer of water immediately below the surface provided exceptional mobility and allowed frogs to flee quickly from potential predators. Also, surface water absorption of radiation that resulted in a surface to subsurface temperature gradient as little as 2 degrees Centigrade caused frogs to rise to the water's surface. On numerous occasions during our capture efforts we were able to observe frogs floating in these shallow water habitats only to dive upon our approach and resurface within 5 to 10 seconds several feet away. In contrast, frogs first located in 1 to 2 cm of water were often forced to hop and navigate dense vegetation to escape. The overriding subsurface layer of plant detritus, matted herbs and soil under the surface water, was not simply hard pan. This layer provided escape cover for frogs, invertebrate habitat, and potential food for metamorph frogs. While our examination of emergent and submergent vegetation types focused on their collective value as cover, their potential importance to the presence and production of specific invertebrates should not be overlooked. Submergent vegetation also provided protection to adult male and female frogs at oviposition sites at a time when they are vulnerable to predators. Although we did not observe avian predation, there was indirect evidence of raptor predation on several frogs in spring. Waterfowl and great blue herons (*Ardea herodias*), which were present in the study area, were likely more common predators during the winter and early breeding period than garter snakes, which were active in large numbers and consumed tadpoles and metamorphs in the summer.

MANAGEMENT AND RESEARCH IMPLICATIONS

Because our study was brief (2 years) our results only gave us a glimpse of frog habits under variable, but perhaps not extreme years of precipitation. Variable precipitation may have dramatic effects on juvenile recruitment (chapter 2), frog dispersal, and ultimately which vegetation communities are used. Our results should be interpreted in light of these conditions.

Based on our experience in these wetlands, the more broken reed canary-grass areas were hydrologically similar to areas with a monoculture mat of reed canary-grass suspended above rising water levels. Lacking controls over its growth and spread, we believe that reed canary-grass would progressively develop into a monocultural mat over the area currently used extensively by Oregon spotted frogs. At this time, it appears that grazing and physical disturbance by cows are preventing this from happening.

Further study of effects of cattle grazing on Oregon spotted frog habitat is warranted from our finding that a moderate degree of grazing in reed canary-grass benefitted frogs. There is a need to better understand the specific degree of grazing, potentially regulated by timing and location, that allows thick stands of grass to be opened up but not removed entirely. Such a study could be accomplished by radio-telemetering cows, stratifying their use of wetland habitats, and monitoring frog use of those areas. Additional research is needed on whether natural disturbances, such as fire, beaver, and meandering stream courses provide and maintain Oregon spotted frog breeding pools, and whether suppression of these factors may allow succession to proceed to climax communities less conducive to frog use.

There is no historic information on the size and extent of the Dempsey Creek frog population that would provide a clearer understanding of the effects of habitat alteration from road-building, grazing, and other human activities on population trends. Comparative studies that evaluate habitat features in other Oregon spotted frog populations are needed to elucidate which features are critical for maintenance of healthy frog populations, and which are simply preferred by frogs. We recommend against use of frog capture locations as the sole means of understanding habitat selection without recognizing the bias in capture success in different habitat types. Additional baseline studies at Dempsey Creek that survey invertebrates, describe food habits and evaluate water quality would provide useful information on the general ecology of the species.

Chapter 4

SEARCHES FOR OREGON SPOTTED FROGS IN THE CHEHALIS RIVER BASIN

In their extensive review of the historic distribution of Oregon spotted frogs (*Rana pretiosa*) McAllister et al. (1993) identified the Black River drainage as a valuable study location for understanding frog ecology. In 1990, the first Oregon spotted frog verified in western Washington since 1968 was discovered on Dempsey Creek, a tributary of the Black River (McAllister et al. 1993). The headwaters of this system are unique because of the large wetlands at the headwaters and along the riverbanks, making it one of the largest contiguous freshwater systems in western Washington (Berg et al. 1995). The Black River extends 39 km from Black Lake to where it joins the Chehalis River to the southwest (Fig. 4.1). The entire Chehalis River Basin is within the historic range of Oregon spotted frogs but has not been intensively surveyed for frogs. This report summarizes surveys conducted in the basin in 1997-99.

METHODS

To survey a larger portion of the basin than could be accomplished with agency biologists, a training workshop was held for volunteer surveyors in 1997. Volunteers attended the workshop, sponsored by the U.S. Fish and Wildlife Service, to view slides and listen to recorded vocalizations to assist in species identification. Reproductions of color photos printed on water resistant paper were distributed for use in the field. Thurston County Conservation District staff identified landowners with potentially suitable habitat who were also willing to have their property surveyed. Volunteers were given aerial photos for their assigned sites. Volunteer surveys were conducted during the breeding and egg development periods (February and March) of 1997, a period when males and females were most likely to be found at oviposition pools. Survey duration and time, and general and legal locations of searched areas were recorded, as were species of all amphibians encountered at each location.

During 1998-99, most searches were conducted by WDFW staff experienced in Oregon spotted frog identification. Searches were conducted throughout the year in conjunction with field work at Dempsey Creek, primarily in nearby areas of the Black River drainage. A specific effort was made to search major segments of Dempsey Creek, and its tributary, Stony Creek. The Thurston County Conservation District arranged for surveys of the Wilson dairy, immediately west of the Dempsey Creek study area. These surveys were conducted with assistance from three high school students as a class project.

RESULTS

The 1997 volunteer-based search effort produced thirty-seven completed searches, totaling 92 hours of active searching (Fig. 4.1; Appendix Table 4). Oregon spotted frogs were not detected outside the Dempsey Creek study area. Frequently encountered species included the red-legged frog (*Rana aurora*), the Pacific treefrog (*Hyla regilla*), and the northwestern salamander (*Ambystoma gracile*).

Twenty-one searches totaling 31 hours were conducted by WDFW staff in 1998-99 (Appendix Table 4.1). We found two previously unknown Oregon spotted frog oviposition sites west of Delphi Road on the Wilson dairy property (Fig. 4.1). One oviposition site was in an ephemeral pool just off the shoulder of Delphi Road. Forty-seven egg masses were laid there in 1998 and 47 individual adult frogs were marked there over the course of several months post-breeding season. In 1999, only one spotted frog egg mass and two adults were found in this pool. Also, on 30 August, 1999, spotted frogs were found in an area of grazed pasture along lower Stony Creek, about 200 meters west of the other oviposition site. All age classes were represented, including recent metamorphs which indicated better larval rearing conditions at this location than were noted during 1999 at any of the other Thurston County spotted frog sites. In general, spring rainfall during 1999 was insufficient to maintain larval rearing habitat and most tadpoles died prior to metamorphosis.

The second major find was at West Rocky Prairie on 3 May, 1998, when Oregon spotted frog tadpoles were captured during an opportunistic survey. A butterfly net was used to sweep for tadpoles in a pool under Oregon white oaks (*Quercus garryana*) adjacent to a pond. To confirm identify of these tadpoles, some were collected and reared to metamorphosis. Subsequently, Oregon spotted frogs were found at other localities in this large wetland complex associated with Beaver Creek (Fig. 4.1). In 1999, we intensified searches for eggs, larvae, and adults at wetlands associated with Beaver Creek. We located two widely-separated oviposition pools. Twenty-six egg masses were counted in shallow waters on the margin of a pond fringed with Oregon White Oak (T16N R2W S12). All larvae from these egg masses perished from dessication. Oregon spotted frog tadpoles were discovered in a pool apparently created by a vehicle entering the wetland near ditches on the east side of Tilley Road (T16N R2W S11). Though the tadpoles in this pool survived longer than those under the oak trees, they too are believed to have been lost to drying of the breeding pool prior to metamorphosis.

DISCUSSION

Oregon spotted frog surveys, to date, have sampled suitable habitat over much of the Chehalis River basin. However, we made no attempt to use existing wetlands inventories, maps or aerial photos to comprehensively evaluate the wetland habitat in the Chehalis basin. Instead, most survey sites were selected based on Thurston County Conservation District staff knowledge of

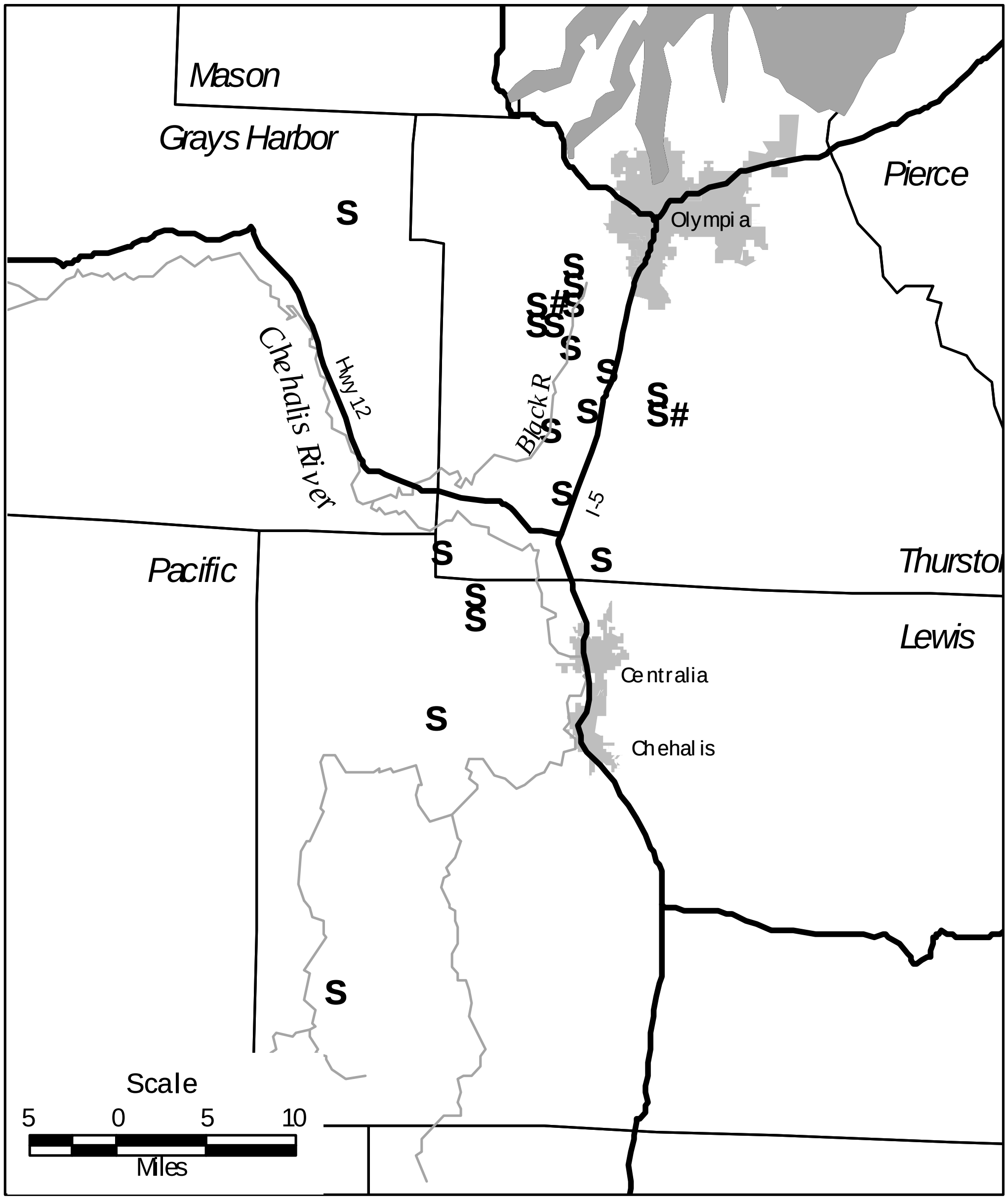


Fig. 4.1. Search locations for Oregon spotted frogs in the Chehalis River Basin, 1997-99. Open circles represent sections where searching occurred. Closed circles identify locations where Oregon spotted frogs were located (specific locations are identified in the Appendix, Table 4.1).

agricultural lands with suitable habitat that also had landowners willing to have their lands surveyed. Undoubtedly, considerable quantities of suitable habitat remain unsurveyed. Attempts at comprehensive surveys are likely to be met with opposition due to the reluctance of many landowners to have their properties surveyed for rare or endangered species. It may, perhaps, be more effective to continue to train biologists and others who work in wetland habitats to recognize all life stages of the Oregon spotted frog so that, over time, considerable geographic area can be effectively inspected in the course of other work. This approach, which could be called networking or outreach, attempts to increase the number of qualified observers and encourage their involvement in the building of a database on wetlands surveyed and Oregon spotted frogs observed.

A systematic attempt to identify suitable habitat within the basin should seek to identify habitat with the following features: 1) extensive (at least 20 acres) contiguous and shallow emergent palustrine wetland habitat; 2) low gradient stream course or ditch draining the wetlands; and 3) high seasonal hydrologic fluctuations such that surface water is extensive in winter and early spring, and extremely limited in late summer.

Finding Oregon spotted frogs on the Wilson dairy, in habitat largely contiguous with that of the core study area, was noteworthy, but not entirely unexpected. Finding them at Beaver Creek, 16 km away from the known population, was extremely important. It provides additional opportunities for conservation and greater potential that extinction of the species can be prevented. In addition, the Beaver Creek population is situated in wetlands adjacent to a significant expanse of mounded prairie, and partially fringed with Oregon white oak woodland, both of which are habitats that have experienced severe declines in the past century. The Beaver Creek habitat, unlike Dempsey Creek, is not currently grazed by domestic livestock, though grazing was apparently the predominant land use up until about a decade ago. The Oregon spotted frog oviposition sites found at Beaver Creek to date have been typical in some ways, unusual in others. Eggs have been found in shallow water at the margins of permanent waters, which is fairly typical. However, one oviposition site was under the canopy of Oregon white oaks in a shallow pool that is seldom connected to permanent water and appears to stand little chance of holding water long enough for tadpoles to metamorphose. Another oviposition site was found in an open area dominated by reed canary-grass (*Phalaris arundinacea*) where tire tracks had created deep ruts in the wetland. A similar situation existed at Dempsey Creek in 1999. Eighty-two egg masses were laid in an area where a vehicle had repeatedly driven through dense sedges, breaking and tearing up the plants and rutting the soil. This was the first year since monitoring began in 1995 that eggs were laid in this location.

ACKNOWLEDGMENTS

This research was conducted by the Washington Department of Fish and Wildlife, Wildlife Management Program, in cooperation with the U.S. Fish and Wildlife Service, Section 6 Program, and Port Blakely Tree Farms, Ltd., under contract # 25170217. K. Risenhoover and B. Murden were responsible for fruitful discussions on study design and for developing digital imagery for habitat analysis. We thank them for their substantial contribution of time and resources to this project. We also thank N. Wilkins, L. Salzer, G. Schirato, and W. Leonard, whose participation was critical to the success of the initital year of the study. Landowners L. Wilson and T. Musgrove allowed vital access to their properties. The Washington State Department of Transportation photogrammetry unit provided custom aerial photography. We thank G. Rathbun for sharing his helpful ideas concerning telemetry techniques, and B. Cosentino for GPS support. Other individuals contributed substantial knowledge and effort to the project including: K. Aitkin, P. Bartelt, T. Carrigan, C. Carruthers, R. Fleming, T. Cyra, L. Hallock, M. Hayes, M. Kelly, J. Konovsky, M. MacDonald, C. Madrona, M. McAllister, C. Peterson, H. Peterson, P. Ritson, J. Skalski, C. Stanley, S. VanderBerg, M. Vander Haegen, W. Vogel, C. Watson, J. Watson, T. Williams, R. Woodin, and B. Ziegler.

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APPENDIX

Table 1. Quantification of field effort (min) spent searching for Oregon Spotted Frogs at Dempsey Creek, Washington.

	Feb	March	April	May	June	July	August	Sept	Oct	Total
1994	0	0	0	105	220	120	60	0	0	505
1995	190	470	0	150	0	0	90	0	0	900
1996	1025	655	120	0	0	75	0	140	415	2430
1997	1410	1615	950	815	470	525	300	1015	1395	8505
1998	1735	795	675	1070	1200	200	490	1115	330	7540
1999	785	1160	645	275	495					3360

Table 2. Centimeters (inches) of rainfall recorded at the airport in Olympia, Washington, and relative levels of juvenile Oregon spotted frog recruitment at Dempsey Creek, 9 km south.

Year	February	March	April	May	June	July	August
Years with low recruitment							
1994	16.2 (6.4)	12.3 (4.8)	4.6 (1.8)	3.7 (1.4)	4.8 (1.9)	0.7 (0.3)	2.0 (0.8)
1995	15.5 (6.1)	17.1 (6.7)	6.9 (2.7)	3.0 (1.2)	2.8 (1.1)	4.3 (1.7)	3.2 (1.2)
1998	12.8 (5.0)	14.5 (5.7)	3.1 (1.2)	5.4 (2.1)	3.3 (1.3)	0.9 (0.3)	0.0 (0.0)
Years with high recruitment							
1993	0.6 (0.2)	12.6 (5.0)	16.9 (6.7)	11.6 (4.6)	4.5 (1.8)	3.4 (1.4)	0.4 (0.2)
1996	28.1 (11.1)	6.7 (2.7)	19.3 (7.6)	8.0 (3.1)	2.9 (1.1)	1.8 (0.7)	1.1 (0.4)
1997	12.8 (5.0)	30.0 (11.8)	12.2 (4.8)	7.9 (3.1)	7.5 (2.9)	3.0 (1.2)	6.2 (2.5)

Table 3. Movement and range characteristics of adult Oregon Spotted Frogs telemetered at Dempsey Creek Washington, 1997-98.

PIT-tag Number	Sex	Inclusive Dates of Observation	No. Days monitored	*n* locations	Range Type[a]	Range Size (ac)[b] 100% MCP	100% Kernel	Total Distance moved (m)[c]	Movement rate (m/day)[c]	Comment
41126D3730	F	7/15/97-6/4/98	156	33	B/D/W	3.48	7.58	662	2.0	Lost 9/27/97-3/12/98
410861757D	F	3/20/97-10/31/97	225	47	B/D/W	2.28	3.32	1,480	6.6	
41086F2651	F	3/24/97-10/10/97	200	47	B/D/W	3.51	4.92	726	3.6	
41086E1A64	F	3/24/97-10/31/97	221	42	B/D/W	18.49	12.42	1,492	6.8	monitored 2 years
41086E1A64	F	5/4/98-9/17/98	136	22	B/D/W	0.26	0.05	260	1.9	
41095C571A	F	5/12/97-10/23/97	164	39	B/D/W	1.36	0.93	542	3.3	
414F112E27	M	2/24/98-7/21/98	147	25	B/D	5.93	6.04	654	4.4	
414F112E27	M	2/24/98-5/29/98	94	14	B	2.04	13.84	445	4.7	
41126D3730	F	3/13/98-6/4/98	83	17	B	0.01	0.10	32	0.4	monitored 2 years
41087D2240	F	3/20/97-6/10/97	82	11	B	3.09	6.14	501	6.1	avg 34 m/day over 10 da
410878025B	F	3/17/97-5/29/97	73	16	B	4.41	6.08	869	11.9	avg 32 m/day over 14 da
410861757D	F	3/20/97-5/29/97	70	17	B	1.28	5.58	554	7.9	
414F1F384B	M	2/17/98-4/27/98	69	11	B	0.67	0.15	194	2.8	
41086F2651	F	3/24/97-5/29/97	66	16	B	0.10	0.71	182	2.8	
4108754677	F	4/7/97-6/5/97	59	15	B	1.32	0.31	447	7.6	avg 54 m/day over 18 da
41086E1A64	F	3/24/97-5/19/97	56	12	B	2.28	7.46	864	15.4	
4112062E79	F	3/13/98-5/1/98	49	11	B	<0.01	0.04	35	0.7	
4109011949	F	4/10/97-5/19/97	39	10	B	2.77	0.98	442	11.3	
4108611424	F	4/7/97-5/15/97	38	16	B	0.50	2.62	371	9.8	
414F1C5961	F	4/6/98-5/18/98	42	8	B	0.01	n/a	26	0.6	
414D0B5831	F	4/24/98-6/9/98	42	2	B	n/a	n/a	n/a	n/a	
41126C610D	M	3/15/98-4/24/98	40	8	B	<0.01	n/a	20	0.5	
414F0C2C30	M	2/20/98-3/30/98	38	8	B	1.45	n/a	493	13.0	
414F052F64	M	3/17/98-4/24/98	38	8	B	0.01	n/a	63	2.5	
4108664046	F	3/24/97-4/24/97	31	9	B	1.30	n/a	260	8.4	
414E781C4C	M	2/12/98-3/11/98	27	6	B	0.02	n/a	145	5.4	
414F090360	M	2/9/98-3/6/98	25	7	B	<0.01	n/a	13	0.4	
411268705C	F	5/1/98-5/26/98	25	6	B	3.63	n/a	964	38.6	avg 111 m/day over 11da
41086E1A64	F	5/4/98-5/29/98	25	5	B	<0.01	n/a	8	0.3	
414F0A0313	M	2/20/98-3/15/98	23	7	B	<0.01	n/a	6	0.3	
414F082060	F	4/6/98-4/24/98	18	4	B	0.02	n/a	7	0.4	

Table 3. cont'd.

PIT-tag Number	Sex	Inclusive Dates of Observation	No. Days monitored	*n* locations	Range Type[a]	Range Size (ac)[b] 100% MCP	100% Kernel	Total Distance moved (m)[c]	Movement rate (m/day)[c]	Comment
414E7B6F5F	F	2/24/98-3/15/98	19	6	B	<0.01	n/a	6	0.3	
4108605170	M	5/18/98-6/4/98	17	4	B	<0.01	n/a	20	1.2	
4109002D3A	M	5/18/98-6/4/98	17	4	B	<0.01	n/a	10	0.6	
410865727C	F	4/12/97-4/28/97	16	6	B	1.17	n/a	270	16.9	avg 50 m/day over 4 da
4108603607	F	3/15/98-3/30/98	15	4	B	<0.01	n/a	12	0.8	
4108611424	F	4/27/98-5/11/98	14	5	B	<0.01	n/a	12	0.9	
41095C571A	F	5/15/97-5/29/97	14	5	B	0.04	n/a	56	4.0	
414F08613A	M	3/3/98-3/15/98	12	5	B	0.90	n/a	253	21.0	avg 88 m/day over 2 da
411266185C	M	2/24/98-3/6/98	10	3	B	<0.01	n/a	3	0.3	
41086E0C34	F	3/17/97-3/27/97	10	4	B	0.25	n/a	258	25.8	avg 80 m/day over 3 da
NOPIT3	M	3/10/97-3/20/97	10	3	B	<0.01	n/a	2	0.5	
NOPIT1	M	3/10/97-3/17/97	7	3	B	0.01	n/a	92	9.2	
NOPIT2	M	3/10/97-3/17/97	7	3	B	<0.01	n/a	2	0.3	
4109086C37	F	3/10/97-3/17/97	7	3	B	<0.01	n/a	2	0.3	
410869263A	F	4/7/97-4/12/97	5	2	B	n/a	n/a	7	1.4	
414E7E3128	F	4/27/98-5/1/98	4	1	B	n/a	n/a	n/a	n/a	
4108790A09	F	2/19/98-2/20/98	1	1	B	n/a	n/a	n/a	n/a	
414D330A39	M	5/4/98	<1	1	B	n/a	n/a	n/a	n/a	
41086F2651	F	6/2/97-8/29/97	88	23	D	2.09	1.50	354	4.0	
41095C571A	F	6/2/97-8/29/97	88	22	D	0.07	0.16	138	1.6	
410861757D	F	6/2/97-8/29/97	88	19	D	0.97	1.43	516	5.9	
41086E1A64	F	6/4/98-8/27/98	84	13	D	0.26	0.08	219	2.6	
41086E1A64	F	6/10/97-8/29/97	80	20	D	0.03	0.10	115	1.4	
4108670F60	F	6/17/97-8/29/97	73	17	D	0.03	0.20	118	1.6	
414D0C147CF		6/30/98-9/4/98	66	10	D	0.57	1.01	319	4.8	
414D10721F	F	6/30/98-8/27/98	58	15	D	<0.01	0.01	41	0.7	
414D183126	F	7/7/98-8/27/98	51	13	D	0.03	0.01	91	1.8	
414F112E27	M	6/4/98-7/21/98	47	11	D	1.17	0.68	204	4.3	
41126D3730	F	7/15/97-8/29/97	45	10	D	0.04	0.02	59	1.3	monitored 2 years
414D273E3E	F	6/30/98-8/27/98	58	8	D	0.13	0.08	94	1.6	
410906294B	M	6/30/98-7/21/98	21	6	D	0.35	n/a	155	7.4	monitored 2 years

Table 3. cont'd.

PIT-tag Number	Sex	Inclusive Dates of Observation	No. Days monitored	*n* locations	Range Type[a]	Range Size (ac)[b] 100% MCP	100% Kernel	Total Distance moved (m)[c]	Movement rate (m/day)[c]	Comment
414D284777	F	8/3/98-8/27/98	24	7	D	0.03	0.91	67	2.8	
411266485B	F	7/3/97-7/22/97	19	3	D	<0.01	n/a	16	0.8	
41127B057E	F	8/27/98-9/4/98	8	3	D	<0.01	n/a	15	1.9	
414F06090A	F	6/23/98	<1	1	D	n/a	n/a	n/a	n/a	
414D314F75	F	8/27/98-1/3/99	129	19	W	2.75	4.94	786	6.1	
414D183126	F	9/1/98-1/23/99	144	19	W	1.16	4.45	676	4.7	
410861757D	F	9/2/97-10/31/97	59	11	W	1.90	2.98	349	5.9	
41086E1A64	F	9/2/97-10/31/97	59	10	W	2.88	6.44	501	8.5	monitored 2 years
41095C571A	F	9/5/97-10/23/97	48	12	W	1.15	1.84	341	7.1	
414D284777	F	9/1/98-11/28/98	88	9	W	0.74	3.40	562	6.4	
414D10721F	F	9/1/98-10/31/98	60	8	W	0.07	0.35	65	1.1	
411274640F	F	9/12/97-10/23/97	41	4	W	0.01	n/a	152	3.7	
41086F2651	F	9/2/97-10/10/97	38	7	W	0.31	0.08	177	4.7	
410906294B	M	9/23/97-10/23/97	30	5	W	0.28	n/a	304	10.1	monitored 2 years
4112660250	M	9/23/97-10/23/97	30	8	W	0.60	n/a	174	5.8	
414D1D6717	M	10/24/98-11/22/98	29	5	W	<0.01	n/a	18	0.6	
414D273E3E	F	9/1/98-9/28/98	27	8	W	<0.01	0.01	16	0.6	
41126D3730	F	9/2/97-9/26/97	24	6	W	0.08	3.34	73	3.0	
414D2C5531	F	9/4/98-9/25/98	21	5	W	0.96	n/a	256	12.2	
41086E1A64	F	9/1/98-9/17/98	16	4	W	<0.01	n/a	18	1.1	
4112755248	M	10/17/97-10/31/97	14	3	W	<0.01	n/a	9	0.6	
4108670F60	F	9/2/97-9/12/97	10	3	W	<0.01	n/a	3	0.3	
41122E1F67	F	9/15/98-9/22/98	7	3	W	<0.01	n/a	0.0	0.0	
411305124F	F	10/15/97-10/20/97	5	2	W	n/a	n/a	n/a	n/a	
414009762A	F	10/24/98	1	1	W	n/a	n/a	n/a	n/a	
4109052D22	F	10/31/97	1	1	W	n/a	n/a	n/a	n/a	

[a] B = breeding period (February through June); D = dry period (June through August); W = wet period (September through December).
[b]100% Minimum Convex Polygon, 100% Fixed Kernel. A minimum of three locations was used to estimate convex polygons, and a minimum of ten locations to estimate kernels. Ranges <0.01 ac occupied <40 m^2 and were confined to one pool.
[c]Movement distance and movement rates were minimums since they were based on locations gathered twice/week.
[d]One record that overlapped adjacent season by a few days was included in sample.

Table 4. Summary of searches for Oregon Spotted Frogs in the Chehalis River drainage, 1997-99.

Date	Time	General location	Twn Rng Sec	Surveyors	Amphibians Identified
2/23/97	1500-1700	Van Zandt property	12N 5W 35	Madrona	*R. aurora, T. granulosa*, *A. gracile*
2/25/97	1647-1730	Mox Chehalis Road pond	18N 5W 26, SE	McAllister, Madrona	*R. aurora*
2/26/97	1500-1520	Bunker Creek pond/stream	14N 4W 26	Rankin	*R. aurora, H. regilla*
2/26/97	1300-1400	unnamed creek, Rochester	15N 4W 14	Rankin	None
2/28/97	1130-1230	Cottage Creek wetlands	15N 2W 17	Aitkin, Kelly	*A. gracile, T. granulosa*
3/1/97	1315-1425	Kinney Road wetlands	17N 3W 1	Goldschmidt, Green, Johnson	None
3/2/97	1430-1615	Van Zandt property	12N 5W 35	Madrona	*R. aurora, T. granulosa, A. gracile*
3/2/97	1000-1100	Scott Creek floodplain pond	17N 2W 32	Gubbe, Murray	None
3/2/97	1100-1200	Scott Creek vicinity stream	16N 2W 7	Gubbe, Murray	None
3/4/97	1200-1400	Scatter Creek Wildlife Area	16N 3W 36	Gubbe, Burkhart	None
3/6/97	1600-1700	Scott Creek floodplain pond	17N 2W 32	Gubbe, Murray	None
3/6/97	1700-1800	Scott Creek vicinity stream	16N 2W 7	Gubbe, Murray	*R. aurora*
3/8/97	1530-1730	Lincoln Creek wetlands	15N 3W 30, 31	Madrona, Kelly	*R. aurora, H. regilla*
3/8/97	1345-1430	Dempsey Headwaters pond	17N 3W 22,23	Madrona, Kelly, Vogel	*H. regilla, A. gracile, T. granulosa*
3/8/97	1300-1400	Kinney Road wetlands	17N 3W 1	Goldschmidt, Green, Johnson	None
3/9/97	1600-1730	Van Zandt property	12N 5W 35	Madrona	*R. aurora, T. granulosa, A. gracile*
3/12/97	1300-1345	unnamed creek, Rochester	15N 4W 14	Rankin	*R. aurora, H. regilla*
3/12/97	1425-1500	Bunker Creek pond/stream	14N 4W 26	Rankin	*R. aurora, H. regilla, T. granulosa*
3/14/97	1315-1615	Lincoln Creek wetlands	15N 3W 30, 31	Madrona, Kelly	*R. aurora, H. regilla*
3/14/97	1130-1230	Cottage Creek wetlands	15N 2W 17	Madrona, Kelly	*A. gracile, T. granulosa*
3/15/97	1300-1345	Kinney Road wetlands	17N 3W 1	Goldschmidt, Green	*H. regilla*
3/16/97	1200-1300	Scatter Creek Wildlife Area	16N 3W 36	Gubbe, Murray	unknown salamander
3/16/97	1000-1100	Scott Creek floodplain pond	17N 2W 32	Gubbe, Murray	unknown vocalizations
3/16/97	1100-1200	Scott Creek vicinity stream	16N 2W 7	Gubbe, Murray	*R. aurora*
3/26/97	1447-1500	Bunker Creek pond/stream	14N 4W 26	Rankin, Baker	*R. aurora*
3/26/97	1240-1300	unnamed creek, Rochester	15N 4W 14	Rankin	None
3/29/97	1430-1530	Scatter Creek Wildlife Area	16N 3W 36	Gubbe, Murray	unknown salamander
3/29/97	1300-1415	Scott Creek floodplain pond	17N 2W 32	Gubbe, Murray	unknown egg mass
3/31/97	1600-1645	Wilson pasture, Delphi Rd.	17N 3W 14, NE	McAllister	*R. aurora, H. regilla, A. gracile, A. macrodactylum*
4/27/97	1700-1830	Glacial Heritage Pk., Black R.	16N 3W 14, NW	McAllister, Leonard	*R. aurora, H. regilla*
7/25/97	1000-1130	Lower Dempsey Creek	17N 3W 12 SW/E	Alvarado, Salzer	None
7/25/97	1700-1720	Black River, 110th bridge	17N 3W 25, SW	McAllister	*Rana catesbeiana*

Table 4. cont'd.

Date	Time	General location	Twn Rng Sec	Surveyors	Amphibians Identified
2/23/97	1500-1700	Van Zandt property	12N 5W 35	Madrona	*R. aurora, T. granulosa*, *A. gracile*
8/1/97	1130-1300	Black R. below Dempsey mouth	17N 3W 13, SE	McAllister, Salzer	None
8/5/97	1200-1245	Black River, 110th bridge	17N 3W 25, SW	McAllister	*R. catesbeiana*
8/5/97	1300-1320	Woodland Est. Waddell Ck Rd	17N 3W 22 N/SW	McAllister	None
8/8/97	0930-1100	Lake Lucinda outflow pond	17N 3W 15SE& 22, NE	McAllister, Salzer	*R. aurora, H. regilla*
8/8/97	1130-1215	Woodland Est. Waddell Ck Rd	17N 3W 22, SW	McAllister, Salzer	*R. aurora, H. regilla*
2/8/98	2000-2310	Black River road route	17N 3W, 16N 3W	McAllister	*R. aurora, Hyla regilla*
2/21/98	1030-1230	Wilson dairy, Dempsey Creek	17N 3W 14, S/NE	McAllister, Konovsky	*R. pretiosa, A. macrodactylum*
5/3/98	1400-1715	Beaver Creek oak pond	16N 2W 12, NW	McAllister, Potter	*R. pretiosa, R. aurora, A. gracile*
8/3/98	1430-1500	Scatter Creek Wildlife Area		McAllister	*T. granulosa*
9/10/98	1000-1130	Beaver Creek at Tilley Road		Alvarado, Salzer	*R. pretiosa*
9/16/98	0900-1100	Beaver Creek at Tilley Road		McAllister, Alvarado	*R. aurora*
9/16/98	1200-1345	Beaver Creek oak pond	16N 2W 12, NW	McAllister, Alvarado	*R. pretiosa, R. aurora*
9/21/98	1415-1430	Beaver Creek at Tilley Road		McAllister	*R. aurora*
9/21/98	1445-1630	Beaver Creek oak pond	16N 2W 12, NW	McAllister	*R. aurora*
2/25/99	1000-1100	Aldridge prop, Beaver Ck trib.		McAllister	*A. gracile, H. regilla*
2/25/99	1120-1200	Scatter Creek Wildlife Area		McAllister	*H. regilla*
3/16/99	1330-1600	Beaver Creek oak pond	16N 2W 12, NW	McAllister, Hallock	*R. pretiosa, R. aurora, H. regilla*
3/18/99	1320-1445	Darlin Creek hdwtr wetlands	17N 3W S22	McAllister, Vogel	*R. aurora, T. granulosa*, *H. regilla, A. gracile*
4/18/99	1315-1430	Beaver Creek oak pond	16N 2W 12, NW	McAllister. Peterson	*Rana pretiosa, Rana aurora*
5/19/99	1400-1700	Beaver Ck ditches Tilley Rd	16N 2W 11, NW	McAllister	*R. pretiosa, R. aurora, H. regilla, A. gracile*
5/31/99	0930-1030	Beaver Ck ditches Tilley Rd	16NR2W 11, NW	McAllister, Peterson	*R. pretiosa, R. aurora*, *A. gracile*
6/2/99	1500-1530	Beaver Creek oak pond	16N 2W 12, NW	McAllister	*R. aurora*
6/3/99	1430-1530	Beaver Creek oak pond	16N 2W 12, NW	McAllister, Hays	*R. aurora*
8/18/99	1130-1230	McIntosh Tree Fm, peat ponds	16N 2W 2, NW	McAllister	*R. aurora, R. catesbeiana, A. gracile*
8/30/99	1230-1300	Floodplain Stony Ck Wils. dairy	17N 3W 14, SW	McAllister, Vogel	*R. pretiosa, R. aurora*
9/2/99	1500-1700	Floodplain Stony Ck Wils. dairy	17N 3W 14, SW	McAllister, Salzer	*R. pretiosa, R. aurora*