A RADIO TELEMETRIC STUDY OF THE MOVEMENT PATTERNS OF ADULT NORTHERN RED-LEGGED FROGS (*RANA AURORA AURORA*) AT FRESHWATER LAGOON, HUMBOLDT COUNTY, CALIFORNIA

by

Judy Ann Ganz Haggard

A Thesis

Presented to

The Faculty of Humboldt State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Arts

In Biology

December, 2000

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We certify that we have read this study and that it conforms to acceptable standards of scholarly presentation and is fully acceptable, in scope and quality, as a thesis for the degree of Master of Arts.

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ABSTRACT

The movement ecology of the adult northern red-legged frog (*Rana aurora aurora*) is essentially unknown throughout its range. Systematic studies, particularly those that investigate terrestrial movements of these animals, are urgently needed since this species has been listed federally and by the state of California as a Species of Special Concern. I conducted a radio-telemetry study to determine the extent of the terrestrial movements and habitat use of 12 adult *R. a. aurora*, 11 females and 1 male, at Freshwater Lagoon, Humboldt County, California, from March through July 1999. The beaded-chain belt method of attaching radio transmitters was tested to evaluate its efficacy on adult *R. a. aurora*. There was considerable variability in the movements and movement patterns of the frogs. A majority of the frogs moved away from the periphery of the lagoon, the assumed breeding site, some to considerable distances (range of furthest distances = 30-270 m). Most of the distances moved per day were 5 m or less (range = 0-87.5 m). Observed range length (the map distance between the two relocation points farthest from each other in an individual's observed range) varied from 5 to 221 m.

Those frogs who made long-distance moves did not, for the most part, do so synchronously, and there was no apparent pattern to these movements on a seasonal basis or in response to daily weather conditions. The frogs, except for one individual, were detected on land during 90% of the survey period, and they tended to stay 5 m or less from water (lagoon, stream, ditch, or seep). Overall distances from water did not appear to decrease as precipitation and soil moisture decreased. Although there was considerable individual variability, the frogs were found much more often in the closed canopy thicket/forest habitat than in the other habitat types, which, in descending order of use, were forb patch, emergent vegetation, grassland, and man-made objects. Sword ferns may be important at the microhabitat level in providing cover for *R. aurora*. Six of the frogs appeared to use intermittent streams, especially those upslope from the lagoon, within the study area as corridors for at least part of their travels.

Conservation efforts should take into consideration that *R. a. aurora* uses upland habitats. Any terrestrial buffer zones should maintain key vegetative components such as dense patches of shrub and herbaceous vegetation. Movement surveys of *R. aurora* should be conducted year-round and for subsequent years. The beaded-chain belt method of attaching transmitters proved to be a relatively safe and effective technique for use on large adult *R. a. aurora*.

ACKNOWLEDGMENTS

I thank the members of my committee: Dr. James F. Waters, Dr. Kenneth L. Lang, Dr. John O. Sawyer, Jr., and Dr. Warren J. Houck. I would like to single out Dr. Lang for his advice and friendship and especially Dr. Waters for his long-term patience, support, encouragement, friendship, and respect for all life forms.

I am especially grateful to the following people:

Kelly Kawsuniak (CDFG), who was instrumental in helping me find my way to the beaded-chain belt;

Marty Reed (HSU) for providing materials and constructing equipment to use for the beaded-chain belt assembly;

Redwood Science Lab (USFS) personnel, in particular, Chet Ogan, for patiently loaning the telemetry equipment on a long-term basis, and Don Ashton, for his encouragement and advice on using the telemetry equipment;

Galen Rathbun (USGS-BRD, Piedras Blancas Research Station), for taking the time to personally show me the process of constructing and attaching the beaded-chain belt assembly and tracking California red-legged frogs (as well as pond turtles), and providing materials for the beaded-chain belt, encouragement, and advice;

John Bulger (Consulting Biologist), for providing much needed advice, information, and encouragement;

Dave Best (GIS Coordinator) and Van Hare (GIS Specialist) at Redwood National and State Parks' Arcata (CA) office, who took the time out of their busy schedules to do the lion's share of the work in producing the beautiful maps; and

Rich and Kathy Machado, who allowed me unconditional access to their property and lent me enthusiastic support.

Many thanks go to my stalwart volunteer mini-army of field assistants. Dan Wake, Sue Smith, Pete Haggard, the Machados (particularly Kathy), and Pat Dougherty braved the elements (especially the thickets and stinging nettles) more than once, some many times. Thanks also to Sandra Von Arb, Vince Romo, Jamie Bettaso, and Joyce Houston.

Thanks are also due to the following contributors: The California Department of Fish and Game (Karen Kovacs and Herb Pierce--Eureka, CA office) for providing radio-telemetry equipment; Simpson Timber Company (Lowell Diller and Jerry Momber) for providing assistance and access to Simpson property; Humboldt State University Department of Biological Sciences for providing partial funding in the form of a Master's Student Grant and materials and equipment: Fred Anderka at Holohil, Inc., for help with the transmitters: Chuck and Ruth Harvey for providing access to their property; Dr. Jerry

Allen (HSU) for help finding a study site; Rob Thompson (HSU) for providing equipment and encouragement; Melinda Christensen (HSU HELPDesk Supervisor) for help with the thesis formatting; and Dr. Rick Golightly (HSU), for advice on the statistics.

Last but far from least, this thesis would not have been possible without the support of my friends and particularly my family--my father, Frederick Ganz; my mother, Ersilia M. Ganz; my brother, Paul H. Ganz; and, most of all, my husband and friend, Peter D. Haggard (entomologist/botanist), who had to put up with the years it took to produce this thesis. This thesis is dedicated to my father, the chemist, from whom I must have inherited those "science" genes.

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INTRODUCTION

The movement ecology of the adult northern red-legged frog (*Rana aurora aurora*) is essentially unknown throughout its range, which extends from northern California to British Columbia. No systematic surveys have been done to investigate the movements of *R. a. aurora* outside the breeding season, and no standards exist for evaluating use of terrestrial habitat by these frogs. This lack of movement data is unfortunate since *R. aurora* apparently spend much of the non-breeding period on land away from their breeding sites (Stebbins 1954, 1972, 1985; Dunlap 1955; Dumas 1966; Licht 1969; Nussbaum *et al.* 1983; Gellman *et al.* 1993; Twedt 1993; Behler and King 1998). Development of effective conservation measures for this subspecies requires an understanding of its habitat requirements and movement patterns. Data on these aspects of its life history are important when evaluating the effects of any habitat modifications.

Very few studies on any aspect of the life history of *R. a. aurora* have been conducted on populations within California (Jennings and Hayes 1994). As it is with other native ranid populations in western North America, populations of *R. a. aurora* are thought to be on the decline in California (Twedt 1993; Jennings and Hayes 1994). This decline has been attributed to habitat loss and fragmentation due to timber harvesting,

grazing, and urban development, particularly coastal development, and predation by bullfrogs (*Rana catesbeiana*) and introduced fishes (Feliz 1988; Jennings and Hayes 1994). Road-kill mortality may also contribute to this apparent decline. Consequently, *R. a. aurora* is listed by the state of California as a Species ("subspecies") of Special Concern (California Department of Fish and Game 1991, 1999; Jennings and Hayes 1994) and federally listed as a Special Concern species (Sensitive Species [U. S. Forest Service]) (California Department of Fish and Game 1999). The status of this subspecies has prompted an urgent call for systematic surveys of this taxon in California, particularly those that focus on movement ecology (Jennings and Hayes 1994). The California red-legged frog (*Rana aurora draytonii*), the only other subspecies within the taxon *R. aurora*, is also a California Species ("subspecies") of Special Concern and has been federally listed as Threatened (California Department of Fish and Game 1991, 1996, 1999; Jennings and Hayes 1994).

In northwestern California, adult and subadult *R. aurora* often use the dense undergrowth along streamside flats and ponds within redwood forests (Gellman *et al.* 1993, Jennings and Hayes 1994), along ponds within coastal dune forests (Feliz 1988, Karen Theiss and Associates 1992), and along coastal freshwater lagoons (Twedt 1993). After breeding, *R. aurora* have been observed in moist areas near their breeding sites through the late spring and early summer (Twedt 1993, Jennings and Hayes 1994). They

then disappear from the sites, apparently dispersing considerable distances until the onset of the next breeding season (Stebbins 1954, Nussbaum *et al.* 1983, Stebbins 1985, Licht 1986, Feliz 1988, Zeiner *et al.* 1988, Karen Theiss and Associates 1992, Gellman *et al.* 1993, Jennings and Hayes 1994).

Radio-tracking, or radio telemetry, is one technique that has been found to be invaluable in investigating habitat selection, migration and movements within home ranges of amphibians (French *et al.* 1992, Jennings and Hayes 1994, Richards *et al.* 1994). However, relatively few radio-telemetry studies have been conducted on anurans (Kusano *et al.* 1995, Rathbun and Murphey 1996). To my knowledge, no radio-telemetry studies on *R. a. aurora* have been attempted.

One of the biggest problems researchers have had to face in using radio-tracking on anurans is finding a successful method of attaching the radio transmitters to the frogs or toads (Rathbun *et al.* 1993; Rathbun and Murphey 1993, 1996; Beebee 1996; Rathbun 1997). One relatively new method of attaching transmitters using a beaded-chain belt was developed for *R. a. draytonii* by Galen Rathbun and Thomas Murphey (Rathbun and Murphey 1993, 1996; Rathbun *et al.* 1993, Rathbun 1997). They found that 1) the beaded-chain belt causes little or no abrasion to the frogs' skin, is easy to use under field conditions, and is not permanent (eventually corrodes and falls off), 2) the belt-

transmitter device has no apparent effect on the frogs' behavior, and 3) the mortality rate associated with the belt and transmitter is very low.

To understand better the movement behavior and habitat requirements of *R. a. aurora*, I conducted a radio telemetry study at a coastal freshwater lagoon in northwestern California. The objectives of my study were as follows: 1) to determine, with the use of radio telemetry, the extent of the movements and habitat use of adult *R. a. aurora* during the spring and early summer months, and 2) to evaluate the efficacy of using the beaded-chain belt method of attaching radio transmitters to adult *R. a. aurora*. Description of the movement patterns of individual frogs included distances moved in relation to habitats, frequency of movement, breeding site, and proximity to free-flowing or standing water.

DESCRIPTION OF THE STUDY SITE

My study was conducted from 17 March 1999 to 27 July 1999 at Freshwater Lagoon, Humboldt County, California (Figure 1). The lagoon, which has well-established populations of *R. a. aurora*, is located 72 km north of Eureka, California (Township 10N, Range 1E, Sections 5 and 8; Latitude 41°N, Longitude 124°W) (Twedt 1993). As its name indicates, it is a freshwater lagoon. The surface area of the lagoon has been estimated at 99 ha (Twedt 1993). Maximum length of the lagoon is 1.6 km, and maximum width is 0.4 km (Twedt 1993).

The west side of the lagoon, consisting of a sand spit and U.S. Highway 101, is sparsely vegetated (Figure 1). The north, south, and east sides of the lagoon are surrounded by forest dominated by red alder (*Alnus oregona*) with some Sitka spruce (*Picea sitchensis*). There is a dense understory of thickets dominated by salmonberry (*Rubus spectabilis*), stink currant (*Ribes bracteosum*), Himalayan berry (*Rubus discolor*), and sword fern (*Polystichum munitum*). This area was logged in the early 1940's (Twedt 1993).

The study site was located on the northeast side of the lagoon (T10N R1E S5) on private property owned by Richard and Kathy Machado (Figures 1 and 2, Map in back

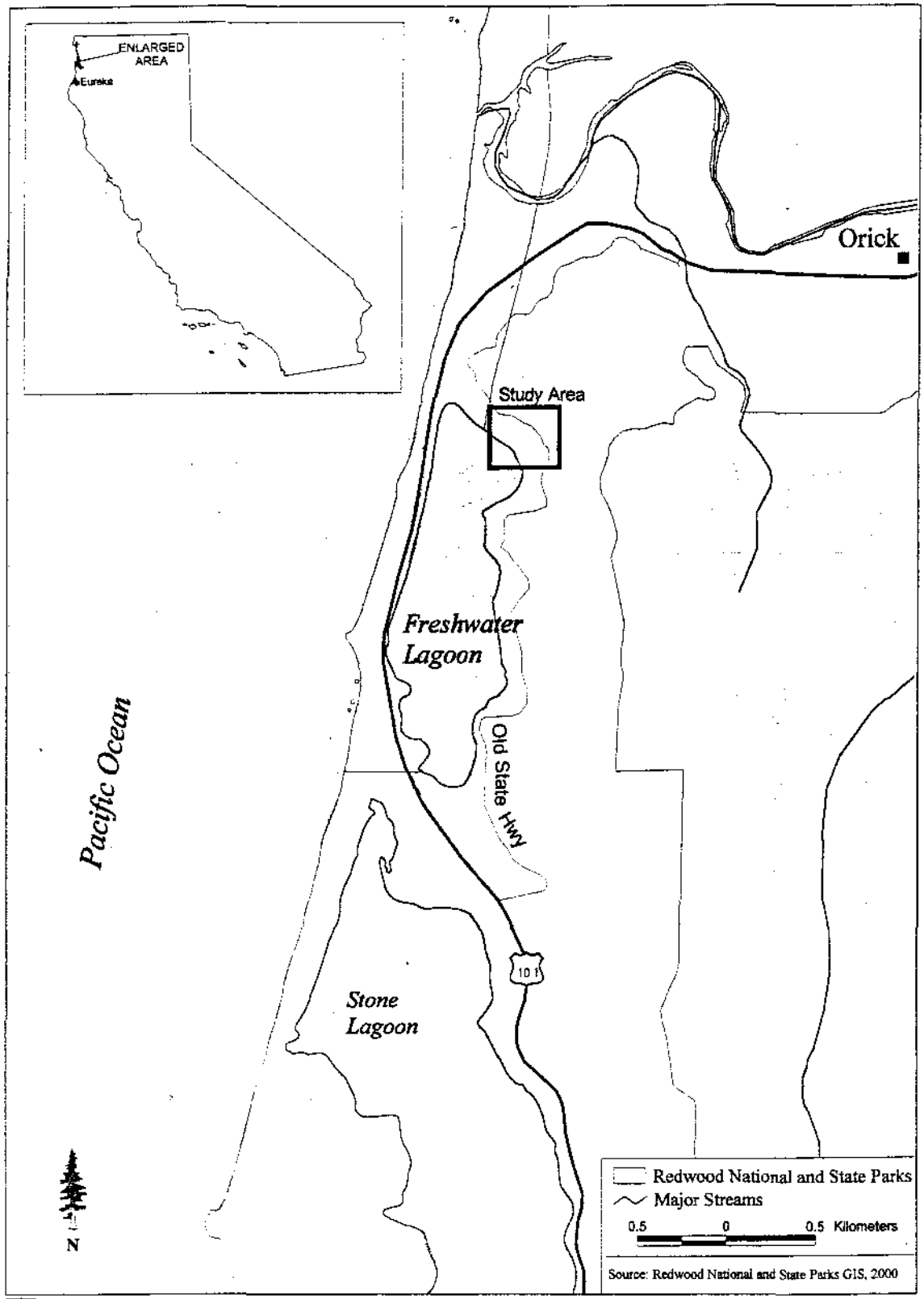


Figure 1. Location map of study site at Freshwater Lagoon, Humboldt County, California.

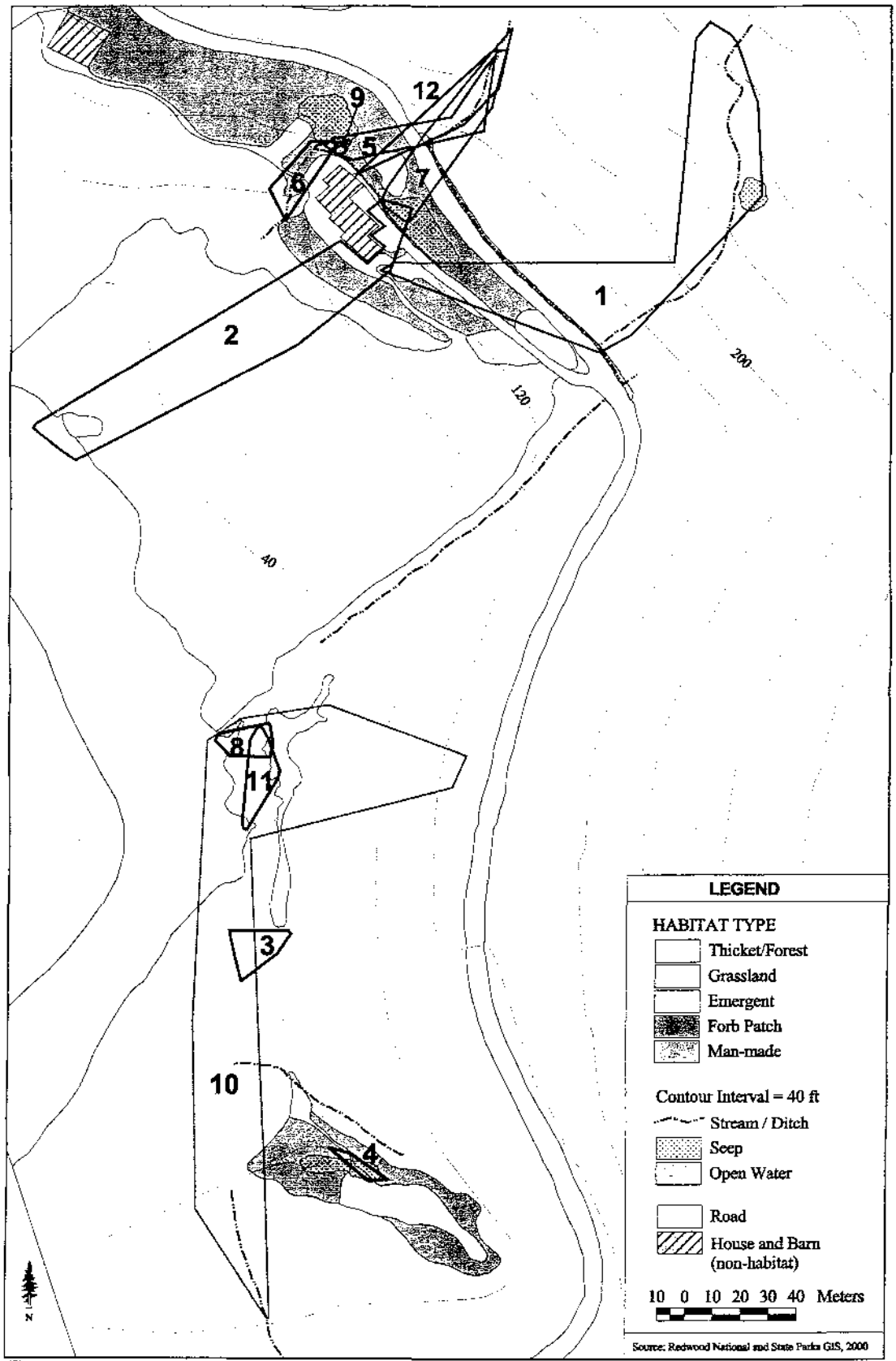


Figure 2. Overview of study site showing minimum convex polygons (MCPs) for Frogs 1 through 12. The MCPs for Frogs 1, 2, 5, and 10 are modified.

pocket). The 6.48-ha property, bordered on the west side by the lagoon and on the east side by the Old State Highway, consists of a 2.83-ha pasture (hereafter referred to as grassland) surrounded by alder/Sitka spruce forest and dense thickets. There is also a 0.4-ha grassland on the southern end of their property. The Machados' house is located on the upslope edge of the 2.83-ha grassland. Vegetation along the edge of the lagoon consists mainly of emergent plants, such as bulrushes (*Scirpus acutus*) and spike rushes (*Eleocharis*), and grasses. Where the forest meets the lagoon, willow (*Salix*) thickets dominate the banks, with some willows extending their branches out over the water.

Upslope from the Machados' house, the alder/Sitka spruce forest continues to the ridge top where the habitat changes to redwood forest. The western boundary of Redwood National Park follows this ridge top.

Elevations range from sea level at the lagoon to 211 m on the ridge top upslope from the Machados' property. In general the gradient of the hillside is approximately 35 percent below the Old State Highway and approximately 45 percent above the Highway. Aquatic habitats include, besides Freshwater Lagoon, several very small intermittent streams that empty into the lagoon and two seasonal ditches that run parallel to the Old State Highway. Seeps are present on the hillside, but the total number of seeps in the area of the study site is not known.

The area has a maritime coastal climate, with wet mild winters and cool summers (Humboldt Co. 1974; Twedt 1993). The average daily temperature varies only 5°C between winter and summer, with a yearly mean temperature of approximately 10°C. Annual rainfall is usually in the range of 127 to 178 cm, with 90 percent of it falling between October and April. Fog is common during the summer and fall months. Because of the prevalence of rain and fog, relative humidity remains high throughout the year (Twedt 1993).

MATERIALS AND METHODS

Capturing and Radio Telemetry

I received approval from the Institutional Animal Care and Use Committee (#95/96.B.37; 18 June 1996) to conduct my research. I also obtained a Scientific Collecting Permit from the California Department of Fish and Game (#803029-03).

I, with an assistant, opportunistically surveyed for adult northern red-legged frogs along the shoreline of the lagoon and in the other terrestrial habitats present on the Machados' property. Although we searched in all the habitat types, we focused our efforts in areas where we were more likely to see frogs (e.g., the stream and the seeps near the house). We found that the frogs were easier to capture on land than in the water. The frogs were captured by hand or with a long-handled dip net.

Frogs with a snout-vent length (SVL) of 60 mm or longer were selected to be fitted with radio transmitters. I had previously decided, on the advice of Galen Rathbun (pers. comm.), that the radio transmitters would be too large and too heavy for frogs with a SVL of less than 60 mm.

Thirteen of the captured frogs, 12 females and 1 male, were large enough to be fitted with radio transmitters. The preponderance of females is due to the fact that all the

males I found, except one, were too small for the transmitters. At any given time 1 to 7 frogs carried radio transmitters.

For each of the 13 frogs, I recorded the location and day and time of capture and the frog's SVL, weight, and sex. SVL was measured to the nearest millimeter with a metric ruler. Weight was measured to the nearest 0.1 g using a digital scale. I sexed the frogs by size (length and weight), with females being significantly larger than males (Hayes and Miyamoto 1984; Twedt 1993), and secondarily by the presence of nuptial tubercles (swollen thumb bases) on the males (this was not necessarily a reliable characteristic since the tubercles are not present throughout the year).

A radio transmitter (Holohil Systems Ltd. Model BD-2G, 1.20 to 1.33 g, battery life approximately nine to ten weeks) was then attached to the frog with a beaded-chain belt (the transmitter with beaded-chain belt weighed approximately 1.50 to 1.63 g). I followed Rathbun and Murphey's (1993, 1996) protocol for attaching the radio belts, with one revision. Before attaching the transmitters to the frogs, I cemented a #3 aluminum ball or beaded chain connector to the tip of each transmitter with Devcon two-ton epoxy. I spray-painted a #3 aluminum ball or beaded chain with black gloss enamel paint to reduce the brightness of the chain and thus avoid increasing the visibility of the frogs to predators. To obtain a good fit for each frog and to reduce the time spent determining which size belt would fit the frog while the frog was being handled, I made sample

beaded chain/connector belts of various sizes, attaching to each belt a label which indicated the number of beads in the chain. For each frog, I noted the number of beads used in its belt, and as I processed more frogs, I was better able to judge which size sample belt to use by the SVL and weight of the frog. This also helped reduce the amount of time spent processing the frog.

With an assistant holding the frog, I would first slip sample chain/connector belts over the extended rear legs of the frog. A sample belt of best fit was one that slipped snugly over the extended legs (and compressed the upper leg muscles slightly as it slipped onto the waist) (Rathbun and Murphey 1993, 1996; Rathbun *et al.* 1993). From the painted chain I then cut with a toenail clipper the number of beads indicated for that sample belt minus one bead, making the belt large enough to fit around the frog's waist but small enough to prevent it from slipping over the frog's thighs. I attached one end of the cut length to a transmitter. The partially assembled radio belt was then attached to the frog by encircling the frog's waist with the chain and attaching the other end of the chain to the transmitter (J. B. Bulger pers. comm.), making sure that the smoother of the two broad sides of the transmitter (the side of the transmitter with lettering) was next to the frog's skin. This manner of attaching the transmitter is somewhat more cumbersome than that used by Rathbun and Murphey (1993, 1996; Rathbun *et al.* 1993) who simply slipped the assembled radio belt over the extended rear legs of the frog. However, adult *R. a.*

aurora are much smaller and less robust (the upper leg muscles are not as developed) than adult *R. a. draytonii*. Consequently, slipping the radio belt over the extended legs of a northern red-legged frog did not ensure that the radio-belt would not slip off the frog after its release. Bulger (pers. comm.) found that the waist method of attachment also works with juvenile *R. a. draytonii*.

I did not use passive integrated transponder (PIT) tags, which Rathbun *et al.* (1993) used on the California red-legged frogs in their study. A PIT tag consists of an encapsulated silicon computer chip and antenna (Monan 1982; Priede 1992). The chip stores codes which can be detected and decoded by a hand-held data scanner, which displays the code in numeric form. The PIT tags, which are injected subcutaneously into the frogs, serve as backup identification in case any frog lost its transmitter.

I decided against using the PIT tags on the northern red-legged frogs in my study for the following reasons: 1) the probability of re-locating tagged frogs without the signal from the radio transmitters turned out to be very low, and 2) I felt the PIT tags would probably have caused irritation to the frogs since there was very little room posterior to the sacral hump of these frogs to accommodate both PIT tag and radio transmitter (the tags are injected into the frogs anterior to the sacral hump and then manually worked to a position just dorsal and anterior to the urostyle [Rathbun *et al.* 1993]).

I tracked the radio-tagged frogs on a daily basis, usually during the late afternoon, with a radio receiver (Telonics TR-2) connected to a hand-held, directional "H"-style receiving antenna (Kenward 1987; Priede 1992; Telonics 2000). An RA-1 dipole antenna (Telonics 2000) was first used but was awkward to handle in the dense vegetation and eventually broke. I replaced the broken antenna with an RA-14 ("rubber ducky") antenna (Telonics 2000), which had flexible elements and thus could be carried through dense vegetation without being damaged. The range of the signal from a transmitter was approximately 100 m under ideal field conditions (Rathbun *et al.* 1993; Rathbun and Murphey 1996). There were many times when dense vegetation precluded pinpointing an exact location and a best guess was made as to where the frog probably was. Each location was flagged.

Most of the detections were by radio only since the frogs were not usually visible in the dense cover. Even if a frog's location was accessible, I did not want to disturb the frog or the vegetation around it.

Care was taken to disturb the habitat as little as possible, to avoid altering the behavior of the frogs. However, some disturbance was unavoidable. Trails had to be cut through dense vegetation in order to follow the frogs who travelled through areas of extensive thickets. Grasses in some areas that were visited frequently were flattened by heavy foot traffic.

For each location, I recorded linear distance (m) and direction from previous location, proximity to water (lagoon, stream, ditch, or seep), and macrohabitat type. I also recorded the date and time of detection, type of detection (whether by radio only or by radio and visually), air temperature (°F), and cloud cover (weather). For most of the locations, I noted the microhabitats in which a frog was found (e.g., under a fern) (Appendix 1).

Distance Measurements

Although the distances were measured with a metric measuring tape, many of the distances, especially the longer ones, were best estimates. Movement was considered to have been in a straight line between successive locations.

The direction of movement was determined by taking a bearing (azimuth) with a compass from that location to the previous location. Determining the azimuth of each location in this manner, instead of taking the bearing from the frog's first capture location each time, invited compounded error: if the bearing was inaccurate for one location, the bearings for subsequent locations were automatically inaccurate. To counter this problem, I recorded more specific information about each location (Appendix 1).

Distances relating to proximity to water were divided into the following categories: 1) in water, 2) equal to or less than 5 m from water, 3) more than 5 m and

equal to or less than 10 m from water, and 4) more than 10 m from water. "Water" was defined as standing or free-flowing water in a lagoon, stream, ditch, or seep. Frogs were not considered "in water" if they were found in the supersaturated (muddy) soil portion of a seep. I considered frogs to be immediately adjacent to water if a frog was within 5 m of water. This distance criterion was chosen to take into account the various interfaces of land and water (e.g., the gently sloping bank of the lagoon versus the vertical bank of the stream). I based the 10-m criterion on Bulger *et al.* (1999), who classified the frogs in their study as being "upland" if they were more than 10 m from water.

At the Redwood National and State Parks (RNSP) Arcata (CA) office I transferred the locations for each frog to base maps for entry into Geographic Information System (GIS) using ARC/INFO 7.2.1 and ARCVIEW 3.2 software (ESRI 1999; David Best and Van Hare, Redwood National and State Parks, Arcata, CA, pers. comm.). Because the frog locations were concentrated in a few discrete areas of the study site, a series of 5 base maps, each focused on a particular area, was prepared. RNSP personnel created the base maps from a scanned 1:6000-scale color aerial photograph (Year 1999, Flight 89, Photo 90) and then scanned them at 600 dots per inch (dpi), with an output at a scale sufficient to distinguish individual frog locations.

Transferring the frog locations to the base maps using the coordinates obtained in the field proved problematic because the field coordinates were hard to identify on the

base maps. RNSP personnel digitized features identified on the base maps and then transformed these features to UTM Zone 10/NAD 27 using a network of 12 control points. The selected control points were visible on both the aerial photograph and the 1993 digital orthophoto quad (DOQ). Root mean square (RMS) error for the transformations was less than 0.5 m. Positional accuracy of frog locations was much more limited by transfer to the base maps than by transformation to the UTM coordinate system. A final GIS map showing the locations of the frogs was generated (Map in back pocket).

The breeding site for each frog was arbitrarily determined. Since I did not capture any of the frogs where they had bred, I had to assume that the lagoon was the general breeding site of this population of *R. a. aurora*. This assumption was based on the fact that the lagoon was the only known water source at the study site that provided adequate breeding habitat for red-legged frogs. The only other possible breeding site was the ditch that ran alongside the Old State Highway, which might at best have had minimal suitable breeding habitat. It was searched for red-legged frog egg masses and tadpoles, but none were found. In the cases of the frogs who travelled parallel to the lagoon, I also had to make the assumption that the specific breeding site in the lagoon was near where I first found the frog.

I used two different methods in measuring on the GIS maps the maximum distance a frog moved away from its hypothetical breeding site. For the frogs whose general direction of movement was upslope (e.g., Frog 1), I measured the linear distance, perpendicular to the long axis of the lagoon edge (determined by inspection), from the lagoon edge to the frog's relocation point furthest from the lagoon. For the frogs whose general direction of movement was parallel to the lagoon (e.g., Frog 10), I first drew a line, perpendicular to the long axis of the lagoon edge, from the lagoon edge to the frog's first location. I then measured the linear distance from where this line intersected the edge of the lagoon to the relocation point furthest from the frog's first location. I took the edge of the lagoon to be at an estimated high-water mark.

Habitat Use

Habitat polygons with the frog locations were delineated on the GIS map (Map in back pocket). I divided macrohabitat types into the following categories: 1) closed-canopy thicket/forest, 2) emergent vegetation, 3) forb patch, 4) grassland, and 5) man-made objects (e.g., metal shed, plywood board). The closed- canopy thicket/forest habitat includes forest with an open understory dominated by sword ferns and forest with a dense understory dominated by thickets of salmonberry/currant, Himalayan berry,

and/or willow. The emergent vegetation habitat includes obligate wetland plants (e.g., bulrushes, rushes, sedges [Cyperaceae], water hemlock [*Cicuta*]) and tall grasses along the shoreline of the lagoon. The forb patch habitat includes plants such as buttercup (*Ranunculus repens*), mint (Lamiaceae), coltsfoot (*Petasites frigidus*), and stinging nettle (*Urtica dioica*). The grassland habitat includes plants such as velvet grass (*Holcus lanatus*), tall fescue (*Festuca arundinacea*), sweet vernal grass (*Anthoxanthum odoratum*), orchard grass (*Dactylis glomerata*), and perennial ryegrass (*Lolium perenne*).

To analyze habitat use and for descriptive purposes, I estimated the "observed range" of each frog using the minimum convex polygon (MCP) (or "minimum area polygon") procedure (Mohr 1947; Harvey and Barbour 1965; Kenward 1987; Weatherhead and Hoysak 1989; White and Garrott 1990; Priede and Swift 1992; Jones 1996; Romsos 1998). I defined the "observed range" as "that area traversed by the individual during the survey period." One of the disadvantages of using the MCP method is that it often includes large areas that may not be used by a radio-tracked animal (Harvey and Barbour 1965; Jones 1996). This was the case for Frogs 1, 2, 5 and 10. Consequently the MCPs for Frogs 1, 5 and 10 were adjusted to represent an area that the frog could hypothetically use based on its relocation points, and the MCP for Frog 2 was adjusted to exclude the Machados' house (Weatherhead and Hoysak 1989; Jones 1996) (Figure 2). I then computed the percentage of each habitat within each MCP. I also

estimated "range length" by measuring the map distance between the two relocation points farthest from each other in an individual's observed range (Harvey and Barbour 1965; Weatherhead and Hoysak 1989) (Figure 2).

The Friedman test was used to determine if habitats identified within the MCPs have identical effects on the difference between selection and availability for all adult *R. a. aurora* using those habitats (Conover 1980; Alldredge and Ratti 1986; 1992; Daniel 1990; Hollander and Wolfe 1999). In other words, do the frogs use a particular habitat more (or less) than the availability of that habitat? Because the sample size is small, the test could only be applied to those frogs whose observed ranges included thicket/forest and forb patch and/or emergent vegetation. Since the forb patch and emergent-vegetation habitats were generally similar in structure, I combined them to increase frequencies and to include the maximum number of frogs possible. The differences in the proportion of use and available habitat were ranked for Frogs 1, 2, 5, 6, 7, 8, 10, 11, and 12, and the ranks were used to compute Friedman's test statistic (Zar 1984; Alldredge and Ratti 1992) (Appendix 2).

RESULTS

Of the thirteen adult northern red-legged frogs fitted with radio transmitters, twelve (11 females and 1 male) were tracked for a minimum of 15 days to a maximum of 56 days (mean = 40.75, median = 39, SD = 12.51). One female was not included in the tracking data because she was tracked for only two days, after which the transmitter's battery apparently expired.

The SVL of the 12 females at the time of initial capture ranged from 65 to 84 mm with a mean of 73 mm (SD = 5.6) and a median of 71.5 mm. The body mass (weight) of the 12 females at the time of initial capture ranged from 28.0 g to 59.6 g with a mean of 41.85 g (SD = 8.84) and a median of 42.25 g. The weight of one female and the weight and length of another female were remeasured when they were recaptured: the weight of the first female increased from 46 g at initial capture to 47 g 7 days later; the weight of the latter female increased from 28 g at initial capture to 48.1 g 56 days later, and her length increased from 69 mm to 77 mm. The one male was 62 mm long and weighed 25.6 g at initial capture.

Individual Frogs

The first frog fitted with a transmitter was a female (SVL = 76 mm, wt. = 40.6 g) captured on 17 March in a patch of bear's breech (*Acanthus mollis*) (forb patch) near the Machados' house (Figure 2, Map in back pocket, Appendix 1a). She stayed in the bear's breech or in sparse grassland immediately adjacent to the patch for a few days. She then moved over 70 m upslope to the ditch on the side of the Old State Highway and continued upslope in the salmonberry/currant thicket above the Highway, generally following a small drainage. For the remainder of days I followed her she stayed within the thicket. She tended to stay in an area for several days and then move approximately 26 to 30 m to another area where she again stayed for several days. The general direction of her movement was upslope. I tracked Frog 1 for 53 days (until 8 May 1999), after which the radio signal faded to such an extent that I could not locate her. The length of the observed range of Frog 1 was approximately 147 m, and the furthest distance Frog 1 was detected from the breeding site was approximately 280 m.

Frog 2 (female, SVL = 70 mm, wt. = 47.6 g) was found on 18 March underneath a plywood board in the ditch next to the Machados' driveway (Figure 2, Map in back pocket, Appendix 1b). For a few days she stayed in or near the seep in the forb patch on the hillside next to the driveway. She then moved to the bear's breech patch near the

house, where she stayed for a few days. She then moved downslope to the edge of the lagoon traversing the grassland below the house in 2 days, covering a distance of approximately 35 m the first day and approximately 88 m the second day. She stayed in the shallow water in the emergent vegetation at the edge of the lagoon the remainder of the days I tracked her. I officially ended the duration of tracking Frog 2 (36 days) on 22 April. I found her unattached transmitter (sans chain, connector, and frog) in approximately the same place I had last located her (although the water had dried up at that point) on 4 May. The length of the observed range of Frog 2 was approximately 155 m, and the furthest distance Frog 2 was detected from the breeding site was approximately 150 m.

Frog 3 (female, SVL = 72 mm, wt. = 38.4 g) was the first frog captured near the lagoon (Figure 2, Map in back pocket, Appendix 1c). We found her on 21 March sitting on the vines of a Himalayan berry thicket. She stayed in this habitat for the remainder of the days that I was certain of her location, eventually heading for the edge of the lagoon. At the end of the tracking session she seemed to be along the bank of the lagoon, but I was uncertain as to her whereabouts since by that time the signal from the transmitter had faded to such an extent that it was difficult to pinpoint a location. I officially ended Frog 3's tracking session at 34 days (on 23 April), although I did try to locate her thereafter but without success. The length of the observed range of Frog 3 was approximately 25 m,

and the furthest distance Frog 3 was detected from the breeding site was approximately 40 m.

Frog 4 was the only male fitted with a transmitter (SVL = 62 mm, wt. = 25.6 g) (Appendix 1d). We captured him on 6 April in very short grass (grassland) immediately adjacent to a skunk cabbage (*Lysichiton americanum*) patch (forb patch) that was located in a seep (Figure 2, Map in back pocket). He travelled upslope for one day to a forb patch in a drier area but returned to his previous location in the seep. He remained in that area for several more days after which he moved downslope to a drier area covered mainly with a mix of coltsfoot and stinging nettle (forb patch). He stayed in this habitat when I ended the tracking session on 20 April after 15 days of tracking. On 24 April I recovered the transmitter assembly where I had last located the frog. The beaded chain belt was broken and appeared to have been gnawed, suggesting that the frog had probably been eaten by a raccoon. The length of the observed range of Frog 4 was approximately 23 m, and the furthest distance Frog 4 was detected from the breeding site was approximately 120 m.

Frog 5 (female, SVL = 76 mm, wt. = 46.8 g) was first found 11 April in a sparse forb patch near the small intermittent stream next to the metal shed near the Machados' garage (Figure 2, Map in back pocket, Appendix 1e). For approximately 3 1/2 weeks she stayed under the shed or in the sparse forb patch near the shed. She then travelled

upslope into the salmonberry/currant thicket above the Old State Highway. She remained in this habitat for the remainder of the tracking session, moving up and down the hillside following a small drainage that contained an intermittent stream. She essentially stayed within 5 m of water throughout the tracking session. The session lasted a total of 52 days, ending on 1 June. I was unable to locate her after that date because by that time the radio signal had completely gone out. The length of the observed range of Frog 5 was approximately 68 m, and the furthest distance Frog 5 was detected from the breeding site was approximately 210 m.

Frog 6 (female, SVL = 68 mm, wt. = 31.5 g) was found on 13 April in a pile of dead water cress (*Rorippa nasturtium-aquaticum*) (emergent vegetation) near where I first found Frog 5 (Figure 2, Map in back pocket, Appendix 1f). Frog 6 generally stayed in the forb patch along the banks of the intermittent stream near the Machados' house, following the drainage to below the house. She then entered a tangle of cape ivy (*Delairia odorata*), Himalayan berry, and red elderberry (*Sambucus racemosa*) (thicket/forest), still following the drainage downslope. I ended the 42-day tracking session on 24 May after having been unable to locate her because of a weak radio signal. Frog 6 was located within 5 m of water every day of the tracking except for one day in which she was found between 5 and 10 m from water. The length of the observed range

of Frog 6 was approximately 33 m, and the furthest distance Frog 6 was detected from the breeding site was approximately 150 m.

Frog 7 (female, SVL = 79 mm, wt. = 49.5 g) was found on 25 April under the same plywood board where I had found Frog 2 (Figure 2, Map in back pocket, Appendix 1g). And, like Frog 2, she stayed for a few days in the seep in the forb patch on the hillside next to the driveway. She then moved upslope to where the ditch that parallels the Old State Highway intersects the small drainage that Frog 5 followed upslope. She stayed in that area for approximately 2 weeks. She then headed up the drainage where she stayed for the rest of the tracking session. Tracking ended with loss of radio signal on 29 May for a total of 35 days. The length of the observed range of Frog 7 was approximately 80 m, and the furthest distance Frog 7 was detected from the breeding site was approximately 220 m.

Frog 8 (female, SVL = 78 mm, wt. = 46.0 g) was found 28 April in medium tall grass (grassland) next to a sword fern which was close to a willow thicket near the lagoon (Figure 2, Map in back pocket, Appendix 1h). For approximately 1 week she stayed near or at the edge of this thicket either in the grassland or in the thicket. On 4 May we found her with the beaded-chain belt still attached, but without the transmitter, in the grassland next to the thicket. We found the transmitter in the thicket approximately 10 m from the frog's location and approximately 1 m from shore. We reweighed Frog 8 (new weight =

47 g) and attached a new transmitter. Thereafter she stayed nearer the shore moving for the most part back and forth between the tall emergent grass and the thicket. I ended the tracking period on 22 June after 56 days. On 24 June we found Frog 8's second transmitter in the tall emergent grass. The frog with the beaded chain belt (I assumed that the belt was still attached) was not relocated. The length of the observed range of Frog 8 was approximately 19 m, and the furthest distance Frog 8 was detected from the breeding site was approximately 20 m.

Frog 9 (female, SVL = 84 mm, wt. = 59.6 g) was first found on 5 May under the edge of the metal shed near the house (Figure 2, Map in back pocket, Appendix 1i). For the duration of the 33-day tracking period she stayed either under or near the metal shed. She spent the last week I tracked her in the sedges in the streambed on the northeast side of the shed. She stayed within 5 m of water until the end of the tracking period when she was in water. I officially ended the tracking on 6 June. We found her transmitter in the stream where she had stayed the last week of the tracking. The length of the observed range of Frog 9 was approximately 5 m, and the furthest distance Frog 9 was detected from the breeding site was approximately 150 m.

Frog 10 (female, SVL = 69 mm, wt. = 28.0 g) was captured 11 May in tall grass (grassland) several meters from the willow thicket near the lagoon (Figure 2, Map in back pocket, Appendix 1j). The next day she was 16 m upslope in the middle of a Himalayan

berry thicket. From there she travelled 48 m upslope into spruce forest with a more open understory dominated by sword ferns. Four days later we found her again in the tall grass (grassland) near the willow thicket close to the lagoon. The beaded-chain belt was still attached to her but not the transmitter. Her transmitter was later located in the spruce forest where she had stayed before travelling downslope. We reweighed her (new weight = 42.6 g), remeasured her SVL (= 77 mm), and attached a new transmitter. For approximately 1 1/2 weeks she stayed in the general area in which Frog 8 was located, alternating between the tall emergent grass near the shoreline and the willow thicket upslope. She then moved south to a thicketed area, where she stayed within 10 m of the shoreline for approximately 2 weeks. She again moved generally in a southerly direction staying closer to shore. She appeared to move approximately 77 m south to an old willow thicket, part of which was in water, and then continued another approximately 63 m south to the interface of the old willow thicket and a spruce forest with an understory dominated by salmonberry and sword ferns. She stayed in this area for approximately 1 week. We next found her on 5 July approximately 40 m upslope in the forest. She was in a streambed in a somewhat open salmonberry thicket. We captured her, removed the transmitter, and reweighed her (new weight = 48.1 g). There was some minor abrasion where the connector had been against the frog's dorsum. Frog 10's tracking period lasted

56 days. The length of the observed range of Frog 10 was approximately 221 m, and the furthest distance Frog 10 was detected from the breeding site was approximately 210 m.

Frog 11 (female, SVL = 68 mm, wt. = 33.5 g) was captured on 28 April in medium tall grass (grassland) several meters upslope from the willow thicket near the lagoon near where Frogs 8 and 10 were first found (Figure 2, Map in back pocket, Appendix 1k). She spent approximately 4 weeks in this area staying either in the thicket or in the grassland at the edge of the thicket. On 8 June she moved approximately 16 m south to young emergent grass in the lagoon. The radio signal had weakened to such an extent that the tracking was terminated on 10 June. The tracking period had lasted 30 days. Neither the frog nor the transmitter was ever found. The length of the observed range of Frog 11 was approximately 35 m, and the furthest distance Frog 11 was detected from the breeding site was approximately 30 m.

Frog 12 (female, SVL = 71 mm, wt. = 43.9 g) was captured on 11 June under a pile of plywood boards next to the northeast side of the Machados' garage (Figure 2, Map in back pocket, Appendix 1l). She moved from that location to a location next to the drainage up which Frogs 5 and 7 had travelled, approximately 64 m upslope in the salmonberry/currant thicket above the Old State Highway. She continued to travel upslope, eventually ending up in the area that Frogs 5 and 7 were last detected. Frog 12 stayed within 5 m of water for the duration of the tracking period, which lasted 47 days.

On 27 July we removed her transmitter. The length of the observed range of Frog 12 was approximately 69 m, and the furthest distance Frog 12 was detected from the breeding site was approximately 210 m.

Movements

Distances from one relocation point to the next varied from 0 to 87.5 m (Table 1, Figure 3). The mean for all frogs was 3.7 m (SD = 5.1 m). Most (80%) of the distances moved per day were 5 m or less (Table 2, Figures 3 and 4). The frogs moved distances of 5.1 - 10.0 m 11% of the days, 10.1 - 15.0 m 3% of the days, and 15.1 - 20.0 m 2% of the days. Frogs who travelled long distances tended to make the longer moves in spurts of a day or two after remaining in one area for several days (Figure 3). Frogs who moved more than 20 m in a day did so 3% of the days, and these distances ranged from 20.5 m to 87.5 m. There was no apparent pattern on a seasonal basis or in response to daily weather conditions as to when the frogs would move long distances (20 m or more). Frogs who made long distance moves did not, for the most part, do so synchronously.

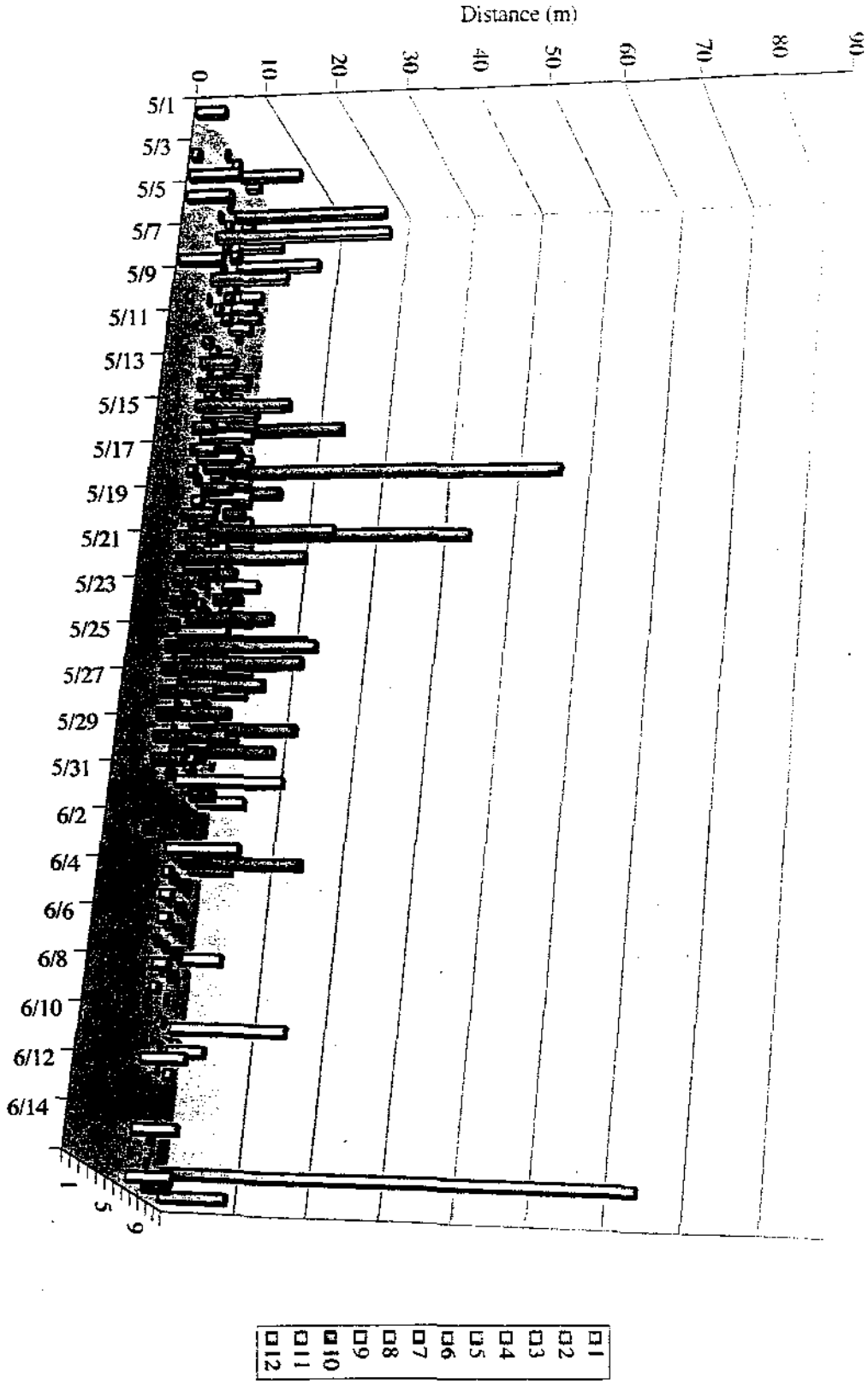
Observed range lengths varied from 5 m to 221 m. The mean for all frogs was 73 m (SD = 67.2 m). Although the range lengths for some frogs were long, their movement

Table 1. Descriptive statistics of the linear distances (m) measured per day for each frog. No. of days tracked=total number of days in tracking period (includes those days on which frogs were not detected).

	Distance(m)/Day					No. of Days Tracked
Frog	Minimum	Maximum	Mean	Median	Standard Deviation	
1	0.3	71.2	5.9	3.0	11.2	52
2	0.0	87.5	5.4	0.9	15.8	35
3	0.0	6.3	1.1	0.7	1.2	33
4	0.1	20.5	4.2	0.4	6.5	14
5	0.0	25.0	4.0	2.8	5.5	51
6	0.0	12.6	2.4	1.0	3.1	41
7	0.0	22.0	3.9	1.1	6.0	34
8	0.0	15.0	2.4	1.5	3.1	55
9	0.0	4.1	1.2	0.7	1.3	32
10	0.0	77.0	8.3	1.4	15.8	55
11	0.0	16.0	2.7	1.4	3.4	29
12	0.0	64.3	3.1	1.0	9.5	46
All frogs	0.0	87.5	3.7	1.1	5.1	

Figure 3. Distances (m) Frogs 1 through 12 moved on a daily basis from 18 March 1999 to 27 July 1999.

Figure 3 continued.



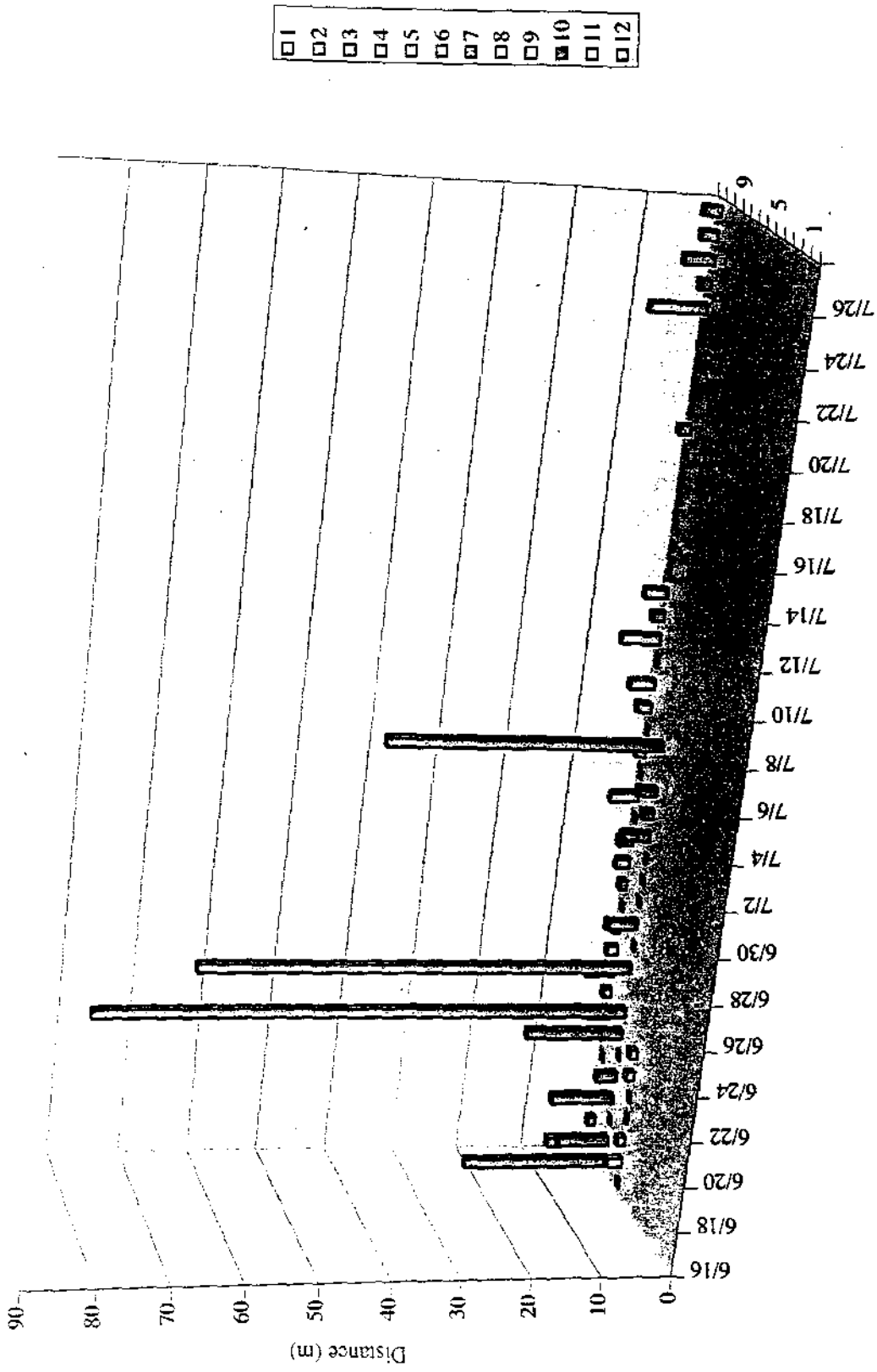


Figure 3 continued.

Table 2. Frequency of distances(m)/day (percentage) travelled by individual frogs. "Total no. of days (detections)" includes only those days on which frogs were detected.

	Distance (m)							Total
Frog	<or=5	>5-10	>10-15	>15-20	>20-25	>25-30	>30	No. Days (Detections)
1	32(67)	12(25)	0(0)	0(0)	1(2)	2(4)	1(2)	48
2	29(85)	2(6)	0(0)	1(3)	0(0)	0(0)	2(6)	34
3	32(97)	1(3)	0(0)	0(0)	0(0)	0(0)	0(0)	33
4	9(69)	1(8)	2(15)	0(0)	1(8)	0(0)	0(0)	13
5	34(76)	6(13)	2(4.5)	1(2)	2(4.5)	0(0)	0(0)	45
6	33(85)	4(10)	2(5)	0(0)	0(0)	0(0)	0(0)	39
7	20(69)	4(14)	2(7)	2(7)	1(3)	0(0)	0(0)	29
8	40(82)	7(14)	2(4)	0(0)	0(0)	0(0)	0(0)	49
9	29(100)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	29
10	29(62)	5(11)	5(11)	2(5)	1(2)	0(0)	5(11)	47
11	22(81)	4(15)	0(0)	1(4)	0(0)	0(0)	0(0)	27
12	38(89)	4(9)	0(0)	0(0)	0(0)	0(0)	1(2)	43
Total no. days	347(80)	50(11)	15(3)	7(2)	6(1)	2(<1)	9(2)	436

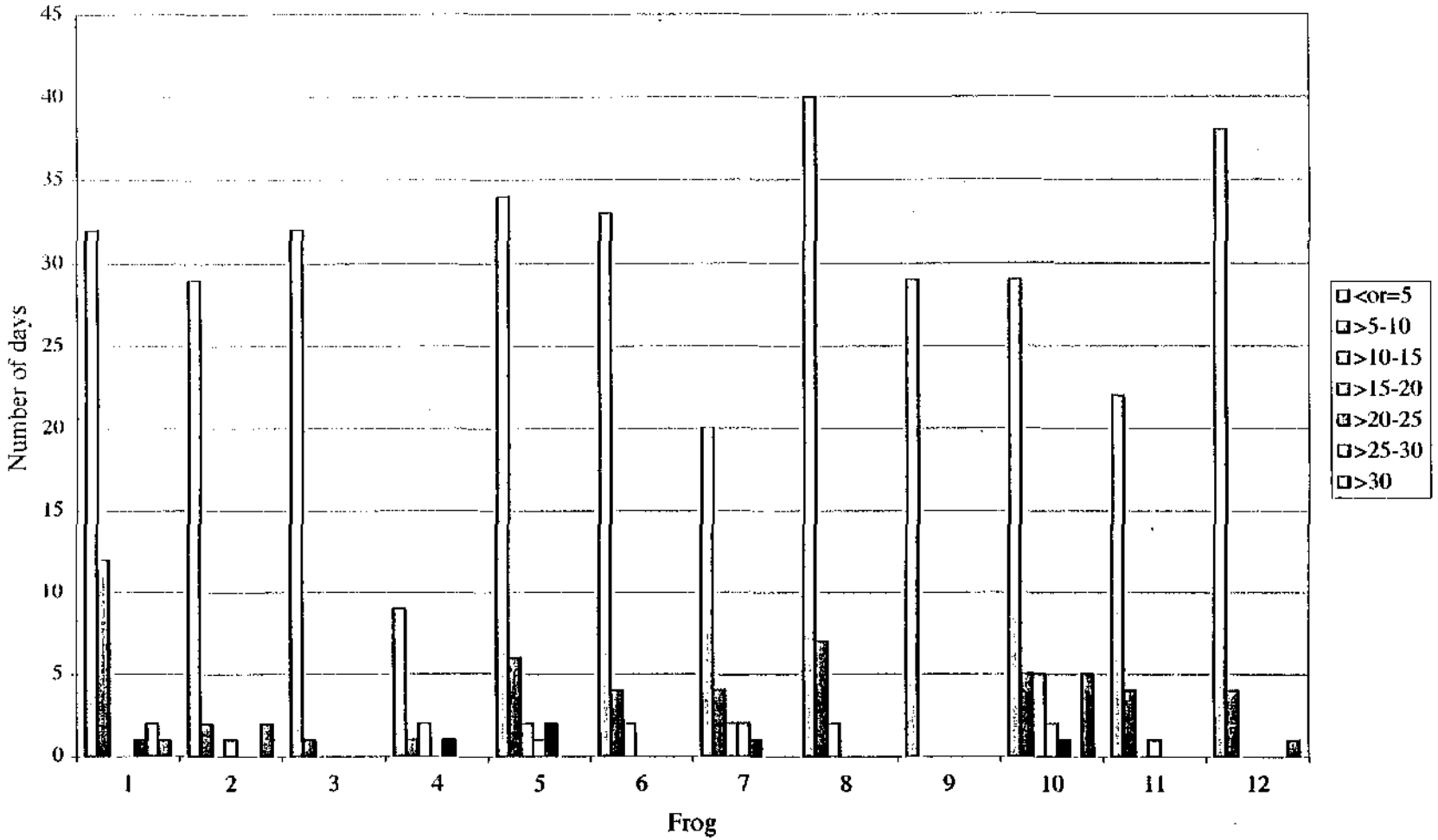


Figure 4. Frequency of distances(m)/day travelled by individual frogs.

per day was relatively short (e.g., Frogs 5, 7, and 12) (Table 2, Figures 3 and 4). Estimations of the furthest map distance from the breeding site ranged from approximately 20 m to approximately 280 m (mean = 149, SD = 83.61).

The frogs, except for one individual, were detected on land 90% of the survey period (Table 3, Figure 5). Of their time spent on land, most of the frogs tended to stay close (5 m or less) to water (lagoon, stream, ditch, or seep) (61% of the days); although one frog was detected spending most of her time more than 10 m from water, she was still relatively close to the lagoon. The longest distances from water were recorded for Frogs 2 (60 m from ditch near house) and 10 (80 m from lagoon) (Map in back pocket).

As the weather became drier (less daily precipitation), the frogs appeared to move away from areas of vegetation and/or soil that were drying up. This was particularly true with regard to the frogs who were found near the house. When first found, several of these frogs were staying in the forb patch near the house (Map in back pocket). It appeared that as these areas started to dry up, most of the frogs who were still in the forb patch moved to the closed canopy thicket/forest, where the relative humidity seemed to be much higher. Within the thicket/forest upslope from the house, as the lower reaches of the streambeds dried up, the frogs appeared to move upslope to those areas that still had some, even minimal, surface water. Even so, overall distances from water did not

Table 3. Number of days (percentage) frogs were located in water and at various distances from water.

	Distance (m)			
Frog	In Water	<or=5	>5 & <or=10	>10
1	0(0)	31(63)	8(16)	10(21)
2	27(75)	3(8)	0(0)	6(17)
3	0(0)	0(0)	1(4)	25(96)
4	3(21)	6(43)	4(29)	1(7)
5	0(0)	46(98)	1(2)	0(0)
6	0(0)	37(97)	1(3)	0(0)
7	5(18)	21(75)	2(7)	0(0)
8	2(4)	41(80)	1(2)	7(14)
9	3(9)	30(91)	0(0)	0(0)
10	1(2)	8(16)	23(47)	17(35)
11	3(11)	3(11)	18(64)	4(14)
12	0(0)	45(100)	0(0)	0(0)
All frogs	44(10)	271(61)	59(13)	70(16)

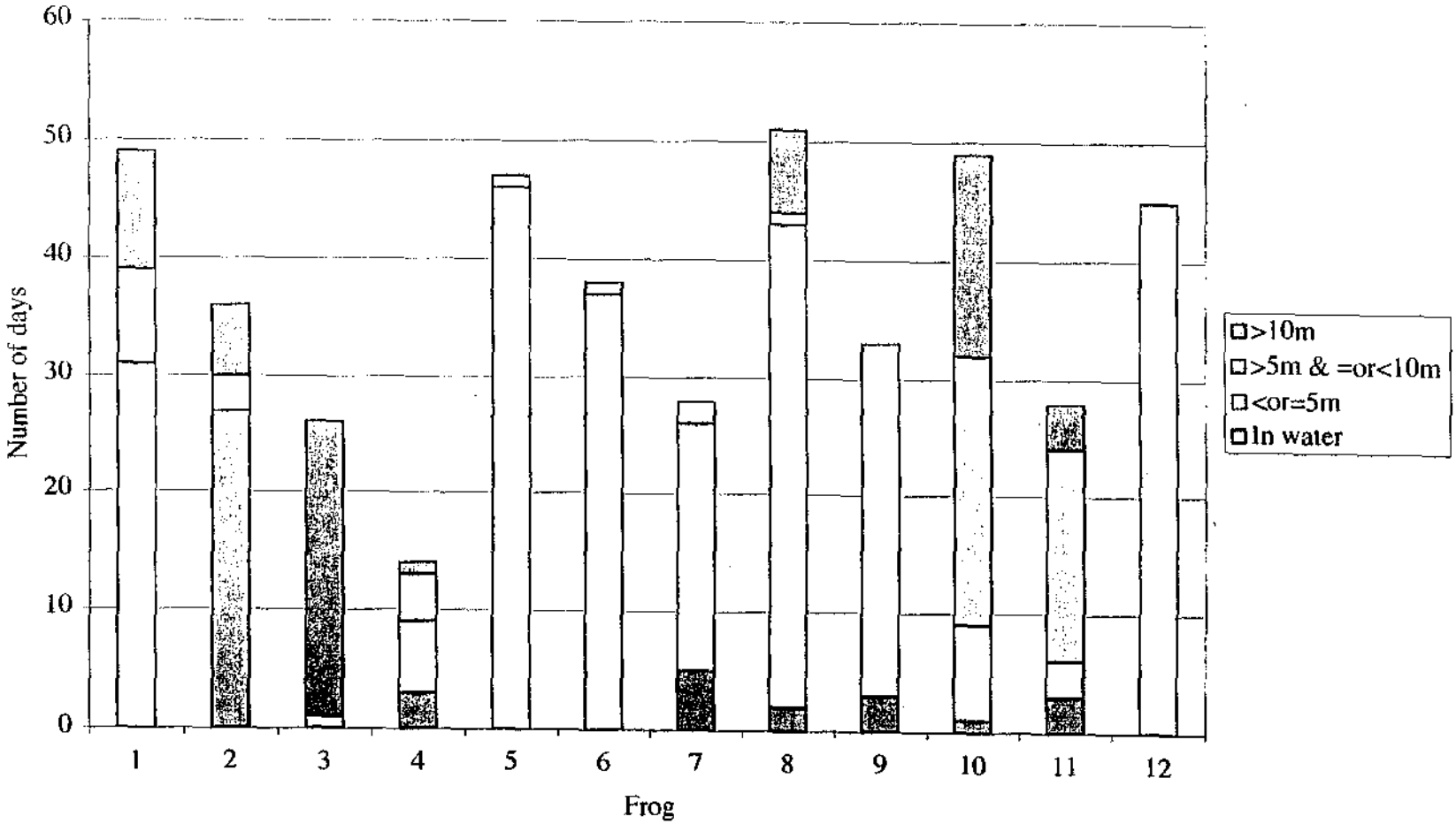


Figure 5. Number of days frogs were located in water and at various distances from water.

appear to decrease as precipitation and soil moisture decreased, this despite the fact that the frogs were usually found on the bank of a streambed, rarely in the streambed itself.

Habitat Use

Overall the frogs were detected in closed canopy thicket/forest 52% of the time, in forb patch 19%, in emergent vegetation 17%, in grassland 8%, and in (under) man-made objects 4% (Table 4, Figures 6 and 7). The results of the Friedman test showed that, for those frogs whose observed ranges included thicket/forest and forb patch and/or emergent vegetation, there is not enough evidence to claim selection of one habitat category over the other ($n=9$, $df=1,8$, $p>0.25$) (Appendix 2). Most of the detections in grassland were near or on the edge of either thickets or forb patches and in grassland areas that were relatively narrow; there was only one detection in the large grassland below the house (Appendix 1, Map in back pocket).

Quite a few male adult, a few juvenile, and a couple of adult female without transmitters were opportunistically encountered in the forb patch in and around the streambed and ditch near the house during the first part of the study. A few more were also encountered in the thicket/forest near the lagoon and around one of the small drainages upslope from the house.

Table 4. Number of detections (percentage) of frogs in macrohabitat types.

	Macrohabitat Type				
Frog	Thicket/Forest	Forb Patch	Emergent	Grassland	Man-made
1	44(85)	4(7.5)	0(0)	4(7.5)	0(0)
2	0(0)	9(25.5)	24(68.5)	1(3)	1(3)
3	26(100)	0(0)	0(0)	0(0)	0(0)
4	0(0)	5(36)	0(0)	9(64)	0(0)
5	22(48)	10(21)	2(4)	2(4)	11(23)
6	13(33)	25(64)	0(0)	1(3)	0(0)
7	17(55)	13(42)	0(0)	0(0)	1(3)
8	10(20)	3(6)	32(64)	5(10)	0(0)
9	0(0)	15(50)	9(30)	0(0)	6(20)
10	44(86)	0(0)	4(8)	3(6)	0(0)
11	14(50)	0(0)	3(11)	11(39)	0(0)
12	43(98)	0(0)	0(0)	0(0)	1(2)
All frogs	233(52)	84(19)	74(17)	36(8)	20(4)

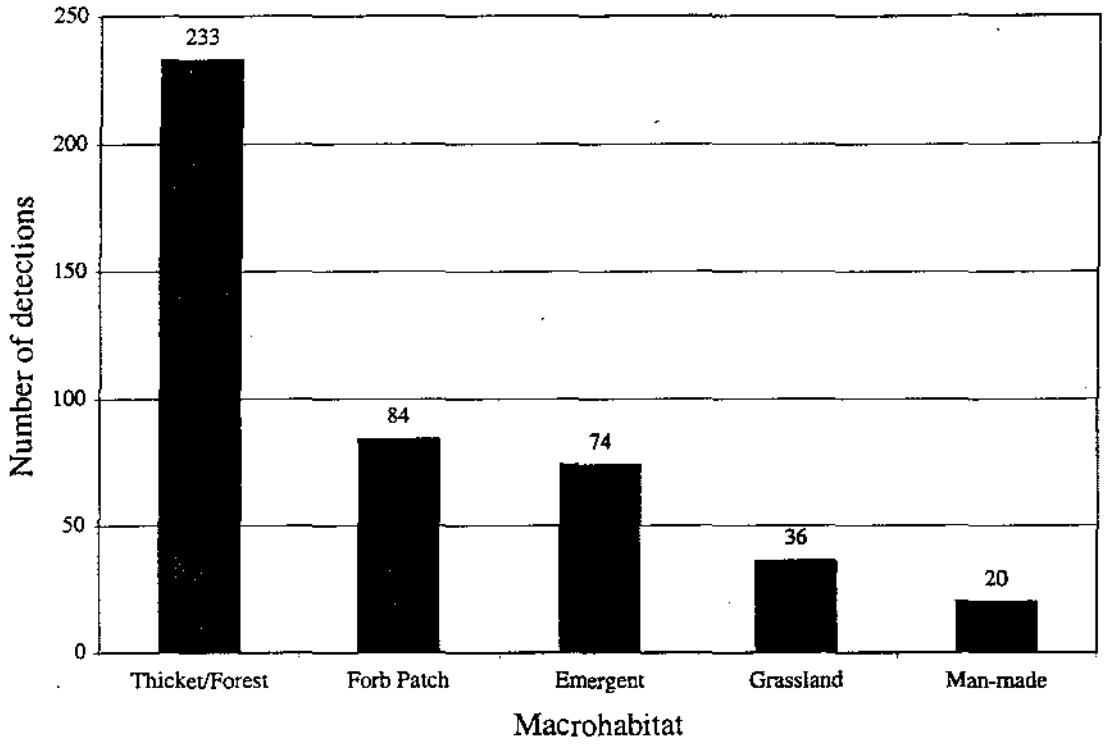


Figure 6. Frequency of detections in macrohabitat types for all frogs.

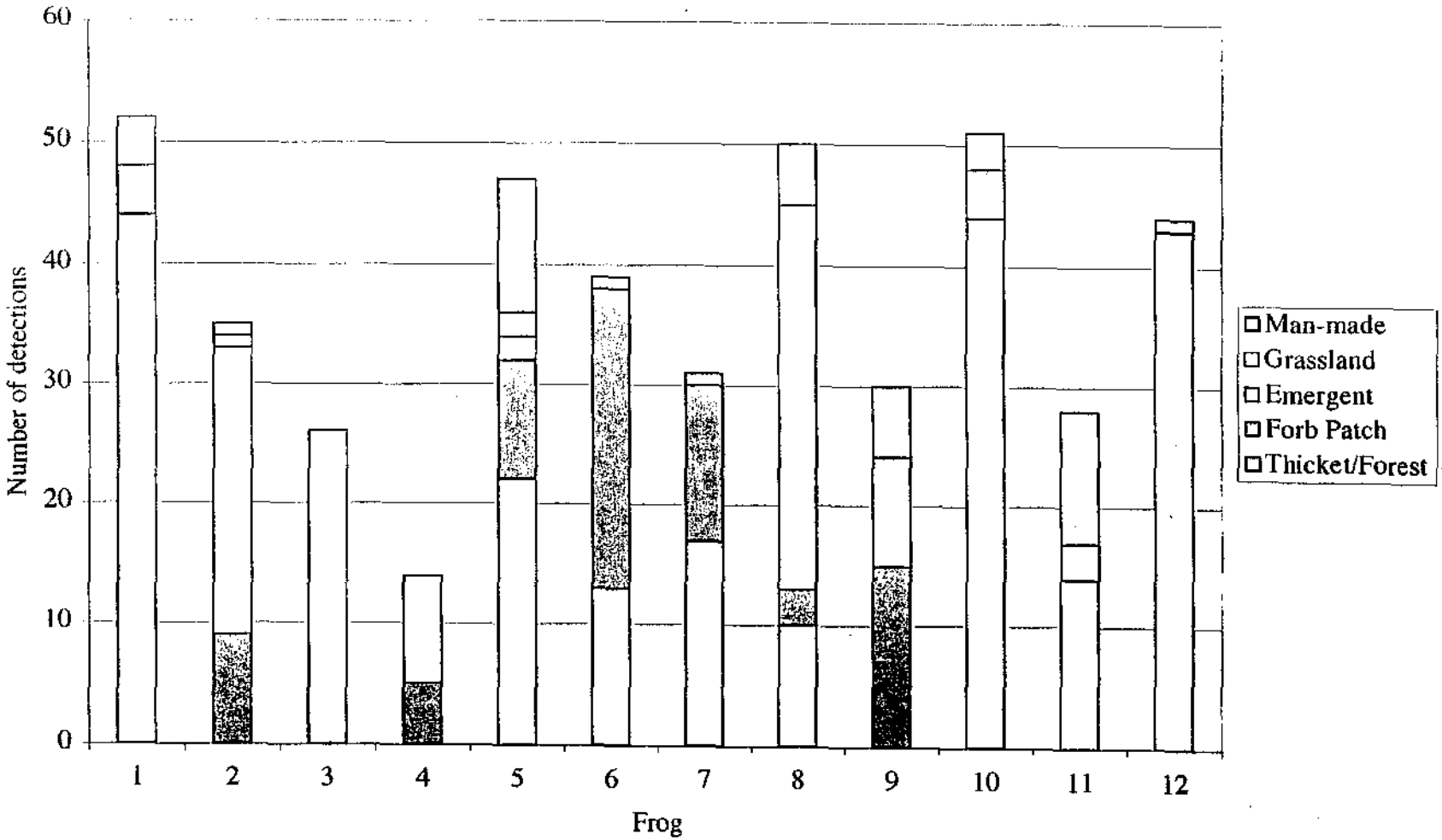


Figure 7. Macrohabitat use of individual frogs.

Some of the radio-tagged frogs followed patterns of habitat use that were similar over time. Frogs 1, 5, 7, and 12 were forb patch first detected near the Machados' house spending a relatively short time in either the, grassland or under boards (Figure 2, Map in back pocket). Thereafter, however, these frogs spent the great majority of their tracking periods following the small drainages upslope in the thicket above the highway. Frog 6 also followed a small drainage, but downslope, starting her tracking period in the forb patch near the house and ending up in thicket below the house.

Most of the frogs who were first found near the lagoon were detected throughout their tracking periods for the most part either in thicket and grassland or emergent vegetation (Figure 2, Map in back pocket). Like some of the frogs found near the house, Frog 10 was found at the end of her tracking period apparently following a small drainage upslope nearer the lagoon.

There were three exceptions to the above patterns of habitat use (Figure 2, Map in back pocket). Frog 2 was first detected in the forb patch near the house but subsequently ended up in the lagoon spending the rest of the tracking period in the emergent vegetation. Frog 4 stayed in a forb patch or in grassland at the edge of a forb patch. Frog 9 stayed mostly under the metal shed located near the house or in the forb patch near the shed.

Assessing microhabitat use was not one of the objectives of this study, but as the study progressed, it became apparent that sword ferns seemed perhaps to be important to the frogs (Appendix 1). In areas where the ferns were present, frogs were quite often detected either under (preferred) or on top of the fern fronds. Unfortunately, I could not quantify the data regarding sword fern use because many times thick vegetation prevented me from viewing a frog; e.g., if a frog was in a thicket, I could not get close enough to see whether or not that frog was under a fern within the thicket.

DISCUSSION

Beaded-chain Belt Method of Attaching Radio Transmitters

The beaded-chain belt method of attaching radio transmitters proved to be a relatively safe and effective radio-tagging technique for large adult *R. a. aurora.* The tagging process was quick and easy, a must under field conditions. Although visual observation of the frogs was limited, I found no discernible effect on the frogs' behavior. The belt assembly did not appear to hinder the movements of the frogs, since there was usually some movement every day during the tracking periods and several frogs did move long distances. No frogs were found entangled in vegetation.

The only two frogs whom I reweighed showed a weight gain. Matthews and Pope (1999) reported that 10 of the 14 mountain yellow-legged frogs (*Rana muscosa*) to whom they had attached transmitters with chain belts had gained weight from the time they were tagged until the transmitters were removed. Rathbun and Murphey (1996) reported that their data indicated that the radio-belts had not significantly affected the frogs' weight in their study.

Skin abrasions were a concern since the beaded-chain belts on some of the frogs fit rather snugly. When the transmitter assembly was removed from one of the frogs (Frog 10) after a 56-day tracking period, there was a small sore on the dorsal side of the

frog where the connector had rubbed against the skin. There had been no sores when this frog had been recaptured after 7 days of carrying a transmitter. Two other frogs who had been recaptured, one after 7 days and the other after 47 days, had no visible abrasions. A possible solution to avoiding the possibility of skin abrasions would be to periodically check the frogs. Both Rathbun and Murphey (1996) and Matthews and Pope (1999) reported that a few of their frogs had small skin abrasions from the transmitters, but when the transmitters were removed, the sores rapidly healed. Likewise the frogs should be checked periodically to evaluate whether the transmitters are causing any other adverse effects, such as behavioral problems.

One major problem encountered with the transmitter assembly was that the transmitter would become unglued from the connector. I recovered transmitters without the chain belt on 4 different occasions; one transmitter had become detached after only 7 days on the frog, and the second transmitter attached to this frog was found 51 days later sans belt. These three frogs were found in water (2 in the lagoon and 1 in the ditch by the metal shed) and in wet areas of emergent vegetation that were next to water. Several transmitters had to be reglued to the connectors after having become detached during the tagging process. The glue that connected these transmitters to the connectors may not have been completely dried when the transmitter assemblies were attached to the frogs. Placing the assembly in the sun to make sure that the glue completely dried seemed to

help keep the transmitters attached to the connectors. To avoid the problem of transmitters becoming detached from the belts while tracking is in progress and thus losing the frogs, the frogs, especially those in water, should be checked periodically to assess the condition of the transmitter assembly.

Another solution to the transmitters becoming detached from the connectors may be at the manufacturing level. Perhaps the manufacturer could modify the design of the transmitter to include an attachment such as the connector (Dr. James Waters, Department of Biological Sciences, Humboldt State University, Arcata, CA, pers. comm.).

Movements

The data in my study indicate considerable variability in the movements and movement patterns of adult *R. a. aurora* at Freshwater Lagoon (Figure 2). Nevertheless, a majority of the frogs, of which all but one were female, did move away from the periphery of the lagoon, some to considerable distances. In contrast, Twedt (1993), in his study of *R. a. aurora* and bullfrogs at Freshwater Lagoon, stated that only the adult and subadult males, as well as the juveniles, dispersed from the lagoon: the adult females did not disperse but remained at the lagoon throughout the summer. A number of adult

females may stay at the lagoon throughout the summer, but my study shows that there are other adult females who do stay away from the lagoon at least during the early summer months. When my study was terminated at the end of July, 8 of the 11 females were still at some distance from the lagoon, and they did not appear to be moving toward the lagoon.

Twedt (1993) indicated that the adult females might be able to stay in the lagoon because their larger size may help them avoid predation by bullfrogs, which are also present in great numbers in the lagoon. If Twedt's assumption is correct that the adult females may avoid predation by bullfrogs by virtue of their larger size, and since this study showed that adult females do leave the lagoon, then factors other than avoidance of bullfrog predation play a role in the females' leaving the water for terrestrial sites.

One factor may be predation by species other than bullfrogs. Three of the major predators of *R. a. aurora* are raccoons, great blue herons (Licht 1974, 1986a) and egrets. Adult female frogs, as well as adult males and juveniles, who stay in or near the lagoon might be at greater risk of predation by these species, who were seen only at the lagoon. I observed one raccoon walking on the exposed roots of the lily plants in the lagoon.

Another factor may be food. Small invertebrates such as spiders and insects are a staple of the diet of postmetamorphic *R. aurora* (Stebbins 1972; Nussbaum *et al.* 1983; Hayes and Tennant 1985; Licht 1986b). Foraging on land would increase the frogs' prey

base. Dispersing away from the lagoon may also allow for less intraspecific competition for food.

Bulger *et al.* (1999) found, in their year-long radio telemetry study of the terrestrial activities of adult *R. a. draytonii* in a forested watershed in Santa Cruz, California, that both males and females moved away from their breeding sites. They determined that there were two distinct movement patterns in adult *R. a draytonii*, and consequently divided the frogs into two categories: 1) non-dispersing frogs--those individuals who made short-range forays into upland habitats but returned to their home site at the end of the upland interval, and 2) dispersing frogs--those individuals (a minority contingent) who additionally made overland movements between two aquatic sites.

Unfortunately because of the short duration of my study and the small sample size, I could not determine if *R. a. aurora* at Freshwater Lagoon could also be divided into similar categories. At a glance the frogs captured near the Machados' house and the frogs captured near the lagoon might constitute 2 different groups akin to those of Bulger *et al.* (1999): the frogs captured near the house had moved considerable distance from the lagoon, their assumed home site, and the frogs captured near the lagoon generally stayed near the lagoon. However, of the 7 frogs captured near the house, two (Frogs 2 and 6) moved downslope with one (Frog 2) returning to the lagoon. Of the 5 frogs

captured near the lagoon, one (Frog 10) appeared to be moving away from the lagoon at the end of her tracking period. Would the other 4 frogs who were last detected near the lagoon also eventually move away and stay away from the lagoon until the onset of the next breeding season? Would the other 6 frogs who were captured near the house and last detected still far from the lagoon also return to the lagoon during the non-breeding season? Or would some of them continue to move away, dispersing to other aquatic sites, e.g., the large wetland approximately 1.4 km (straight-line map distance) from the lagoon on the other side of the hill? Bulger *et al.* (1999) found that the frogs in their study travelled straight-line map distances of up to 2.8 km in a single season. Other anuran species have also been known to make seasonal migrations of several kilometers (Bulger *et al.* 1999). However, the frogs in my study may not be migrating to another aquatic site: Bulger *et al.* (1999) found that approximately one-third of the non-dispersing frogs, using ravines that had at least some surface flow during most of the year, moved up to 150 m from home ponds and stayed away for as long as 38-42 days before returning to them. The frogs in my study were found as far away as 270 m from the lagoon. The answers to all the above questions require a more extensive telemetry study.

Perhaps the movement patterns in my study and that of Bulger *et al.* (1999) may not be comparable at all because of differences in habitat configurations. The frogs in the

Bulger *et al.* (1999) study inhabited permanent, small ponds some of which were located in grassland, scrub, or agricultural fields. In contrast, the frogs in my study inhabited the lagoon, a large, complex wetland, surrounded mostly by an extensive matrix of forest and thickets. The Bulger *et al.* (1999) frogs may have had to cross more open areas, such as grasslands, to reach the other aquatic sites, whereas the frogs in my study had more extensive areas of thick vegetation, such as thickets, adjacent to or surrounding aquatic sites available to them.

Certain features of long distance movements by the frogs in my study were shared by the dispersing *R. a. draytonii* in the Bulger *et al.* (1999) study: the dispersal movements were spread out over time, asynchronous, and typically characterized by brief spurts of movement separated by longer intervals of relative inactivity (Figure 3). A major difference in long-distance movement exists between the two, however, in that most of their dispersing *R. a. draytonii* moved overland in nearly straight lines to target sites, i.e., ponds. The only frog in my study who fit Bulger *et al.*'s (1999) description of target-oriented straight-line movement was Frog 2, who moved through the large grassland from near the house to the lagoon. Again, habitat configuration may play a role in the difference: the frogs in the Bulger *et al.* (1999) study may have had to cross a more fragmented landscape than exists at Freshwater Lagoon.

In general the frogs stayed close to water sources but not in water throughout the duration of the study. Similarly, Twedt (1993), who sampled only the shoreline habitats of Freshwater Lagoon for *R. a. aurora*, found a majority of the *R. a. aurora* in spike-rush habitat on land. Dunlap (1955), Gregory (1979) and Licht (1986a, 1986b) also reported that most of their sightings of postmetamorphic *R. a. aurora* were on the vegetated banks of waterways rather than in the water; Licht (1986b), in fact, never saw adult *R. a. aurora* in the channel of the river he surveyed. The non-dispersing *R. a. draytonii* in the Bulger *et al.* (1999) study also "...routinely occupied a fringe of land immediately adjacent to water..." In his description of the postbreeding behavior of adult *R. a. aurora*, whom he labeled "wood frogs", Dumas (1966) stated that the frogs were "...not closely tied to open water but may wander into adjacent moist habitats." In contrast, Calef (1973), in his study of *R. a. aurora* at Marion Lake in British Columbia, thought that the males, unlike the females, remained in the lake after amplexus.

Although the frogs in my study were mostly found near water, some of the frogs were found at considerable distances from any known water source (Map in back pocket). These detections support statements in the literature that *R. aurora* may occur far from water (I assume that any reference to "water" in the literature means a body of water such as a lake, pond, river, or stream) (Stebbins 1954, 1985; Dumas 1966; Corkran and Thoms 1996). Dumas (1966) noted that adult *R. a. aurora* may be found "...as much as 1,000

yds away from the nearest water." The consensus of these authors seems to be that the frogs are far from water only during damp conditions. However, Licht (1986a) reported that *R. a. aurora* in southwestern British Columbia move many meters away from water in both dry and wet conditions. But, he also stated that from April to October (spring through fall) he often found them on land near rain pools, or near a river in summer, and during rainfall they moved some distance away from standing water. Bulger *et al.* (1999) found that their non-dispersing frogs made forays of short duration into upland habitats to distances of up to 130 m from water in response to summer rain. *R. aurora* have been encountered in dry upland sites in coastal northwestern and central California in late summer and early fall (Dr. James Waters, Department of Biological Sciences, Humboldt State University, Arcata, CA, pers. comm.; pers. obs.). The two frogs in my study who travelled considerable distances from water did so in the rainy season, so it remains to be seen if the frogs at Freshwater Lagoon would make these upland forays during the "dry" season (late summer and early fall).

At Freshwater Lagoon, the moderate coastal climate, in which the relative humidity remains high throughout the year (with mild temperatures and frequent fog throughout the summer), probably provides suitable conditions for the frogs to be at least a short distance from water at almost any time. Bulger *et al.* (1999), who described the

area of their research as having a similar climate, stated that the frogs in their study stayed on land regardless of weather conditions.

In addition, as the weather becomes relatively drier as spring turns to summer, soil moisture may remain high enough on the banks of the waterways that have thick vegetation for the frogs to remain there. Although the intermittent streams within the thicket/forest did start to dry up, the streambanks may have still been moist enough for the frogs by virtue of the protective cover of the closed canopy.

Habitat Use

The data in this study suggest that, overall, adult *R. a. aurora* use the closed canopy thicket/ forest in preference to the other habitat types found at Freshwater Lagoon (Table 4, Figure 6), although there was considerable individual variability (Table 4, Figure 7). Even when frogs were found in grassland areas that were next to thicket/forest, they were usually near or at the edge of the thicket/forest.

Forb patch and emergent vegetation were used to a lesser degree but at approximately the same frequency (Table 4, Figure 6). Four of the six frogs who were at some point in close proximity to the lagoon were detected at least some of the time in the emergent vegetation of the lagoon. Of these four frogs, only two spent a majority of the

time in the emergent vegetation. Frogs used either densely or sparsely vegetated parts of the forb patches.

The results of the Friedman test gave no evidence of frog preference regarding thicket/forest versus forb patch/emergent vegetation, but the small sample size limits the power of the test. This very limited applicability of a statistical test to radio-tracking data is not uncommon. In fact, small sample size is a major problem with radio-tracking studies that report patterns of movement and habitat use, and consequently these studies are usually only descriptive in nature (Richards *et al.* 1994). To determine habitat use in relation to habitat availability at Freshwater Lagoon, a study with a much larger sample size needs to be conducted.

The one area the frogs appeared to avoid was the large grassland downslope from the house. Only one frog (Frog 2) on one occasion was found in this grassland, and she apparently was only passing through, travelling from the forb patch near the house to the emergent vegetation in the lagoon. No other frogs were encountered in the large grassland even though we traversed it many times. Even as summer approached and the grass grew taller, frogs were still not found in the large grassland. Consequently, I assume that the frogs captured near the house probably travelled from the lagoon through the thicket/forest on the northside of the grassland.

Bulger *et al.* (1999) described macrohabitat use only in relation to the dispersing *R. a. draytonii*: in their straight-line movements to target sites, the frogs apparently showed neither avoidance nor preference for any particular habitat type. The vegetation types in their study area included coniferous forest, grass/scrub rangeland, and agricultural land. Perhaps *R. a. aurora* at Freshwater Lagoon who disperse to other breeding sites also make straight-line target-oriented movements regardless of habitat type.

Nevertheless, it seems reasonable that the *R. a. aurora* at Freshwater Lagoon would prefer thicket/forest, forb patch, and emergent vegetation over grassland. Although the relative humidity at Freshwater Lagoon is high in general, the thicket/forest, forb patch, and emergent vegetation habitats, especially where the vegetation is dense, may provide even more moist conditions, which the frogs need to prevent dehydration. Also the water sources in the form of seep, stream, ditch, and lagoon seemed to be more associated with the thicket/forest, forb patch, and emergent vegetation habitats than with the grassland habitat.

It has been commonly stated in the literature that *R. aurora* use dense shoreline vegetative cover as well as "damp woods" and moist patches of herbaceous vegetation away from water (Stebbins 1954, 1972, 1985; Storm 1960; Dumas 1966; Nussbaum, *et al.* 1983; Licht 1986a; Twedt 1993; Jennings and Hayes 1994; Corkran and Thoms 1996;

Behler and King 1998). Hayes and Jennings (1988) and Rathbun *et al.* (1993) reported that an important habitat variable for *R. a. draytonii* was found to be areas of largely intact dense emergent or shoreline vegetation that included shrubby willows. Most of the detections in my study were in areas such as these but also in the dense thickets within the alder/Sitka spruce forest. Frog 10 was the only frog found in part of the forest that had a relatively open understory, and she was there only for a few days.

Not only do the thicket/forest, forb patch, and emergent vegetation habitats provide the frogs with a moist environment, but these habitats, especially thicket/forest, probably also provide good cover from predators. During the late spring months we encountered common garter snakes (*Thamnophis sirtalis*), another major predator of *R. a. aurora* (Licht 1974, 1986a), quite frequently in and only in the grassland. The only frog presumably eaten by a raccoon was detected either in low grass (grassland) or in more open forb patch/grassland near the lagoon. We saw no evidence of raccoons in the thickets. Raccoons may avoid this habitat, especially where the vegetation is thick, because it would be difficult to move through. In fact, one of our concerns was that, in clearing part of the thicket to make trails in order for us to track the frogs, we were not only altering the habitat but also creating access for predators where there had been no access previously.

Prey abundance is probably not a limiting factor in the habitat preferences of adult *R. aurora*. Ranids in general are known to feed opportunistically (Licht 1986b), and the different habitat types in which the frogs were found in this study probably provide a rich variety of prey organisms.

There are several possible explanations for why the frogs bother to travel so far upslope into the thicket/forest when there appears to be plenty of thicket/forest (dense vegetation) near the lagoon. One factor may be that going upslope may allow frogs to take advantage of other areas that offer more moist conditions. As the relatively drier-weather season progressed, there seemed to be a marked difference in the amount of wind and relative humidity between the thicket/forest and the other habitat types. The amount of wind decreased and the relative humidity increased as one went from a more open habitat to the closed canopy areas. This difference in wind and relative humidity was even more striking the further one was from the lagoon: there was much less wind, if any, and much higher relative humidity in the thicket/forest upslope from the house, which was dominated by salmonberry/currant thicket, than in the thicket/forest near the lagoon.

Another explanation for the frogs' upland movements may be that, if the frogs stay in or near the lagoon, they might be at greater risk of predation by raccoons or avian predators such as herons and egrets, who were seen only near the lagoon. We saw a large

number of raccoon tracks only near the lagoon. The raccoons may frequent the lagoon since both red-legged frogs and bullfrogs, especially the tadpoles and recently metamorphosed frogs, can be found in the shallow edges of the lagoon, sometimes in great numbers (Twedt 1993).

Lastly, competition for food may be greater at the lagoon. Dispersing upslope may allow the frogs to take advantage of prey items in other areas with less competition from other frogs.

Sword ferns may be an important microhabitat in providing excellent cover for *R. aurora*. As a fern grows, the lower fronds die and droop, creating an "enclosure" at the base of the fern. Moisture levels are probably higher in these enclosures, especially as ambient conditions become drier. The ferns probably also provide good hiding places from predators, especially in areas that have a more open understory. On one occasion, the transmitter signal led me to a large fern. Although the signal indicated that I was extremely close to the frog ("right on top" of her), it took me a minute or so to visibly locate the frog, who had assumed a cryptic position among the dead fronds. Ferns are mentioned in the literature, but only as part of a general description of the types of habitat in which *R. aurora* are found (Stebbins 1954; Gellman *et al.* 1993; Jennings and Hayes 1994).

Although most of the detections of the radio-tagged frogs were not in seeps *per se*, it seemed that *R. a. aurora* in general were more likely to be found in the seeps, or in areas that had supersaturated soils. This was particularly the case on the east side of the house, where the hillside below the highway is essentially either seep or at least of heavily saturated soil. This area was where 7 of the 12 radio-tagged frogs were first caught and most of the frogs without transmitters were seen. These seeps, especially those associated with thick vegetation, may serve as "way stations" as the frogs move upslope. A good example of this is Frog 1: she stayed a number of days apparently "resting" in a seep in the thicket upslope from the highway, after which she continued upslope.

Use of Corridors

It has been suggested in the literature that biological corridors may play an important role in the seasonal migrations of some amphibians as they move to and away from breeding sites (Dodd and Cade 1998; Rosenberg *et al.* 1997). Amphibian use of migratory corridors, however, has only been attributed to salamanders (Shoop 1965, 1968; Stenhouse 1985; Verrell 1987; Beebee 1996). I know of no reference in the

literature that has established corridor use *per se* by ranids as well as other anurans (Kusano *et al.* 1995; Dodd and Cade 1998; Bulger *et al.* 1999).

Rosenberg *et al.* (1997) describe a corridor as a "...linear landscape element that provides for movement between habitat patches." Applying this description to the study area at Freshwater Lagoon, the intermittent streams and ditches are the only obvious features of the landscape that might serve as corridors, although it is not obvious which habitat patches they would be connecting.

In my study, 6 of the frogs (Frogs 1, 5, 6, 7, 10, and 12) appear to have used some of the known intermittent streams as corridors for at least part of their travels. As the frogs moved further away from the lagoon, they seemed more likely to follow these tiny drainages. This seemed particularly the case regarding the intermittent stream segments upslope from the Old State Highway: Frogs 1, 5, 7, and 12 appeared to be closely tied to them. In contrast, Bulger *et al.* (1999) found that the dispersing *R. a. draytonii* in their study did not use obvious migration corridors in the form of watercourses or riparian vegetation strips in preference to overland routes. However, approximately one-third of their non-dispersing frogs spent at least some time in ravines that had some surface flow of water and were contiguous with some of the ponds.

It would be interesting to find out if individual *R. a. aurora* at Freshwater Lagoon follow these same pathways, or at least use the same areas, from year to year. There is

evidence in the literature that individual salamanders, at least, use essentially the same pathways year after year (Stenhouse 1985; Verrell 1987; Beebee 1996).

It was somewhat puzzling that no radio-tagged frogs were found in or even near the intermittent stream segment that runs parallel to the southside of the large grassland (Figure 2, Map in back pocket). This stream seems an obvious corridor, especially for those frogs found near the lagoon in the southern part of the study area. Even Frog 1 who ended upslope in a nearby stream assumedly travelled from the north side of the study area. Perhaps this drainage was more exposed since it bordered the grassland.

Management Considerations

Most conservation measures concerning wetland-breeding amphibians focus on protecting only the wetlands where the amphibians breed or areas immediately adjacent to those wetlands (Dodd and Cade 1998). The results of this study suggest that any conservation efforts that do not take into consideration the use of upland habitats by R. *a. aurora* may well fail in protecting them. Particularly in light of the fact that the *R. a. aurora* at Freshwater Lagoon seem to use corridors, i.e., the intermittent streams, and mostly at a substantial distance from the lagoon, a distance and directional component should be considered when establishing any terrestrial buffer zones for *R. a. aurora*.

In addition to streamside buffer zones, buffer zones around seeps may be important in that the frogs may use these areas as "rest stops" as they travel upslope. Any construction, such as roadbuilding, that may divert or dry up intermittent streams or seeps may have a negative effect on the movements of the frogs. In addition, roads have been shown to act as dispersal barriers for ranids (Gellman *et al.* 1993, Vos and Chardon 1998).

It is essential that terrestrial buffer zones function to maintain key vegetative components. Bulger *et al.* (1999) identified shrub patches and herbaceous vegetation as particularly important habitat elements for *R. a. draytonii*. Another important vegetative feature for *R. a. draytonii*, according to Rathbun *et al.* (1993), includes plants that provide good vertical structure, such as tall cattails, dense tangles of vines, and low willow root and branch tangles. Dumas (1966) stated that adult *R. a. aurora* are also commonly found "...among tangled complexes of logs." For the *R. a. aurora* at Freshwater Lagoon, I would also include thickets and sword ferns as important components. Buffer zones should include large enough patches of vegetation, especially around streams and seeps, to maintain adequate levels of relative humidity for the frogs.

My study has helped show the value of radio-tracking as a tool in studying the movement ecology of amphibians. In contrast to other methods that have been used to examine migratory behavior, radio-tracking has allowed researchers to better measure the

movement of individuals. As a result, it has provided direct evidence of the movement patterns and habitat use of animals where only hypotheses based on indirect data have prevailed (Rosenberg *et al.* 1997).

As my study has shown, surveys carried out over short time spans are inadequate to fully assess the terrestrial movement patterns and habitat requirements of *R. a. aurora*. It is imperative that studies on the movements of these frogs be conducted year-round and for subsequent years. In addition, surveys are needed on a finer time scale, perhaps on an hourly basis, to get a more detailed description of the frogs' movements.

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Appendix 1. Key to Appendices 1a through 1l.

SEX: F = Female, M = Male

SVL: Snout-to-vent length, in mm

LOCATION NO.: Frog location number in GIS ARC/INFO 7.2.1 vector database (Redwood National Park, Arcata, CA)

DATE: Month/day/year

TIME: 24-hour clock

DISTANCE FROM WATER:

0 = In water
1 = 5 m or less from water
2 = >5 m to 10 m from water
3 = >10 m from water

HABITAT TYPE:

T = Closed canopy thicket/forest
E = Emergent vegetation
F = Forb patch
G = Grassland
B = Man-made objects
U = Undetermined

TEMP: Temperature in °F

CLOUD COVER: Percentage of cloud cover (and weather conditions)

Appendix 1a. Data sheet for Frog 1.

ID#: TRANSMITTER#: 329 RADIO FREQ.: 9.760
SEX: F SVL(mm): 76 WEIGHT(g): 40.6 GRAVID: no #BELT BEADS: 17

LOCATION NO	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
1	3/17/99	1700	*	*	V	3	F	55	>50	In clump of bear's breech near house
2	3/18/99	1540	0.3	96E	V	3	F	60	100	In clump of bear's breech near house
3	3/19/99	1440	2.5	79E	V	3	G/F	59	>50	In short grass/short herbaceous plants, moved to bear's breech
4	3/20/99	1458	0.5	59NE	V	3	G/F	59	<50	In short grass/short herbaceous plants, moved to bear's breech
5	3/21/99	1700	0.6	76NE	V	3	G/F	54	<50	Flattened down on small patch of ground next to short grasses near bear's breech
6	3/22/99	1525	1.4	195S	V	3	G/F	47	100;rain	Flattened down on small patch of ground next to short grasses near bear's breech
7	3/23/99	1500	71.2	98E(113E?)	V	1	F/E	50	100	At bank/water interface in ditch next to Old State Hwy.
8	3/24/99	1503	3.4	126SE	R	1	F/E	48	100;rain	At bank/water interface in ditch next to Old State Hwy.
9	3/25/99	1503	8.6	49NE	R	2	T	56	100	E upslope from ditch in mixed thicket
10	3/26/99	1504	3.4	71E	V	2	T	60	<50	On top of dead fern fronds in thick vegetation
11	3/27/99	1622	1.2	261W	R	2	T	60	<50	In thick vegetation
12	3/28/99	1610	2.8	62E	R	2	T	56	>50;windy	In thick vegetation
13	3/29/99	1500	30.0?	**11N?	R	3	T	55	>50	Rained previously; moved upslope but couldn't pin down location
14	3/30/99	1810	~25.0	25N	R	1	T	43	100;hail,rain	Moved upslope to near big spruce but no exact location
15	3/31/99	1611	-	-	-	-	T	48	>50;showers	No signal at all; in creek?
16	4/1/99	1600	~5.0	325NW	R	1	T	61	<50	In dead fern fronds next to small creek?
17	4/2/99	1621	<1.0?	?	R	1	T	60	>50	Across creek in seep area that's more open with clumps of short herbs, open ground/leaf litter
18	4/3/99	1745	~8.0?	83E	R	1	T	50	<50	In seep area that's more open with clumps of short herbs, open ground/leaf litter

Appendix 1a continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (degF)	CLOUD COVER (%)	DESCRIPTION
19	4/4/99	1614	1.5	124SE	V	1	T	56	100	In wet area next to more running water of seep, flattened down on ground/leaf litter (dead fern fronds) in open salmonberry/currant thicket
20	4/5/99	1614	3.1	241W	R	1	T	58	>50;hi clouds	Under open tangle of ferns & salmonberry; possibly under dead fern fronds; in wet area next to running seep
21	4/6/99	1753	0.4	299NW	R	1	T	59	<50	Open thicket; in dead fern frond/leaf litter/rock close to running water of seep
22	4/7/99	1739	1.4	299NW	R	1	T	55	100	Starting to sprinkle; nearer running water of seep; in same habitat as 4/6
23	4/8/99	1640	1.2	126SE	R	1	T	54	30	App. same place as 4/6
24	4/9/99	1600	0.7	324NW	R	1	T	56	20	Next to running water of seep; under old salmonberry branches
25	4/10/99	1613	0.8	127SE	V	1	T	51	100;rain	Essentially same place as 4/9
26	4/11/99	1628	0.6	206SW	R	1	T	65	0	Essentially same place as 4/9
27	4/12/99	1533	0.5	307NW	R	1	T	63	60	Essentially same place as 4/9; windy
28	4/13/99	1636	0.5	287W	R	1	T	69	0	Essentially same place as 4/9
29	4/14/99	1415	0.5	40NE	R	1	T	72	<1	
30	4/15/99	1635	~10.0?	7N	R	1	T	82	60;hi clouds	Upslope on open bank of seep; maybe under the few leaf litter patches or burrowed into bank, under open salmonberry/currant thicket
31	4/16/99	1815?	5.0?	249W?	R	1	T	72	60;hi clouds	Relatively weak signal to N? (towards creek) of 4/15 location, but couldn't get exact location--in creek bed in/under bank?
32	4/17/99	1849	~5.0?	191S	R	1	T	57	99;hi fog	Weak signal--in creek bed under rocks or roots
33	4/18/99	1523	2.3	6N	R	1	T	60	100;hi fog	Weak signal--upslope in creek bed under rocks or roots
34	4/19/99	1447	7.2	196S	R	1	T	67	50;hi clouds	Still in creek bed (under bank, rocks/branches?); following creek bed?; narrow creek bed ~2'W with very steep banks at this point

Appendix 1a continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (degF)	CLOUD COVER (%)	DESCRIPTION
35	4/20/99	1537	~1.5?	20N	R	1	T	68	20;hi thin clouds	Upslope in creek bed
36	4/21/99	1513	~7.5?	19N	R	1	T	63	100	Very weak signal so very unsure of location but fairly sure still in creek bed
37	4/22/99	1510	26.5?	9N	R	2	T	67	15	Quit search--antenna broke
38	4/23/99	1611	6.1	46NE	R	2	T	68	1	Upslope from 4/22 under dead fern fronds?
39	4/24/99	1728	8.0	305NW	R	1	T	58	100;fog	In thicket--dead fern fronds/branches/leaf litter
40	4/25/99	1909	7.3	324NW	R	1	T	53	100	In creek bed under branches, rocks?
41	4/26/99	1635	2.8	39NE	R	1	T	60	0	On mossy somewhat open bank w/few ferns, many dead branches of salmonberry
42	4/27/99	1535	~4.0?	302NW	R	1	T	62	40	On mossy open area w/ferns, twigs/branches under open salmonberry/currant thicket
43	4/28/99	1655	~3.3?	~73E?	R	1	T	69	1;windy	In open salmonberry/currant thicket a little >50 cm from creek
44	4/29/99	1721	~6.0	~337NW?	R	2	T	71	10;hi fog	In dead fern fronds in open salmonberry/currant thicket
45	4/30/99	1715	~5.0?	~94E?	R	1	T	66	60	She may be near creek again
46	5/1/99	1802	~4.0?	~314NW?	R	2	T	65	90	Saw 1 large female NRL & 1 male NRL near Frog 1's location
47	5/2/99	-	-	-	-	-	-	-	-	Didn't do search
48	5/3/99	1708	~1.0?	~74E?	R	1	T	57	100;rain	Under salmonbery/currant thicket
49	5/4/99	2008	~7.0?	~256W?	R	3	T	57	0	Upslope in thicket/ferns
50	5/5/99	1848	~6.0?	~13N?	R	3	T	66	10	Upslope in thicket
51	5/6/99	-	-	-	-	-	T	-	100;rain	Didn't do search
52	5/7/99	1700	-	-	-	-	T	-	-	Didn't find her--got a weak signal but wasn't hers--on wrong frequency!
53	5/8/99	1643	~6.0?	212SW?	R	3	T	70	25	Upslope

ADDITIONAL NOTES: Brown dorsum

*First location: 9m 100°E from edge of deck's SW corner

3/29/99: **BEARING may be 25°N?

Appendix 1b. Data sheet for Frog 2.

ID#: TRANSMITTER#: 335a RADIO FREQ.: 9.947
SEX: F SVL(mm): 70 WEIGHT(g): 47.6 GRAVID: no #BELT BEADS: 16

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
54	3/18/99	1650	*	*	V	1	B	54	100	At mud/water edge under board in ditch next to driveway
55	3/19/99	1604	7.5	102E	V	1	F	59	<50	Near seep in short herbs on hillside
56	3/20/99	1650	1.1	104E	V	0	F	55	<50	Under dead herbaceous in seep on hillside; shower
57	3/21/99	1652	2.2	272W	V	1	F	54	<50	Near seep in short herbs on hillside
58	3/22/99	1600	2.7	172S	R	0	F	51	>50	In very thick short herbs in seep
59	3/23/99	1517	0.75	108E	R	0	F	50	100	In thick short herbs in seep
60	3/24/99		-	-	-	3	-	48	100;rain	May be in bear's breech patch--gave up search
61	3/25/99	1548	19.4	186S	R	3	F	56	100	In bear's breech patch near house
62	3/26/99	1515	1.1	102E	R	3	F	59	<50	In bear's breech patch near house
63	3/27/99	1639	0.4	234SW	R	3	F	60	<50	In bear's breech patch near house
64	3/28/99	1626	0.15	23N	V	3	F	54	>50;windy	In app. same place as 3/27
65	3/29/99	1527	35.3	220SW	V	3	G	57	>50	Previously rained; in short grass
66	3/30/99	1614	87.5	227SW	V	0	E	43	>50	Been stormy; in shallow water at lagoon edge in short emergent grasses
67	3/31/99	1513	2	295W	V	0	E	52	>50;showers	In shallow water at lagoon edge in emergent grasses
68	4/1/99	1417	1.4	317NW	R	0	E	60	<50	In shallow water at lagoon edge in emergent grasses
69	4/2/99	1505	2.4	139SE	R	0	E	64	<50	In shallow water at lagoon edge in emergent grasses
70	4/3/99	1533	2.1	319NW	R	0	E	54	<50;very windy	In shallow water at lagoon edge in emergent grasses
71	4/4/99	1524	3.3	298NW	R	0	E	55	>50	In shallow water at lagoon edge in emergent grasses; pending storm
72	4/5/99	1510	8.8	306NW	R	0	E	58	>50;showers	In tall grasses, dead sedges in water
73	4/6/99	2005	2.3	315NW	R	0	E	53	0	In shallow water at lagoon edge in tall emergent grasses
74	4/7/99	1807	0.2	213SW	R	0	E	53	100;rain	Same habitat as 4/6
75	4/8/99	1702	0.15	183S	R	0	E	54	20	Same habitat as 4/6
76	4/9/99	1622	1.1	106E	R	0	E	59	20	Same habitat as 4/6

Appendix 1b continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (degF)	CLOUD COVER (%)	DESCRIPTION
77	4/10/99	1624	0.6	315NW	V	0	E	49	100;rain	Same habitat as 4/6
78	4/11/99	1820	0.4	169S	V	0	E	69	0	Same habitat as 4/6
79	4/12/99	1636	0.3	161S	R	0	E	65	90	Same habitat as 4/6
80	4/13/99	1833	0.3	217SW	R	0	E	67	0	Same habitat as 4/6
81	4/14/99	1642	~0	-	R	0	E	80	1	Same habitat as 4/6
82	4/15/99	1735	0.4	78E	R	0	E	79	80;hi clouds	Same habitat as 4/6
83	4/16/99	1726	0.4	13N	R	0	E	76	60;hi clouds	Same habitat as 4/6
84	4/17/99	1637	0.7	263W	R	0	E	62	100;hi fog	Same habitat as 4/6
85	4/18/99	1616	0.8	87E	R	0	E	59	100;hi fog	Same habitat as 4/6
86	4/19/99	1539	0.3	169S	R	0	E	72	90;hi clouds	Same habitat as 4/6
87	4/20/99	1518	0.4	303NW	R	0	E	75	50	Same habitat as 4/6
88	4/21/99	1613	1.1	290W	R	0	E	66	99	Same habitat as 4/6
89	4/22/99	1610	0.9	111E	R	0	E	67	20;very windy	Same habitat as 4/6
	5/4/99	-	-	-	-	-	-	-	-	Found transmitter sans chain, connector and frog, in app. same place as 4/6

ADDITIONAL NOTES: Very red dorsum

*First location: app. 7m 4°N from SE corner of house

Appendix 1c. Data sheet for Frog 3.

ID#: TRANSMITTER#: 321 RADIO FREQ.: 9.489
SEX: F SVL(mm): 72 WEIGHT(gm): 38.4 GRAVID: no #BELT BEADS: 16

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
90	3/21/99	1843			V	3	T	50	<50	On top of Himalayan berry vines at lower end of thicket
91	3/22/99	1645	2.6	85E	R	3	T	49	>50	Down in berry thicket at upper end
92	3/23/99	1555	0.7	316NW	R	3	T	50	100	Down in berry thicket at upper end
93	3/24/99	1545	0.7	243W	R	3	T	48	100;rain	In middle of thicket
94	3/25/99	1603	0.6	216SW	R	3	T	56	100	At lower (?) end of berry thicket
95	3/26/99	1546	1.0	80E	R	3	T	50	<50	In middle of thicket
96	3/27/99	1808	0.9	3N	R	3	T	57	<50	In middle (?) of thicket
97	3/28/99	1713	0.8	218SW	R	3	T	56	>50	In middle of thicket
98	3/29/99	1555	2.1	231SW	R	3	T	56	>50	In berry thicket--lower end
99	3/30/99	1635	0.2	77E	R	3	T	43	100	In berry thicket--lower end
100	3/31/99	1525	0.2	216SW	R	3	T	52	100;rain	In berry thicket--lower end
101	4/1/99	1427	0.5	310NW	V	3	T	64	<50	In berry thicket--lower end;sitting on top of veg. (getting rays?!)--warm
102	4/2/99	1515	0.2	213SW	V	3	T	65	<50	In berry thicket--lower end;sitting on top of veg. (getting rays?!)--warm
103	4/3/99	1625	1.3	237SW	R	3	T	54	<50;very windy	In berry thicket,a little downslope on other side of lower trail
104	4/4/99	1535	0.5	19N	R	3	T	55	100	At app. same location as 4/3
105	4/5/99	1528	0.7	253W	R	3	T	58	<50	At app. same location as 4/4--a little down further?
106	4/6/99	1824	0.4	49NE	R	3	T	55	<50	At app. same location as 4/5
107	4/7/99	1818	0.7	161S	R	3	T	53	100;inter. rain	At app. same location as 4/6
108	4/8/99	1720	1.3	311NW	R	3	T	55	20	At app. same location as 4/7
109	4/9/99	1641	~1?	210SW	R	3	T	59	90	In same habitat; moving toward water?
110	4/10/99	1646	0?	-	R	3	T	49	100;rain	In same place as 4/9?
111	4/11/99	1850	1.4	121SE?	R	3	T	68	0	In same habitat
112	4/12/99	1605	0.7	92E	R	3	T	68	20	In same habitat; upslope from 4/11

Appendix 1c continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (degF)	CLOUD COVER (%)	DESCRIPTION
113	4/13/99	1849	0.5	254W	R	3	T	66	0	In same habitat; upslope from 4/11
114	4/14/99	1558	0.9	151SE	R	3	T	85	1	In same habitat; upslope from 4/11
115	4/15/99	1757	2.0	255W?	R	2	T	81	60;hi clouds	In same habitat; downslope
116	4/16/99	1745	~4?	243SW?	R	1/0?	U	76	60;hi clouds	Signal much weaker so may be in water under bank which drops off or on/under/in willow limbs/Himalayan berry thicket, at least at edge of bank
117	4/17/99	1700	0?	-	-	1/0?	U	61	100;hi fog	No signal therefore under bank?
118	4/18/99	1628	0?	-	R	1?	U	58	100;hi fog	Weak signal so must be at water's edge app. same place as 4/16
119	4/19/99	1551	0?	-	R	1/0?	U	72	100	Signal weaker again so may be in app. same place as 4/16
120	4/20/99	1638	~1.0	168S?	R	1/0?	U	74	40	Signal very weak, seems to be a little further S along bank?
121	4/21/99	1627	~6.3	347N?	R	0/1?	U	69	99	Signal very weak, seems to be a little further N along bank?
122	4/22/99	1627	~1.2	168S?	R	0/1?	U	67	20;windy	Signal very weak, seems to be a little further S along bank?
123	4/23/99	1510	~1.3	168S?	R	0?	U	71	1	Signal very weak, seems to be a little further S along bank?
	5/5/99	-	-	-	R	-	-	-	-	Stopped search; am certain transmitter is detached from connector--cannot find

ADDITIONAL NOTES: Brown dorsum

Appendix 1d. Data sheet for Frog 4.

ID#: TRANSMITTER#: 331a RADIO FREQ.: 9.820
SEX: M SVL(mm): 62 WEIGHT(gm): 25.6 GRAVID: no #BELT BEADS: 14

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
124	4/6/99	1848	*	*	V	1	G	55	0	In short grass right next to skunk cabbage patch
125	4/7/99	1835	0.1	221SW	V	1	G	53	100	Same as 4/6
126	4/8/99	1742	11.7	114E	V	2	F	53	20	In low herbs/grass/nettle
127	4/9/99	1714	7.3	283W	V	1	G	54	100	Sunny previously during day; in more open low grass
128	4/10/99	1649	2.1	327NW	R	0	G	49	100;rain	In low grass in wet area (seep)
129	4/11/99	1917	0.4	201SW	R	0	G	64	0	In low grass in wet area (seep)
130	4/12/99	1617	0.5	46NE	V	0	G	68	60	In low grass in wet area (seep)
131	4/13/99	1902	2.4	307NW	V	1	G	64	0	In low grass in wet area (seep)
132	4/14/99	1615	0.1	355N	V	1	G	82	1	In low grass in wet area (seep) next to skunk cabbage patch
133	4/15/99	1818	0.1	39NE	R	1	G/F	80	50;hi clouds	Right next to skunk cabbage patch in wet area
134	4/16/99	-	-	-	-	-	-	-	-	Can't get exact location--giving up in frustration
135	4/17/99	1728	20.5	300NW	R	3	F	59	99;hi fog	In coltsfoot/grass/nettles downslope
136	4/18/99	1658	13.4	95E	R	2	F	57	100	In coltsfoot,etc. & dead branches
137	4/19/99	1603	0.2	136SE	R	2	F	70	100	App. same place as 4/18
138	4/20/99	1654	0.1	355N	R	2	F	68	40	App. same place as 4/18
	4/24/99	-	-	-	-	-	-	-	-	Found transmitter sans frog at above site; frog probably eaten by raccoon

ADDITIONAL NOTES: Brown dorsum
*1st location: ~9.9m 190°S of creek

Appendix 1e. Data sheet for Frog 5.

ID#: TRANSMITTER#: 334 RADIO FREQ.: 9.928

SEX: F SVL(mm): 76 WEIGHT(gm): 46.8 GRAVID: no #BELT BEADS: 19

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
139	4/11/99	1714	*	*	V	1	F	66	0	On open patch of ground w/sparse grass & herbs near creek
140	4/12/99	1658	3.1	339NW	R	1	E/G	66	50	On other side of creek, just barely >50cm from water, in nettles, horsetail, watercress
141	4/13/99	1656	3.0	219SW	V	1	F	73	0	In tangle of "weeded" watercress
142	4/14/99	1519	3.4	101E	V	1	F	77	0	In low grass next to metal shed
143	4/15/99	1712	1.0	31NE	R	1	E	81	60;hi clouds	In sedges, next to water
144	4/16/99	1703	1.1	207SW	V	1	F	74	50;hi clouds	In low grass next to metal shed
145	4/17/99	1536	7.5	132SE	R	1	F	66	100;hi fog	In med. grass/sedges/buttercup near metal shed
146	4/18/99	1542	3.3	292W	V	1	F	60	100;hi fog	In buttercup/low grass near metal shed
147	4/19/99	1514	0.9	322NW	V	1	F	70	50;hi clouds	On bare ground but right next to metal shed under which she escaped
148	4/20/99	1555	1.1	8N	R	1	B	75	20	Under metal shed
149	4/21/99	1535	1.5	176S	V	1	F	65	99	In low grass/buttercup patch--on outer edge, visible
150	4/22/99	1536	0.7	266W	R	1	F	64	30;windy	In buttercup patch right next to metal shed
151	4/23/99	1428	0.4	92E	R	1	F	70	1	In buttercup patch near metal shed
152	4/24/99	1524	3.3	287W	V	1	B	69	99;fog	Under edge of metal shed
153	4/25/99	1710	3.4	111E	R	1	F	57	100	In buttercup patch next to shed
154	4/26/99	1453	0.4	296NW	R	1	B	74	10	Probably under metal shed
155	4/27/99	1418	2.8	287W	V	1	B	62	45	Under edge of metal shed (see 4/24)
156	4/28/99	1427	0.0	-	V	1	B	75	1;windy	Under edge of metal shed--same place as 4/27
157	4/29/99	1515	0.0	-	V	1	B	70	2;windy	Under edge of metal shed--same place as 4/27
158	4/30/99	1520	0.0	-	V	1	B	80	0	Same place as 4/29
159	5/1/99	1526	0.2 or0.3	99E	R	1	B	64	100	Under shed
160	5/2/99	-	-	-	R	1	B	51	100;rain	
161	5/3/99	1539	1.5	81E	R	1	B	57	100;rain	Under shed towards middle

Appendix 1c continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (degF)	CLOUD COVER (%)	DESCRIPTION
162	5/4/99	1645	0.3	195S?	R	1	B	66	1	Under metal shed
163	5/5/99	1820	~25.0	54NE	R	1	F	66	10	In nettles on side of hill near jct. of creek & ditch
164	5/6/99	-	-	-	-	-	-	-	100;rain	Didn't search--couldn't get signal
165	5/7/99	1720	~11.0?	~60NE	R	1	T	65	0	Up creek app. 10-12 m from rd.; think she's high up on bank
166	5/8/99	1806	~0?	-	R	1	T	60	25	App. same place?
167	5/9/99	-	-	-	-	-	-	-	-	Didn't search
168	5/10/99	1646	~1.0?	336N?	R	1	T	67	100;lt.rain	Up on N side of drainage
169	5/11/99	1749	~5.0?	8N?	R	1	T	60	100;lt.rain	Further up bank in thicket of salmonberry, currants, ferns, cucumbers, cape ivy, lot of downed old wood
170	5/12/99	1741	~7.0	200S	R	1	T	64	99	Lower down in drainage
171	5/13/99	1645	~13.4	9N	R	1	T	71	<1	Up creek--I think still in creekbed
172	5/14/99	1833	2.8	103E	R	1	T	67	<1	Location uncertain; in elderberry, ferns near creek
173	5/15/99	1840	3.5	149SE	R	1	T	65	<1	In ferns(?)
174	5/16/99	1535	1.0	212SW	R	1	T	73	60;hi clouds	In ferns(?)
175	5/17/99	-	-	-	-	-	-	-	-	
176	5/18/99	1642	~4.5	155SE	R	2	T	70	100;rain	In ferns, nettles, salmonberry, etc.; upslope
177	5/19/99	1946	~4.0	335NW	R	1	T	56	95	
178	5/20/99	1719	~18.0	5N	R	1	T	72	100	On bank?
179	5/21/99	1634	3.5	339N	R	1	T	80	60	In thicket
180	5/22/99	1710	~3.0	111E	R	1	T	78	1	In nettle, salmonberry/currant thicket
181	5/23/99	1713	~1.0	~5N	R	1	T	59	0	Essentially same place as 5/22
182	5/24/99	1626	20.8	1N	R	1	T	63	100;hi fog	Near creek
183	5/25/99	1644	8.5	32NE	R	1	T	66	100;hi fog	
184	5/26/99	1544	7.5	204SW	R	1	T	73	90;hi fog	On other side of drainage; in fern fronds? App. 1 m? upslope from water
185	5/27/99	1544	9.8	21N	R	1	T	65	0	<1 m upslope from water
186	5/28/99	1611	9.8	202S	R	1	T	62	100;hi fog	In fern
187	5/29/99	1639	4.3	182S	R	1	T	71	100;hi fog	Near creek

Appendix 1e continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (degF)	CLOUD COVER (%)	DESCRIPTION
188	5/30/99	-	-	-	-	-	-	-	-	
189	5/31/99	-	-	-	-	-	-	-	-	
190	6/1/99	1656	1.2	307NW	R	1	T	58		Essentially same place as 5/29
	6/3/99	-	-	-	-	-	-	-	-	No signal; not found

ADDITIONAL NOTES: *First location: app. 9m 343°N from NE corner of garage

Appendix 1f. Data sheet for Frog 6.

ID#: TRANSMITTER#: 327 RADIO FREQ.: 9.721
SEX: F SVL(mm): 68 WEIGHT(gm): 31.5 GRAVID: no #BELT BEADS: 15

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
191	4/13/99	1707	*	*	V	I	F	65	0	In pile of "weeded" watercress
192	4/14/99	1508	1.0	17N	R	I	F	77	0	In pile of "weeded" watercress
193	4/15/99	1717	1.9	136SE	V	I	F	80	60;hi clouds	Next to mint, buttercup
194	4/16/99	1706	0.2	32NE	V	1	F	74	50;hi clouds	In mint & buttercup
195	4/17/99	1544	12.6	252W	V	1	F	66	100;hi fog	On patch of ground next to herbs on bank of small creek next to garage
196	4/18/99	1558	3.3	103E	R	1	F	60	100;hi fog	In rushes, foxglove, nettles, etc., mix
197	4/19/99	1522	4.2	333N	V	1	F	70	50;hi clouds	In foxglove, horsetail
198	4/20/99	1602	3.7	164S	V	I	F	75	30	In small patch of mixed herbs next to creek
199	4/21/99	1555	12.3	196S	R	I	F	65	99	In med. tall grass & mint on bridge, right next to rd.
200	4/22/99	1555	4.9	222SW	R	I	F	64	30;windy	In mint, cape ivy, etc., below culvert
201	4/23/99	1438	3.2	353N	R	1	F	70	1	Upslope in nettle patch
202	4/24/99	1539	3.9	164S	R	1	F	69	100;fog	In mint, cape ivy, etc., below culvert
203	4/25/99	1732	1.8	232SW	R	1	F	58	100	In mint, ferns, cape ivy
204	4/26/99	1503	1.1	212SW	R	1	F	74	1	In mint, blackberry
205	4/27/99	1426	0.5	214SW	V	1	F	62	60	In mint, cape ivy, etc., below culvert
206	4/28/99	1441	0.0	-	V	I	F	75	1;windy	Same place as 4/27
207	4/29/99	1521	0.0	-	V	I	F	70	10;windy	Same place as 4/27
208	4/30/99	1527	2.5	161S	R	I	?	80	0	
209	5/1/99	1536	1.0	28NE	R	1	F	64	100	In creek bed in cape ivy, ferns, mint
210	5/2/99	-	-	-	-	-	-	51	100;rain	Didn't search
211	5/3/99	1546	0.3	39NE	R	I	F	57	100;rain	In creek bed in cape ivy, ferns, mint
212	5/4/99	1715	0.7	218SW	R	I	T	66	0	In creek bed in cape ivy, ferns, mint thicket
213	5/5/99	1513	0.6	88E	R	I	T	66	1	In creek bed in cape ivy, ferns, mint thicket
214	5/6/99	1515	0.3	283W	R	I	T	62	100;rain	Essentially same place as 5/5

Appendix 1f continued.

LOCATION NO	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
215	5/7/99	1548	0.0	-	R	1	T	71	0	Essentially same place as 5/5
216	5/8/99	1519	~0.7	147SE	R	1	T	67	25	In cape ivy thicket
217	5/9/99	-	-	-	-	-	-	-	-	Didn't search
218	5/10/99	1442	1.0	297NW	R	1	T	65	100	In cape ivy thicket
219	5/11/99	1458	0.2	113E	R	1	T	64	100;off/on rain	In app. same place as 5/10
220	5/12/99	1448	0.8	126SE	R	1	T	64	70	In app. same place as 5/10
221	5/13/99	1514	7.4	300NW	R	2	F	71	1;windy	Up on "N" slope in mint, cape ivy, etc.
222	5/14/99	1632	7.3	55NE	R	1	G/F	74	10	In grass/mint next to dirt rd. bridge
223	5/15/99	1534	5.5	176S	R	1	F	69	5;windy	Mint, elderberry, Himalayan berry on "S" slope
224	5/16/99	1608	0.5	301NW	R	1	F	75	40;hi,thin clouds	App. same place as 5/15
225	5/17/99	1741	1.3	194S	R	1	F(T)	70	100;rain	Same habitat as 5/16
226	5/18/99	1508	0.6	317NW	R	1	F(T)	70	85	Same habitat as 5/16
227	5/19/99	1758	0.7	123SE	R	1	F(T)	62	100	App. same place as 5/16
228	5/20/99	1508	4.5	220SW	R	1	T	69	85	Down again near creek in cape ivy tangle
229	5/21/99	1520	~0.6	290W	R	1	T	73	1	Same habitat as 5/16
230	5/22/99	1604	~0.8	48NE	R	1	T	84	0	Same habitat as 5/16
231	5/23/99	1500	~7.0?	185S?	R	1?	T	67	100;hi fog	Very faint signal downslope
232	5/24/99	1433	0?	?	R	1?	T	68	90;hi fog	Faint signal
	6/3/99	-	-	-	-	-	-	-	-	No signal

ADDITIONAL NOTES: Reddish brown dorsum

*First location: 10.1m 331°NW from NE corner of garage

Appendix 1g. Data sheet for Frog 7.

ID#: TRANSMITTER#: 331b RADIO FREQ.: 9.820
SEX: F SVL(mm): 79 WEIGHT(gm): 49.5 GRAVID: no #BELT BEADS: 17

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
233	4/25/99	1557	*	*	V	1	B	63	100	Under board in ditch at water's edge near house
234	4/26/99	1405	7.6	116SE	R	0	F	74	20	In buttercup, onion flowers in seep
235	4/27/99	1447	1.2	88E	R	0	F	62	30	Upslope in buttercup, nettles in seep
236	4/28/99	1421	1.9	315NW	R	0	F	75	1;windy	Upslope in buttercup, nettles, English ivy, gladiolas in seep
237	4/29/99	1509	0.0	252W?(0?)	R	0	F	70	2;windy	Essentially in same place as 4/28
238	4/30/99	1507	0.0	196S(0?)	R	0	F	80	0	Essentially in same place as 4/28
239	5/1/99	1515	9.0	333NW	R	2	"T"(F)	64	100	In low thicket of blackberry, horsetail, cape ivy, nettles, etc.
240	5/2/99	-	-	-	-	-	-	-	100;rain	No search
241	5/3/99	1524	22.0	43NE	R	1	F	57	100;rain	In ditch parallel to old hwy., on bank in med. tall grass
242	5/4/99	2030	0.3	158SE	R	1	F	56	0	In grass & few other herbs right next to ditch
243	5/5/99	1812	~1.3	333NW?	R	1	F	66	10	In grass & few other herbs right next to water in ditch at bottom of "cliff"
244	5/6/99	-	-	-	-	-	-	-	100;rain	No search--couldn't get signal
245	5/7/99	1600	1.0	219SW	R	1	F	69	0	In med. tall grass near water in ditch
246	5/8/99	1754	1.1	9N	R	1	F	59	25	In herb mix: grass, cape ivy, berry, right next to water
247	5/9/99	-	-	-	-	-	-	-	-	No search
248	5/10/99	1612	1.7	352N	R	1	F	67	100;off/on rain	In tall grass in ditch near water at jct. of ditch & creek
249	5/11/99	1743	1.7	32NE	R	1	T	60	100;lt rain	In creekbed in thicket of cape ivy, salmonberry, wild cucumbers
50	5/12/99	1736	0.5	227SW	R	1	T	64	99	In same habitat as 5/11
251	5/13/99	1626	0.5	317NW	R	1	T	72	<1	In same habitat as 5/11
252	5/14/99	1810	~4.0	67E	R	1	T	67	<1	In same habitat as 5/11
253	5/15/99	1752	6.0	266W	R	1	F	69	1	In tall grass, mustard next to ditch

Appendix 1g continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
254	5/16/99	1520	4.0	112E	R	1	F	73	90;hi thin clouds	On bank at jct. of creek & ditch in high grass, berry, ferns, etc.
255	5/17/99	-	-	-	-	-	-	-	100;rain	No search
256	5/18/99	1640	19.5	61NE	R	1	T	68	99	In creekbed --went up creek
257	5/19/99	1929	0.9	6N	R	1	T	56	100	On opposite bank
258	5/20/99	1658	~6.0	153SE	R	2	T	72	60	In nettle, salmonberry/currant thicket
259	5/21/99	1627	0.6	306NW	R	1	T	80	1	Same habitat as 5/20
260	5/22/99	1721	~12.0	~359N	R	1?	T	78	0	Up creek drainage (?)
261	5/23/99	1730	-	-	-	?	T	59	100;hi fog	No signal; went further up creek?
262	5/24/99	1631	17.0	20N	R	1?	T	63	100;hi fog	Up creek drainage
263	5/25/99	1701	~12.0	203SW	R	1	T	66	99;hi fog	High on bank in dead fern fronds/thicket
264	5/26/99	1526	0.4	125SE	V	1	T	73	0	Under same fern
265	5/27/99	1537	0.0	-	V	1	T	65	100;hi fog	Essentially in same place as 5/26
266	5/28/99	1618	2.2	347N	R	1	T	62	100;hi fog	
267	5/29/99	1647	0.8	240SW	R	1	T	71	-	Below (or in) fern on bank
	6/3/99	-	-	-	-	-	-	-	-	No signal; not found

ADDITIONAL NOTES: Dark brown dorsum with many spots

*1st location: 6.1m from closest side of house and 43°NE from closest corner of house

Appendix 1h. Data sheet for Frog 8.

ID#: TRANSMITTER#: 325>322 RADIO FREQ.: 9.620>9.511

SEX: F SVL(mm): 78 WEIGHT(gm): 46 GRAVID: no #BELT BEADS: 17

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
268	4/28/99	1545			V	3	G	69	1;windy	In med. high grass near fern, somewhat close to elderberry/willow thicket
269	4/29/99	1617	~5.0?	253W	R	3	T	72	1;windy	In willow/elderberry thicket
270	4/30/99	1557	~4.0?	142SE	R	3	G	76	10	In med. tall grass under willow next to willow/elderberry thicket
271	5/1/99	1650	2.0	323NW	V	3	G	61	100	Found frog in grass next to thicket (sans transmitter?)
272	5/2/99	-	-	-	-	3	-	-	100;rain	No search
273	5/3/99	1608	1.6	324NW	R	3	T	57	100;rain	Near upper edge and under elderberry, Himalayan berry thicket
274	5/4/99	1749	6.3	2N	V	3	G	66	1	Found frog in grass next to thicket sans transmitter, replaced with another transmitter. New wt: 47g. Found old transmitter ~5 m W from 5/3 location under thicket in many dead twigs app. 1 m from shoreline.
275	5/5/99	1703	~12.0	241SW	R	1	E	65	40	In tall grass near shore
276	5/6/99	1540	0.3	0N	R	1	E	62	100;rain	Essentially same place as 5/5
277	5/7/99	1453	3.3	110E	R	1	F	67	0;windy	In tall water parsnip & buttercup
278	5/8/99	1347	~3.0	176S	R	1	E	71	10;windy	In tall grass near shoreline
279	5/9/99	-	-	-	-	-	-	-	-	no search
280	5/10/99	1505	~1.0	259W	R	1	E	67	100	In tall grass near shoreline
281	5/11/99	1526	~1.0	91E	R	1	E/T	65	100;lt. rain	In tall grass/willow thicket near shoreline
282	5/12/99	1517	~5.5	327NW	R	1	E	67	90;windy	In tall grass, rush, water parsnip mix again near shoreline
283	5/13/99	1530	2.1	329NW	R	1	G	68	<1	In tall grass, nettles next to log
284	5/14/99	1657	3.6	99E	R	1	F	69	1	In tall grass, water parsnip, nettles
285	5/15/99	1617	1.4	320NW	R	1	F	76	0	In same habitat as 5/14
286	5/16/99	1627	5.9	247SW	R	0	E	74	40;hi thin clouds	In water in tall grass, dead stems
287	5/17/99	1803	0.8	126SE	R	0	E	65	100;rain	Same habitat as 5/16

Appendix 1h continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
288	5/18/99	1528	1.7	72E	R	1	E	74	90	In tall grass, rushes, app. 1 m from water
289	5/19/99	1856	0.0	-	R	1	E	60	100	Same as 5/18
290	5/20/99	1621	~1.0	121E	R	1	E	71	15;windy	In same habitat
291	5/21/99	1539	0.8	165S	R	1	E	73	1	
292	5/22/99	1622	2.2	93E	R	1	E	78	0	A little further on shore in same habitat
293	5/23/99	1518	1.9	246SW	R	1	E	66	100;hi fog	In mid rushes
294	5/24/99	1451	2.4	89E	R	1	E	70	99;hi fog	In same habitat--more in tall grass this time
295	5/25/99	1533	~1.5	140SE	R	1	E	77	95;hi fog	Nearer thicket
296	5/26/99	1723	~3.0	277W	R	1	E	72	<1	At 5/21 location--nearer shoreline
297	5/27/99	1632	0.0	-	R	1	E	64	99;hi fog	Same as 5/26
298	5/28/99	1706	2.4	91E	R	1	E	62	100;hi fog	Same as 5/24
299	5/29/99	1750	~15	111E	R	2	T	68	0	Downslope in dead stems, thicket
300	5/30/99	-	-	-	-	-	-	-	-	-
301	5/31/99	-	-	-	-	-	-	-	-	-
302	6/1/99	1442	~10	270W	R	1	T/E	62	100;drizzle	At edge of willow thicket & tall grass near shore
303	6/2/99	1749	~1.0	343N	R	1	E	71	1	In tall grass further from shore
304	6/3/99	1546	~1.5	184S	R	1	E	75	30	At tall grass/thicket interface--more in tall grass
305	6/4/99	1554	~1.5	327NW	R	1	E	71	100;hi fog	In tall grass
306	6/5/99	1448	0.4	123SE	R	1	E	73	65	In tall grass
307	6/6/99	1512	~2.0	165S	R	1	T/E	71	<1	At edge of thicket/tall grass near shore
308	6/7/99	1504	~1.0	~165S	R	1	T	76	15	In willow thicket near shore
309	6/8/99	1746	0?	-	R	1	T	63	<1	Same as 6/7
310	6/9/99	1541	0?	-	R	1	T	80	20;hi clouds	Same as 6/7
311	6/10/99	1625	~6.0	3N	R	1	E	80	10	Back in tall grass, water parsnip, dock, rushes
312	6/11/99	-	-	-	-	-	-	-	-	No search
313	6/12/99	-	-	-	-	-	-	-	-	No search
314	6/13/99	1908	~6.0	169S	R	1	T	67	95	
315	6/14/99	1711	~0?	-	R	1	T	70	100;hi fog	Essentially same place as 6/13

Appendix 1h continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
316	6/15/99	1611	~6.0	3N	R	I	E	68	100;drizzle	
317	6/16/99	1644	~0	-	R	I	E	74	100	In app. same place as 6/15
318	6/17/99	1556	~2.0	158S	R	I	E/T	67	100;hi fog	At interface of tall grass & thicket nearer shore
319	6/18/99	1651	~1.0	351N	R	I	E	74	99	In tall grass
320	6/19/99	1640	~0	-	R	I	E	79	30	Same place as 6/18
321	6/20/99	1811	0.0	-	R	I	E	72	99	Same place as 6/18
322	6/21/99	1745	~1.0	332NW	R	I	E	76	25	
323	6/22/99	1749	~1.0	165S	R	I	E	76	0	In tall grass
	6/24/99	-	-	-	-	-	-	-	-	Found transmitter near 6/22 location

Appendix 1i. Data sheet for Frog 9.

ID#: TRANSMITTER#: 324 RADIO FREQ.: 9.599

SEX: F SVL(mm): 84 WEIGHT(gm): 59.6 GRAVID: no #BELT BEADS: 19

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
324	5/5/99	1443	*	*	V	1	B	66	1	Under "NW" edge of metal shed near house
325	5/6/99	1508	3.0	110E	V	1	F	62	100;rain	In buttercup right next to metal shed
326	5/7/99	1542	3.0	289W	V	1	B	71	0	Under same edge of shed as on 5/5
327	5/8/99	1505	0.4	105E	R	1	B	71	65	Under metal shed, nearer middle on side of shed
328	5/9/99	-	-	-	-	-	-	-	-	No search
329	5/10/99	1426	2.5	117SE	V	1	F	65	100;inter.rain	In buttercup right next to metal shed
330	5/11/99	1448	1.6	283W	R	1	F/B	64	100;inter.rain	In mix of nettles, horsetail, grass; under board next to metal shed on bank of ditch
331	5/12/99	1439	4.1	68E	V	1	F	64	60	In mix of nettles, horsetail, cape ivy near shed
332	5/13/99	1503	0.4	239SW	R	1	F	71	1;windy	Essentially same place as last time
333	5/14/99	1622	1.0	12N	R	1	E/F	74	10	In rushes, nettles patch near shed
334	5/15/99	1513	0.0	-	R	1	E/F	69	5;windy	Same location as 5/14
335	5/16/99	1550	0.0	-	R	1	E/F	75	75;hi thin clouds	Same location as 5/15
336	5/17/99	1724	0.8	244SW	V	1	F	70	100;rain	On bare ground right next to shed
337	5/18/99	1452	2.2	185S	V	1	F	70	90	In sparse (edge of) buttercup, horsetail patch by shed
338	5/19/99	1750	0.0	-	V	1	F	62	100	Same place as 5/18
339	5/20/99	1502	0.0	-	V	1	F	69	85	Essentially same place, just a few inches into herb patch
340	5/21/99	1514	0.3	183S	R	1	F	73	1	In same buttercup patch
341	5/22/99	1557	3.1	277W	R	1	F	84	0	In grass, buttercup, nettles, etc.
342	5/23/99	1420	0.0	-	R	1	F	67	100;hi fog	Essentially same place as 5/22
343	5/24/99	1422	1.0	338N	V	1	B	68	90;hi fog	Under shed--partway out
344	5/25/99	1449	1.4	341N	V	1	F	73	100;hi fog	In buttercup, grass, nettles, etc., next to burn barrel
345	5/26/99	1639	3.5	147SE	R	1	F	76	0	In buttercup, grass, water parsnip, horsetail near ditch
346	5/27/99	1605	2.8	47NE	R	1	B	64	100;hi fog	Under shed
347	5/28/99	1640	0.8	206SW	R	1	B	59	100;hi fog	Under shed

Appendix 1i continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
348	5/29/99	1704	0.8	125SE	V	1	F	71	1	In nettles, horsetail, fern, etc., near shed
349	5/30/99	-	-	-	-	-	-	-	-	No search
350	5/31/99	-	-	-	-	-	-	-	-	No search
351	6/1/99	-	2.8	354N	R	1	E	-	100;drizzle	In sedges in creek bed behind metal shed
352	6/2/99	1708	0.6	113SE	R	1	E	67	1	Essentially same place as 6/1
353	6/3/99	1522	0.0	-	R	1	E	75	85	Essentially same place as 6/1
354	6/4/99	1557	0.6	344N	R	0	E	76	100;hi fog	Essentially same place as 6/1
355	6/5/99	1417	0.4	43NE	R	0	E	73	30	Essentially same place as 6/1
356	6/6/99	1435	0.0	-	R	0	E	73	<1	Essentially same place as 6/1
	6/20/99	-	-	-	-	-	-	-	-	Found transmitter, sans frog, in water essentially same place as 6/1

ADDITIONAL NOTES: Dark (olive) brown dorsum with many black spots
*First location: 6.8m 334°NW of NE corner of garage

Appendix 1j. Data sheet for Frog 10.

ID#: TRANSMITTER#: 330>325 RADIO FREQ.: 9.800>9.620
SEX: F SVL(mm): 69 WEIGHT(gm): 28 GRAVID: no #BELT BEADS: 15

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
357	5/11/99	1534			V	3	G	65	100;lt.rain	In tall grass several m from willow thicket
358	5/12/99	1538	~16.0	59NE	R	3	T	67	100;windy	In middle of Himalayan berry thicket
359	5/13/99	1553	?	?	R	3	T	71	0;windy	Upslope in forest (under fern fronds?); signal weak?
360	5/14/99	1746	48.0	97E(111E?)	R	3	T	69	1	In forest (under fern fronds?)
361	5/15/99	1714	8.0	12N	R	3	T	70	0	In forest under fern
362	5/16/99	1703	2.8	71E	R	3	T	73	90;hi thin clouds	In middle of fern upslope from fern of 5/15
363	5/17/99	1921	~36.0?	226SW?	V	3	T	65	100;rain	Transmitter's location is in fern lower down slope; frog found in tall grass a little upslope from thicket near lagoon*
364	5/18/99	-	-	-	-	-	-	-	-	No search
365	5/19/99	-	0.0	-	V	3	G	60	100	Rereleased at 5/17 location
366	5/20/99	1603	3.8	206SW	R	3	T	72	60	In thicket
367	5/21/99	1551	~5.7	263W	R	3	T	73	1	Lower in thicket near shore
368	5/22/99	1629	~14.0	256W	R	0	E	78	0	In tall grass in water near shore
369	5/23/99	1527	10.3	52NE	R	2	E	66	100;hi fog	In tall grass, nettles
370	5/24/99	1514	~7.0	97E	R	3	T	70	95;hi fog	In thicket
371	5/25/99	1532	~1.0	243SW	R	3	T	73	99;hi fog	Downslope
372	5/26/99	1758	~14.0	251W	R	1	E	69	0	In tall grass near shoreline
373	5/27/99	1648	~11.0	87E	R	3	T	64	99;hi fog	Back in thicket
374	5/28/99	1719	0.0	-	R	3	T	62	100;hi fog	Same as 5/27
375	5/29/99	1756	3.2	14N	R	3	T	68	0	At upper edge of thicket
376	5/30/99	-	-	-	-	-	-	-	-	No search
377	5/31/99	-	-	-	-	-	-	-	-	No search
378	6/1/99	1428	16.8	169S	R	2	T	62	100;drizzle	Near edge of thicket
379	6/2/99	1805	1.4	219SW	R	2	T	71	1	Same habitat as 6/1 (Himalayan berry, ferns, etc.) but further downslope under fern

Appendix 1j continued.

LOCATION NO	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
380	6/3/99	1601	0.9	217SW	R	2	T	78	1	Near 6/2 location--under fern, Himalayan berry
381	6/4/99	1606	~1.0	181S	R	2	T	71	100;hi fog	Downslope in thicket
382	6/5/99	1510	~1.2	355N	R	2	T	77	85;hi fog	In fern?
383	6/6/99	1459	0.9	131SE	R	2	T	73	<1	In fern in thicket
384	6/7/99	1512	~0	-	R	2	T	76	15	Essentially same place as 6/6
385	6/8/99	1754	0.0	-	R	2	T	63	0	Back at 6/6 location
386	6/9/99	1549	0.0	-	R	2	T	80	30;hi clouds	At same location as 6/8
387	6/10/99	1637	0.0	-	R	2	T	80	10	At same location as 6/8
388	6/11/99	-	-	-	-	-	-	-	-	No search
389	6/12/99	-	-	-	-	-	-	-	-	No search
390	6/13/99	1917	~0.4	351N	R	2	T	69	100;hi fog	Essentially same place as 6/10
391	6/14/99	1659	0.0	-	R	2	T	71	100;hi fog	Same location as 5/13
392	6/15/99	1602	~3.5	177S	R	2	T	68	100;drizzle	
393	6/16/99	1454	21.2	345N	V	2	G	74	100;hi fog	In tall grass near upper edge of thicket
394	6/17/99	1611	7.5	240SW	R	1	T	67	100;hi fog	In salmonberry/willow thicket, near shore
395	6/18/99	1707	0.0	-	R	1	T	74	98	Same place as 6/17
396	6/19/99	1612	9.3	171S	R	1	T	79	20	In open willow/Himalayan berry thicket with many old branches on bare ground, very near shore
397	6/20/99	1755	~3.0	101E	R	1	T	72	90;hi clouds	In open willow/Himalayan berry thicket but under ferns, further from shore
398	6/21/99	1744	0.0	-	R	1	T	76	25	Same place as 6/20
399	6/22/99	1738	14.2	174S	R	1	E	76	0	Near shoreline in young grass
400	6/23/99	1208	~77?	194S?	R	?	T?	68	10;fog	In area where willows extend out above water
401	6/24/99	1759	-	-	R	?	T?	70	100;drizzle	In about same place(?) but further "south"
402	6/25/99	1657	~63?	180S?	R	3	T	70	<1	South of 6/24
403	6/26/99	1539	0?	-'?'	R	3	T	70	0	In old willow thicket, under fern, salmonberry
404	6/27/99	1410	4.6	140SE	R	2	T	73	5	In fern
405	6/28/99	1757	0.0	-	R	2	T	70	<1	In same place as 6/27

Appendix 1j continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
406	6/29/99	1642	0.0	-	R	2	T	74	55;hi fog	In same place as 6/27
407	6/30/99	1624	0.0	-	R	2	T	74	100;hi fog	In same place as 6/27
408	7/1/99	1614	4.0	206SW	R	2	T	71	0;windy	In ferns
409	7/2/99	1648	1.4	152SE	R	2	T	67	0;windy	In ferns
410	7/3/99	1605	2.7?	78E?	R	2	T	60	3;windy	In ferns, dead branches
411	7/4/99	1129			R	2	T	65	<1;windy	Stopped search upslope--unsure of location--distant?
412	7/5/99	1550	~40.0?	147SE	V	1	T	65	95;fog	In creekbed under sparse fern, dead branches of salmonberry**

ADDITIONAL NOTES: Very light brown dorsum

*Took frog home--reweighed (42.6 g), put on new transmitter (#325, 17 beads)

**Removed transmitter and reweighed (48.1 g); some abrasion from connector

Appendix 1k. Data sheet for Frog 11.

ID#: TRANSMITTER#: 335b RADIO FREQ.: 9.947
SEX: F SVL(mm): 68 WEIGHT(gm): 33.5 GRAVID: no #BELT BEADS: 17

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
413	5/12/99	1545			V	2	G	67	85	In grass several m upslope from willow/elderberry thicket
414	5/13/99	1608	1.9	186S	R	2	G/T	71	0;windy	In grass at edge of willow/elderberry thicket
415	5/14/99	1709	2.1	316NW	R	2	G	69	1	In grass at very edge of willow/elderberry thicket
416	5/15/99	1539	2.4	341N	R	2	G/F	76	0;windy	At interface of grass & fern next to thicket
417	5/16/99	1643	3.0	302NW	R	2	G/T	73	75;hi thin clouds	At interface of grass & thicket
418	5/17/99	1817	3.3	220SW	R	1	T	65	100;rain	Downslope in Himalayan berry thicket
419	5/18/99	-	0.5	294W	R	1	T	74	90	At app. same place as 5/17; in thicket at edge of bank
420	5/19/99	1813	~5.0	55NE	R	2	T	60	100	Still in Himalayan berry thicket
421	5/20/99	1531	1.1	68NE	R	2	T	72	60	Upslope still in thicket (edge)
422	5/21/99	1555	1.3	350N	V	2	G	73	1	In grass near thicket
423	5/22/99	1639	1.4	308NW	R	2	G/T	78	0	Edge of tall grass/thicket (upper end)
424	5/23/99	1618	5.0or6.0	314NW	R	2	T	66	100;hi fog	In willow/elderberry thicket just beyond fence
425	5/24/99	1503	~5.0	29NE	R	3	T	70	95;hi fog	In thicket
426	5/25/99	1549	~1.0	69NE	R	3	T	73	95;hi fog	
427	5/26/99	1752	4.5?	159SE	R	3	T/G	69	<1	At edge of thicket
428	5/27/99	1641	0.0	-	R	3	T/G	64	99;hi fog	Essentially same location as 5/26
429	5/28/99	1714	1.1	152SE	R	2	T/G	62	100;hi fog	At edge of thicket
430	5/29/99	1803	6.5	185S	R	1	T	68	0	In dead stems, thicket near water
431	5/30/99	-	-	-	-	-	-	-	-	No search
432	5/31/99	-	-	-	-	-	-	-	-	No search
433	6/1/99	1505	5.8	1N	R	2	G/T	67	100;drizzle	In tall grass at upper edge of willow thicket
434	6/2/99	1815	0.0	-	R	2	G/T	71	1	Essentially same place as 6/1
435	6/3/99	1608	0.0	-	R	2	G/T	78	2	Essentially same place as 6/1
436	6/4/99	1617	0.0	-	R	2	G/T	71	100;hi fog	Essentially same place as 6/1
437	6/5/99	1540	5.8	183S	V	2	T	77	100;hi fog	On same fern of 5/29 at edge of embankment

Appendix 1k continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. ('F)	CLOUD COVER (%)	DESCRIPTION
438	6/6/99	1505	0.0	-	V	2	T	73	<1	On almost exact same spot on fern of 6/5
439	6/7/99	1516	0.0	-	V	2	T	76	15	Same spot!
440	6/8/99	1854	~16.0	180S?	R	0	E	63	0	Signal weak, several m from shore
441	6/9/99	1603	~5.0	156S	R	0	E	80	30;hi clouds	Signal weak--app. 2 m from shore in short grass
442	6/10/99	1647	~1.0	168S	R	0	E	80	10	Same habitat as 6/9
	6/14/99	-	-	-	-	-	-	-	-	No signal

ADDITIONAL NOTES: Dorsum light brown w/red

Appendix 11. Data sheet for Frog 12.

ID#: TRANSMITTER#: 323 RADIO FREQ.: 9.539
SEX: F SVL(mm): 71 WEIGHT(gm): 43.9 GRAVID: no #BELT BEADS: 17

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
443	6/11/99	-	*	*	V	1	B	-	-	Captured by Cathy Machado under wood pile next to "E" side of garage
444	6/12/99	-	-	-	-	-	-	-	-	
445	6/13/99	-	-	-	-	-	-	69	35	Released at 6/11 location
446	6/14/99	1735	64.3	54NE	V	1	T	68	100;hi fog	Went uphill; on dead fern fronds near creek
447	6/15/99	1525	9.1	39NE	R	1	T	71	100; drizzle	Went uphill; in/under fern
448	6/16/99	1405	6.8	17N	V	1	T	72	100; hi fog	On trail (littered w/branches, leaves, etc) so pretty much in open, although in salmonberry/currant thicket (cleared part)
449	6/17/99	1535	1.0	77E	V	1	T	68	100;lt.drizzle	Next to trail under salmonberry/fern in somewhat open thicket
450	6/18/99	1627	~1.0	58NE	R	1	T	72	99;hi fog	Under fern, salmonberry near trail
451	6/19/99	1438	0.0	-	R	1	T	79	30	Same place as 6/18
452	6/20/99	1710	0.0	-	R	1	T	68	35	Same place as 6/18
453	6/21/99	1720	0.7	142SE	R	1	T	74	25	Near 6/18 site, in same habitat
454	6/22/99	1655	3.2	12N	R	1	T	76	0	Upslope under fern fronds, nettles, salmonberry
455	6/23/99	1143	1.2	50NE	R	1	T	70	35;fog	Upslope under fern fronds, nettles, salmonberry
456	6/24/99	1826	4.3	239SW	R	1	T	63	100;rain	On bank underneath fern, salmonberry
457	6/25/99	1612	1.6	34NE	R	1	T	70	<1	On bank underneath fern?, salmonberry
458	6/26/99	1437	1.0	286W	R	1	T	71	0	In fern on opposite bank
459	6/27/99	1536	0.0	-	R	1	T	72	6	In same place as 6/26
460	6/28/99	1733	~1.0	250W	R	1	T	73	<1	In same habitat but not under fern?
461	6/29/99	1607	1.9	201S	R	1	T	75	35;hi fog	In same habitat but not under fern?
462	6/30/99	1559	~2.0	95E	R	1	T	76	100;hi fog	Back to trailside bank, in same habitat, under fern?
463	7/1/99	1539	0.0	-	R	1	T	71	1;windy	Same place as 3006
464	7/2/99	1616	4.1	185S?	R	1	T	72	0;windy	On same bank, upslope in more open stuff?

Appendix 11 continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
465	7/3/99	1448	0.0	-	R	1	T	69	3;windy	Same place as 7/2
466	7/4/99	1450	~1.3	313NW	R	1	T	65	<1;windy	In fern on opposite bank, a little higher up bank
467	7/5/99	1434	~0	-	R	1	T	65	65;fog	In fern at about same place as 7/4
468	7/6/99	1547	~2.0?	235SW	R	1	T	66	100	In dead branches, ferns; a little ways from creekbed; vegetation wet
469	7/7/99	1538	3.5	216SW	R	1	T	73	20;hi fog	In dead fern, branches, a little further away from creek bed
470	7/8/99	1528	0.0	-	R	1	T	77	75;fog coming	In fern, branches--same place as 7/7
471	7/9/99	1528	5.6	130SE	R	1	T	72	80;fog	Under fern next to trail on opposite side of creek; ~2 m from creekbed
472	7/10/99	1603	1.6	77E	V	1	T	68	100;hi fog	More in open (under open thicket); a little upslope
473	7/11/99	1527	3.2	193S	V	1	T	74	0	Under bank of dead fern fronds--nice place!
474	7/12/99	1553	~0	-	R	1	T	72	0	Essentially same place as 7/11--under large fern, a little further under fern
475	7/13/99	1645	~0	-	R	1	T	67	0	Essentially same place as 7/12
476	7/14/99	1505	~0	-	R	1	T	74	0	Essentially same place as 7/13
477	7/15/99	1309	~0	-	R	1	T	74	<1	Essentially same place as 7/14
478	7/16/99	1635	~0	-	R	1	T	72	100;hi fog	Essentially same place as 7/15; a little to N
479	7/17/99	1620	~0	-	R	1	T	76	0	Essentially same place as 7/16
480	7/18/99	1354	1.6	140SE	R	1	T	75	99;hi fog	Under same fern bank
481	7/19/99	1430	~0	-	R	1	T	68	85;hi fog	Under same fern bank; about same place as 7/18
482	7/20/99	1409	~0	-	R	1	T	68	100	Under same fern bank; about same place as 7/19
483	7/21/99	1430	~0	-	R	1	T	67	100	Essentially same place as 7/20
484	7/22/99	-	-	-	-	1	-	-	-	No search
485	7/23/99	1727	8.0	343N	R	1	T	71	35;windy	High on bank (~1 m up from creekbed); under fern, dead leaves
486	7/24/99	1606	1.5	218SW	R	1	T	65	99;drizzle	Lower on same bank---1 ft. up from creekbed, but hardly any water in creek at that point; under fern, branches of salmonberry, leaves

Appendix 11 continued.

LOCATION NO.	DATE (m/d/y)	TIME	DISTANCE (m)	BEARING	SIGHTING	DISTANCE FROM WATER	HABITAT TYPE	TEMP. (°F)	CLOUD COVER (%)	DESCRIPTION
487	7/25/99	1504	4.2	296NW	R	1	T	71	100;hi fog	Higher up on opposite bank; in duff?,fern?--more open
488	7/26/99	1605	2.3	50NE	R	1	T	66	100;hi fog	Lower on bank under fern in more open habitat
489	7/27/99	1416	2.4	102E	V	1	T	61	100;hi fog	In fern, debris on opposite bank >1 m upslope of creekbed; removed transmitter!

ADDITIONAL NOTES: Dark brown dorsum

*First location: next to E side of garage, 3.4m from NE corner of garage

Appendix 2. Data tables for Friedman test for the 9 frogs using thicket/forest and forb patch/emergent vegetation habitat types.

a) Proportion of habitat use by each frog within its minimum convex polygon (MCP).

	Proportion of Telemetry Locations		Total No.
Frog no.	Thicket/Forest	Forb Patch/Emergent Veg.	Detections
1	0.92	0.08	48
2	0.00	1.00	33
5	0.61	0.39	36
6	0.33	0.64	38
7	0.57	0.43	30
8	0.22	0.78	45
10	0.92	0.08	48
11	0.82	0.18	17
12	1.00	0.00	43

b) Proportion of habitat types available to each frog within its minimum convex polygon (MCP).

	Proportion of MCP		Total
Frog no.	Thicket/Forest	Forb Patch/Emergent Veg.	Area m^2
1	0.89	0.11	3400
2	0.42	0.58	863
5	0.65	0.35	505
6	0.38	0.62	224
7	0.73	0.27	759
8	0.72	0.28	169
10	0.88	0.12	6166
11	0.96	0.04	234
12	0.91	0.09	507

Appendix 2 (continued)

c) Difference (rank) between proportion of habitat used by and proportion available to each frog.

Frog no.	Thicket/Forest	Forb Patch/Emergent Veg.
1	0.03(2)	-0.03(1)
2	-0.42(1)	0.42(2)
5	-0.04(1)	0.04(2)
6	-0.05(1)	0.02(2)
7	-0.16(1)	0.16(2)
8	-0.5(1)	0.5(2)
10	0.04(2)	-0.04(1)
11	-0.14(1)	0.14(2)
12	0.09(2)	-0.09(1)
Sum of ranks	12	15