An Aggregation of Overwintering Leopard Frogs, *Rana pipiens*, and Common Map Turtles, *Graptemys geographica*, in Northern Vermont

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An aggregation of at least several dozen Northern Leopard Frogs was observed in November 1998 at a previously described Common Map Turtle hibernaculum in the Lamoille River, Vermont. The frogs were sometimes under the turtles and were always exposed to well-oxygenated water. We suggest that frogs that overwinter submerged require a high-PO_2 microenvironment, and that this requirement overrides other considerations, such as avoidance of predators.

Key Words: Northern Leopard Frog, *Rana pipiens*, Common Map Turtle, *Graptemys geographica*, overwintering, hibernation, aquatic respiration, Vermont.

Ranid frogs in cold temperate climates, other than the Wood Frog (*Rana sylvatica*), which is freeze-tolerant, only occasionally overwinter on land; aquatic overwintering is the rule (reviewed by Pinder et al. 1992). Overwintering in liquid water eliminates freezing and desiccation challenges that must be met during terrestrial hibernation; however, frogs must then cope with problems of gas exchange, ionic regulation, and water balance. Frogs, and probably most amphibians, are generally anoxia-intolerant, even at cold temperatures (Christiansen and Penney 1973; Pinder et al. 1992), although they can tolerate a significant hypoxia for months while submerged (Boutilier et al. 1997; Donohoe and Boutilier 1998). Laboratory studies describing anoxia intolerance of overwintering frogs have been supported by reports of anoxic winterkill of frogs (Olson 1932; Manion and Cory 1952; Bradford 1983). Anoxia intolerance would seem to rule out overwintering while buried in mud, as mud is anoxic.

Experimental and field studies thus suggest that frogs that overwinter submerged must be exposed to water with a high enough PO_2 to drive O_2 diffusion via extrapulmonary pathways at a rate great enough to prevent a lethal accumulation of anaerobic end-products. However, there are relatively few reports of the microenvironments of overwintering frogs, and most of those do not provide data on ambient PO_2.

We have been collecting Common Map Turtles (*Graptemys geographica*) by SCUBA diving at a hibernaculum in the Lamoille River, Chittenden County, in northern Vermont (Graham and Graham 1992). During an exploratory and collecting site visit on 21-23 November 1998, approximately 100 map turtles were observed resting on the bottom of the river at depths of approximately 6-8 m. The air temperature was unseasonably warm at 16°C and ice had not yet formed on the river, but previous cold spells had reduced the water temperature, which was only 2°C; dissolved O_2 was near saturation. As had been the case during previous years, the turtles were on, rather than in, the substrate, resting exposed singly or in small groups on sand, gravel, or rock ledges, in crevices between rocks, and beneath logs. At least several dozen Northern Leopard Frogs, *Rana pipiens,* were found in the same area. Unlike the turtles, no frogs were found away from cover. The frogs were most commonly wedged into rock crevices, but they were also often located under turtles, which they apparently considered to be just another rock. In one location, for example, 10-12 frogs were located in a depression under a group of 5 or 6 adult female map turtles. The turtles were quite responsive to the divers, and dispersed when divers approached within a meter or so, by walking off, or in a few cases, swimming. In contrast, the frogs, while not torpid and capable of movement, were not nearly as mobile as the turtles and were easily captured.

The site was also visited once each month in December through March, but we did not search for frogs, as the purpose of each visit was to collect three map turtles as rapidly as possible for blood sampling, and then to leave the site to take the samples to the laboratory for analysis. In addition, low visibility made chance observations of frogs unlikely; they may well have been present, but we cannot be certain.

Emery et al. (1972) also used SCUBA gear to observe overwintering *R. pipiens*. During under-ice dives in March in a pond in Ontario, Canada, they found them in pits that the frogs apparently excavated. The frogs were visible and largely exposed to the water, which was 0-2°C with a PO_2 of about 80 mmHg. These authors found that frogs become an

increasingly important part of the diet of trout during winter; thus exposure to predation risk is apparently outweighed by the requirement for a well-oxygenated overwintering site. Cunjak (1986) also observed overwintering in Ontario *R. pipiens*, but in a stream environment. The frogs were mostly located among rubble on the bottom, where water with an O_2 content that was close to air-saturation passed over their hibernaculum continuously; however the rubble was coarse enough that the frogs were better able to hide from view than in the situation reported by Emery et al. (1972). As in our observations, Cunjak (1986) also found the frogs to be relatively immobile and easily captured.

The map turtles may have fidelity to specific hibernacula. We attached sonar transmitters to 15 map turtles at the hibernaculum in the autumn of 1997, and at least seven of those returned the following autumn (it is possible that some transmitters were lost among the other turtles, so more than seven may have returned). Hibernaculum site fidelity among the Leopard Frogs is still an open question. One of us (TEG) has visited this site during seven recent winters from 1989–1998, and on at least three occasions (mostly in October and November) has observed solitary adult Leopard Frogs (a group of two on one occasion) resting on the bottom among cottonwood leaves, as well as occasional Red-spotted Newts, *Notophthalmus viridescens*, and a single Mudpuppy, *Necturus maculosus*. However, this is the first time that a concentration of frogs has been noted at this site, which suggests that hibernaculum selection by the frogs is likely more opportunistic than by the turtles. We suggest that the factor of most importance in the selection of a hibernaculum among frogs that overwinter underwater is a continuous supply of well-oxygenated water about the frogs (we found that PO_2 remains $\geq 80\%$ of saturation throughout the winter at this site, even during extended periods of ice cover), and that once such a site is located, the animals will hide themselves as well as possible within the restrictions of their O_2 requirements. A similar conclusion has been drawn by Lamoureux and Madison (1999) for Green Frogs (*Rana clamitans*), which they tracked throughout a winter in New York.

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