

THE DISTRIBUTION AND HABITAT OF THE PICKEREL FROG  
IN WISCONSIN

by  
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## ABSTRACT

The distribution, habitat and breeding behavior of the pickerel frog (Rana palustris), a Wisconsin Threatened Species, was investigated during the period May 1980 through November 1981. Pickerel frogs were identified at 61 Wisconsin locations in 19 counties; 91% of these sites were in southern or southwestern Wisconsin regions containing many spring streams. Chemical analyses of 52 water samples, collected at 38 sites where pickerel frogs were found, indicated they bred and existed in or near waters that varied widely in water quality. Water temperatures recorded at summer sites where pickerel frogs were found, although mostly cool (range: 18-21.5 C), were not significantly different from water temperatures measured at similar sites where pickerel frogs were not found.

Pickerel frogs were associated with both canopied areas and shrubby wet meadows with spring-fed streams during this study. The presence of dense vegetation in both of these areas was important for frogs inhabiting these areas. Land use practices did not influence pickerel frog occurrence with the exception of plowed fields which reduced ground cover and possibly insect biomass; only 4 of 52 sites were associated with this land use practice.

Twenty-three pickerel frogs were fitted with radio-transmitters and monitored from 15 April - 1 November 1981; data from 12 of these frogs were used to determine habitat preferences. Once they had migrated from the breeding areas pickerel frogs remained mostly sedentary and were located in or near the streams significantly more times than expected by

chance alone during both the spring and summer periods.

Pickereel frog breeding behavior was monitored at 2 sites during 1981. Breeding calls were first heard on 7 April and lasted through 1 June of 1981. Average water and air temperatures recorded while pickereel frogs were calling were 18.6 C and 14.6 C, respectively. Pickereel frog egg masses were attached to submergent vegetation in shallow, sluggish waters, and concentrated where they would receive the greatest amount of sunlight allowing for faster and longer warming and accelerated rate of development. Pickereel frog egg masses all hatched within 24 days with tadpoles metamorphosing 75 days after first hatching. Size of local breeding populations were estimated from adult pickereel frogs captured at both breeding sites. Males appeared to outnumber females at these sites, however, the higher capture of males may be attributed to their more conspicuous breeding behavior.

Pickereel frogs and leopard frogs were rarely found in the same areas, habitat separation would reduce competition for the same food source.

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TABLE OF CONTENTS

	Page
ABSTRACT.....	iii
ACKNOWLEDGEMENTS.....	v
LIST OF TABLES.....	viii
LIST OF FIGURES.....	ix
LIST OF APPENDICIES.....	x
INTRODUCTION.....	1
STUDY AREAS.....	2
METHODS.....	4
Wisconsin Pickerel Frog Distribution.....	4
Habitat Characteristics.....	6
Habitat Selection.....	8
Breeding Biology.....	11
RESULTS AND DISCUSSION.....	13
Wisconsin Pickerel Frog Distribution.....	13
Habitat Characteristics.....	18
Habitat Selection.....	33
Breeding Behavior.....	41
CONCLUSIONS.....	47
LITERATURE CITED.....	49
APPENDICIES.....	53

LIST OF TABLES

	Page
Table 1. Verified locations of pickerel frogs in Wisconsin, summers of 1980 and 1981.....	15
Table 2. Seasonal ranges of water quality at active Wisconsin pickerel frog sites.....	19
Table 3. Ranges of water quality at 4 sites where pickerel frogs were absent during the summer of 1980.....	22
Table 4. Water temperature summary from active Wisconsin pickerel frog sites, May 1980 through March 1982.....	24
Table 5. List of Wisconsin pickerel frog sites where the vegetation was measured by releve method.....	26
Table 6. List of plant species present at 11 Wisconsin pickerel frog sites measured using the releve method.....	27
Table 7. Characteristic species of wooded and open sites, based on plant fidelity and constancy, at 11 Wisconsin pickerel frog sites.....	29
Table 8. Current land use patterns observed at 52 Wisconsin pickerel frog sites.....	32
Table 9. Observed weight changes in radio-tagged and toe-clipped pickerel frogs, during the spring and summer of 1981.....	34
Table 10. Habitat use by radio-tagged pickerel frogs at the WFP study site.....	35
Table 11. Habitat use by radio tagged pickerel frogs at the MCR study site.....	37
Table 12. Habitat use by toe-clipped pickerel frogs at the WFP and MCR study sites.....	38
Table 13. Post migration movement patterns of 8 radio-tagged pickerel frogs during the spring and summer of 1981.....	40
Table 14. Population estimate of pickerel frogs at the Willis Forest Preserve, using mark-recapture data in a modified Schnabel formula.....	44

LIST OF FIGURES

	Page
Figure 1. Location of the Willis Forest Preserve (WFP) and Messenger Creek (MCR) study areas in Sauk County, Wisconsin.....	3
Figure 2. Procedure for radio-attachment to pickerel frogs.....	9
Figure 3. Radio-package and radio-tagged pickerel frog.....	10
Figure 4. Areas searched for pickerel frogs during the summers of 1980 and 1981.....	14
Figure 5. Distribution of 61 active pickerel frog sites in Wisconsin, during the summers of 1980 and 1981.....	17

## LIST OF APPENDICIES

	Page
Appendix A. Scientific and common names of plant species mentioned in the text.....	54
Appendix B. Pickerel frog information request form....	57
Appendix C. Wisconsin pickerel frog measurement data.....	58
Appendix D. Locations of water sample collection sites.....	65
Appendix E. Water quality data collected at 38 active, and 4 inactive, Wisconsin pickerel frog locations, May 1980 through March 1982.....	66
Appendix F. Plant species which occurred at only 1 pickerel frog site, and were not used for diferentiating plant communities.....	68

## INTRODUCTION

The pickerel frog (Rana palustris) was reported to be one of the rarest frogs in Wisconsin (Vogt 1981). It was classified as a Wisconsin Threatened Species in 1979 (Wis. Adm. Code NR 27.03). It was also reported as being rare in the Lake Michigan drainage basin (Pentecost and Vogt 1976), and as declining in Iowa (Christiansen 1981).

Pickerel frogs prefer spring-fed, clear-water habitats (Schaaf and Smith 1970, Vogt 1981) and are especially sensitive to alterations of habitat (Knudsen 1959, Vogt 1981). Campbell (1974) stated that agricultural and recreational pressures were more threatening than urbanization to pickerel frogs in southern Ontario. Pentecost and Vogt (1976) reported that pickerel frogs were among the first herpetofauna to disappear with reduced dissolved oxygen in the water, forest cutting, urbanization, and intense agriculture or pesticide use. Vogt (1981) suggested that changes in water quality and habitat destruction were responsible for their apparent decline in Wisconsin.

No studies, to my knowledge, provide information on specific pickerel frog habitat requirements. This study was conducted in Wisconsin, from May 1980 through December 1981, to collect such information. Objectives of this study were to: (1) determine the present distribution of pickerel frogs in Wisconsin, (2) describe the components of pickerel frog habitat, (3) examine local habitat use by pickerel frogs, and (4) determine aspects of their breeding biology.

2

Scientific names of plant species conform to Gleason and Cronquist (1963) and are contained in Appendix A.

#### STUDY AREAS

Pickerel frog surveys were conducted in Wisconsin from May through September in 1980 and 1981. The surveys were restricted mainly to areas of current or previously reported pickerel frog occurrence. Pickerel frog abundance in 1980, and lack of disturbance were the criteria used to select an intensive study area for 1981. Movements, habitat selection, and breeding behavior of pickerel frogs were studied in 1981 at the Nature Conservancy's Willis Forest Preserve (WFP), 8 km southwest of Baraboo, Wisconsin, and at Messenger Creek (MCR), 5 km south of Baraboo (Fig. 1).

WFP, located in the Baraboo Hills, is an unglaciated area with gentle to steep slopes, quartzite outcroppings, and medium textured soils over precambrian quartzite bedrock (Gundlach 1980). The west branch of Otter Creek originates on the WFP and flows 20 km south to the Wisconsin River. A 4.5-ha section of mixed hardwood forest, through which Otter Creek flows, was selected for a study area. The dense forest canopy is dominated by sugar maple, red oak, basswood, and quaking aspen; the understory is dominated by speckled alder. The forest floor is uneven with rock outcrops, exposed roots, decaying logs, and areas of bare ground. Marsh marigold, jewelweed, a and skunk cabbage provide cover in the wet muck soil that often have standing water, while Pennsylvania sedge and large-leaved

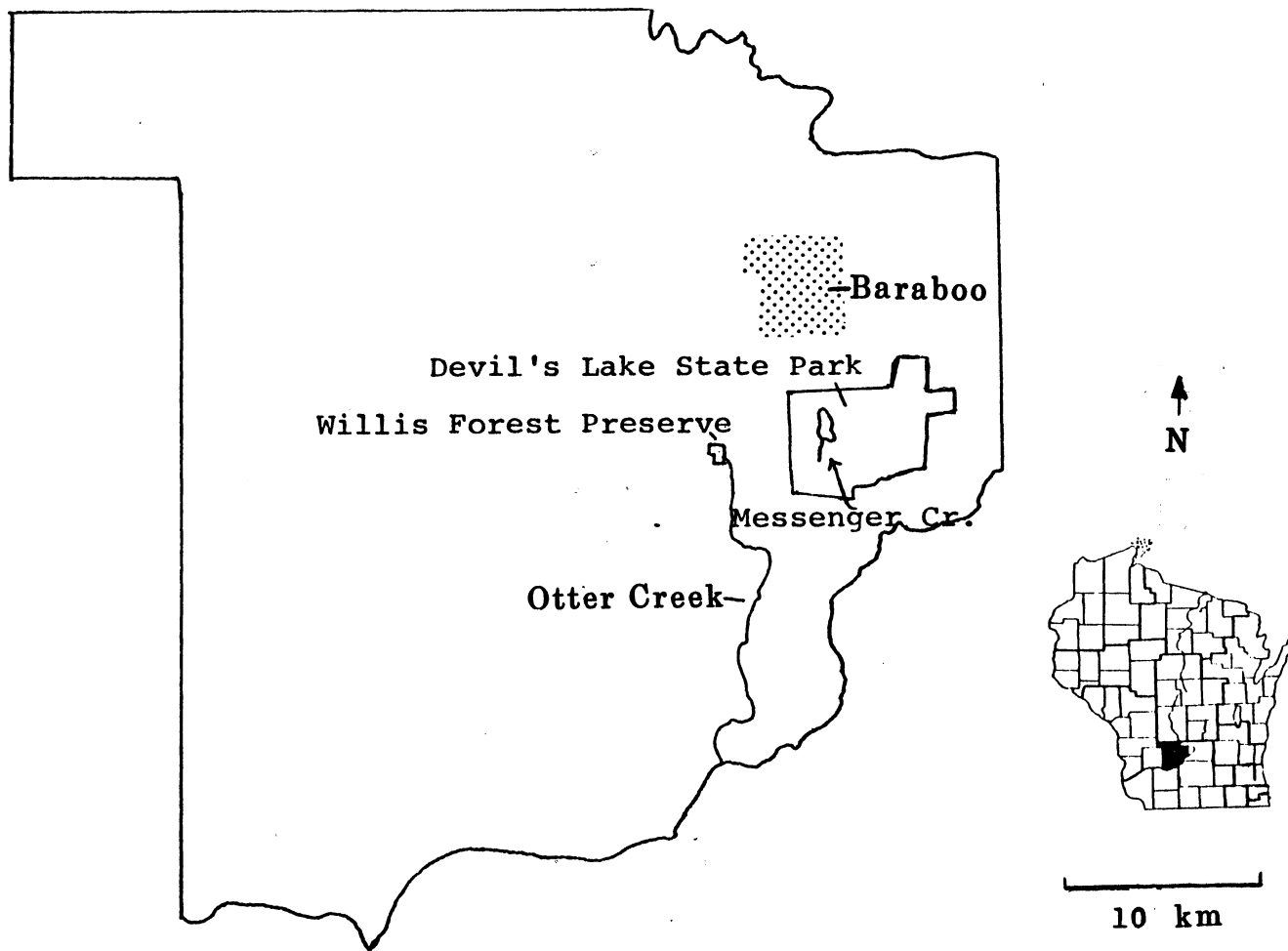


Fig. 1. Location of the Willis Forest Preserve (T11N R6E Sec. 29) and Messenger Creek (T11N R6E Sec. 23) study areas in Sauk county, Wisconsin.

aster are characteristic species on more well-drained sites. The spring-fed, high quality water of Otter Creek (Hilsenhoff 1977), with adjacent mesic forest, is "typical" pickerel frog habitat. Otter Creek supported a population of pickerel frogs from 1968 until 1975 when they were apparently absent (R. Vogt pers. commun.). A private campground was operated on this site from 1961 through 1978 (E. Mueller pers. commun.) and pickerel frogs appeared to decrease as camping increased. They were again present at WFP in 1980 when I surveyed the area.

MCR is in a valley between the south and west bluffs of Devil's Lakes State park (DLSP); area terrain is nearly level and consists of poorly drained fluvaquent soils, cambrian sandstone over quartzite, and occasional rock outcrops (Gundlach 1980). DLSP has over 1,000,000 visitors annually (Lange and Berndt 1980). The south shore road of DLSP, heavily used during May-August, crosses MCR within 200 m of Devil's Lake. A nearby parking facility makes this area popular for hiking and fishing. In spite of this disturbance, pickerel frogs were more abundant here than at any other site in 1980.

## METHODS

### Wisconsin Pickerel Frog Distribution

Historic locations and potential pickerel frog habitat were surveyed during the summers of 1980 and 1981. Historic locations were obtained from: (1) Vogt (pers. commun.),

(2) Wisconsin Department of Natural Resources (WDNR) files, (3) published records (Nelson 1915, Schmidt 1926, Pope 1930, Suzuki 1951, Dickinson 1965, 1972), and (4) museum records from the University of Wisconsin-Stevens Point Natural History Museum, University of Wisconsin-Madison Museum of Zoology, Milwaukee Public Museum, U.S. National Museum of Natural History, Chicago Field Museum of Natural History, University of Michigan Museum of Zoology, and the University of Illinois Museum of Natural History. Locations often were not specifically described; in these instances, likely aquatic habitats in the area (Schaaf and Smith 1970) were identified, from WDNR surface water resource maps and USGS quadrangle maps, and searched.

Pickerel frog presence in an area was confirmed by direct observation, capture, or by identifying calling males. Searches were conducted in areas by walking through and pushing down the vegetation within 10 m of the water's edge. Frogs were captured by hand or with dip-nets; captured frogs were measured (snout-urostyle, tibia), weighed, and marked by toe-clipping (Brekenridge and Tester 1961). Searches were made during the day and lasted from 10 minutes where frogs were obviously abundant, to 3 hours where they were scarce or absent. Spring-fed wetlands were inventoried during the breeding season (April - May) by listening for calling males on calm, warm nights (air temperatures  $\geq 10$  C).

Additional information on pickerel frog distribution was obtained from questionnaires sent to WDNR personnel and

and other interested individuals (Appendix B). Pickerel frog locations that were reported by experienced field biologists were regarded as valid and were not always searched; all other reported sites were searched.

### Habitat Characteristics

Water quality, vegetation analysis, and area land-use patterns were used to characterize Wisconsin pickerel frog habitat.

Water Quality. Grab water samples were collected at sites where pickerel frogs were active, and areas of suitable looking habitat from which pickerel frogs were absent during May 1980-March 1982. Chemical analyses of these samples were conducted by the Environmental Task Force Laboratory at the University of Wisconsin-Stevens Point. Parameters tested included: pH, conductivity, alkalinity, total hardness, calcium hardness ( $\text{Ca}^{++}$ ), dissolved oxygen (DO), 5-day biochemical oxygen demand ( $\text{BOD}_5$ ), chemical oxygen demand (COD), reactive phosphorus (P), total phosphorus, ammonia nitrogen ( $\text{NH}_4$ ), nitrite-nitrate nitrogen ( $\text{NO}_2 + \text{NO}_3$ ), kjeldahl nitrogen (TKN), chloride ( $\text{Cl}^-$ ), sulfate ( $\text{SO}_4$ ), and total suspended solids (TSS); test procedures used were according to Standard Methods 15th ed. (American Public Health Association 1980). Additional pH, conductivity, total and  $\text{Ca}^{++}$  hardness data for 4 active sites (5 samples) were provided by K. Mello, biologist at Ft. McCoy Department of the Army, Sparta, Wisconsin.

Surface water temperature data were collected at sites where pickerel frogs were active, and also at areas from which pickerel frogs were absent during 1980-1981.

Temperatures were measured with a thermometer, graduated in 1 C increments, held 6-10 cm below the water's surface for 60 seconds.

Vegetation. Vegetation analysis was conducted during June - October 1981. Species composition was inventoried at active pickerel frog sites using the relevé method (Braun-Blanquet 1932, Benninghoff 1966). A representative area at each site was chosen, and all canopy and shrub-sapling species within a 5 x 10 m quadrat, and all herbaceous species in a 2 x 5 m nested quadrat, were recorded. Percent cover and abundance were estimated for all species. Relevés were tabulated, and grouped into associations based on presence of similar species. Species similarity indices (Curtis 1959: 83) were used to compare the degree of similarity among relevés.

Vegetation density and screening efficiency at Wisconsin pickerel frog locations were measured with a Robel-pole (Robel et al. 1970). A transect was established at each site through habitat that was determined to be typical of the area; 5-10 points were randomly selected along this line for measuring the obstruction value. Obstruction readings were taken 4 m from the pole from a height of 1 m.

Land Use. Land use practices adjacent to sites where pickerel frogs were active during 1980-81 were classified as

either: (1) Undisturbed - areas that received little or no human use or alteration during the months when frogs were active, or (2) Disturbed - areas that were altered by human activities or received intensive human use during the months frogs were active. These areas were further categorized by the type of disturbance: grazed, plowed, mowed, or compacted banks and surrounding area.

### Habitat Selection

Pickerel frog movements and habitat use were monitored at the WFP and MCR sites in 1981 with radio-telemetry and recapture information from marked individuals. The transmitter package consisted of an SMI transmitter with a 1.5-v mercury battery (AVM Trinity, CA) potted in black PDS<sup>®</sup> (Plasti-Dip International, St. Paul, MN) with a protruding 6-cm whip antenna (Jansen 1982), (Fig. 3). The radio-package was attached to the backside of an 8 x 8-mm "looped" velcro strip<sup>®</sup> (Talon American, Manchester, NH); the corresponding "hooked" piece of velcro was reinforced with an elastic band of the same dimensions. The finished radio-packages and attachments weighed 2.0-3.0 g.

Pickerel frogs were immersed in a pan of 10% ethyl alcohol until lethargic; in this condition the reinforced velcro patch could be attached to their lower backs without struggle. A surgical thread was run through the patch and the frog's back, around the illium bone, back out the patch, and then tied off. This procedure was repeated on all 4 corners of the patch (Fig 2). The corresponding velcro

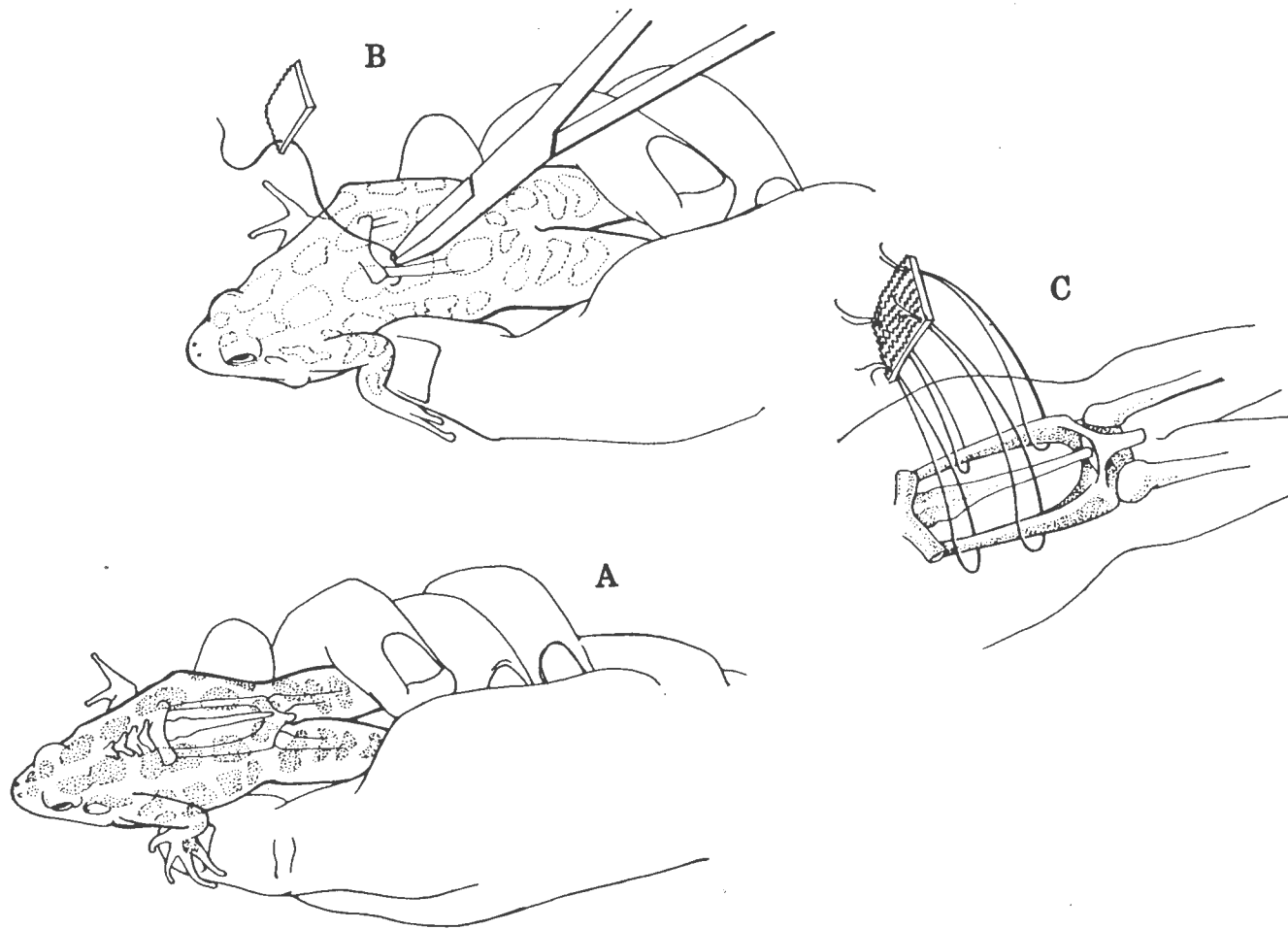


Fig. 2. Radio-transmitter attachment procedure: A) anesthetized frog is held so that pelvic bones protrude, B) surgical thread is inserted through patch, into the frog's back, around the ilium and out again, C) procedure is repeated on all 4 corners of the patch.

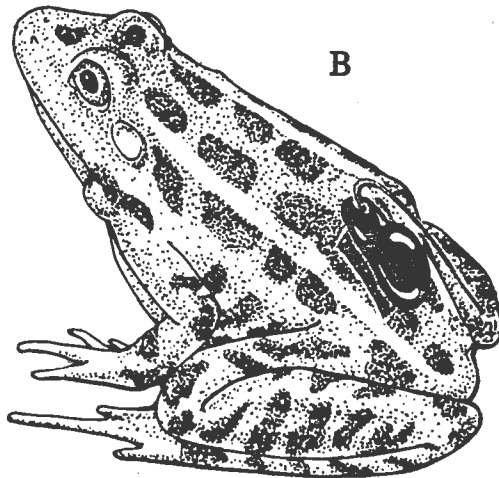
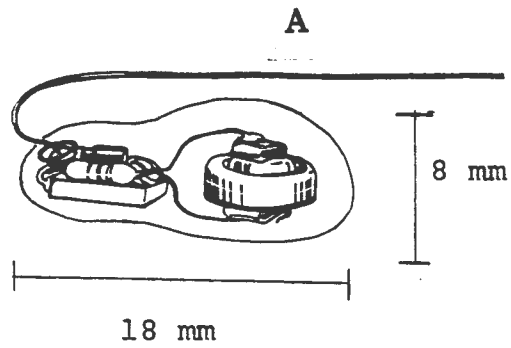


Fig. 3. A) Radio-transmitter package, and B) pickerel frog with radio-package attached.

patches, with radio-packages attached, were then pressed together and sutured at 1 corner (Fig. 3). The pickerel frogs were then placed in a shallow pan of water until they recovered; usually for 15-20 minutes. Frogs were then placed in a bucket of water for 1-4 hours, and were monitored for any sign of swimming difficulty related to the radio package; after this, they were released at their original capture site.

Battery life for the package averaged 3 weeks, at which time the frog was hand-captured and a new radio-transmitter attached; this procedure took < 5 minutes.

Radio-tagged frogs were located an average of twice daily. A 2-element hand held antenna was used to locate frogs; maximum receiving range was 400 m. Frog locations were determined to within 1 meter without disturbing the animals. Distance and direction moved from last location were measured and recorded along with habitat occupied and current climatic conditions.

The proportion of radio locations in each habitat type was compared to an equal distribution of use, using a 90% family confidence interval (Neu et al. 1974), to determine if habitat use was significantly greater or less than expected by chance alone.

### Breeding Biology

Pickerel frog breeding biology was monitored at the WFP and MCR sites during 1981. Beginning in late March, these areas were visited weekly until the onset of calling by male

pickerel frogs was detected. Thereafter, daily visits were made to determine the extent of use for breeding, to count the number of calling males, and to subsequently count egg masses. Pickerel frog egg masses were differentiated from those of breeding wood frogs (Rana sylvatica) and leopard frogs (Rana pipiens) by egg coloration (Livezey and Wright 1947). The dimensions of the egg masses were measured, their location, substrate to which they were attached, and hatching dates recorded. Air and water temperatures were recorded at breeding sites, and at locations visited where pickerel frogs were calling during 1981.

Pickerel frogs were captured by hand, measured, marked by toe-clipping, and released. Mature males were identified by the presence of a swollen and pigmented thumb pad; mature females by their size, gravid condition, and absence of thumb pad. All other frogs were classified as juveniles.

The majority of pickerel frog breeding activity at WFP occurred in a 7 x 22-m pool of standing water ( $\bar{x}$  depth = 22.8 cm) in an abandoned swimming area. Aluminum valley drift-fences, with 18.9 liter pit traps on the ends (Vogt and Hine 1982), were placed between the pool and nearby Otter Creek. Mark-recapture data from frogs that migrated between these 2 habitats were used in the modified Schnabel formula (Ricker 1975) to estimate the size of the local breeding population.

## RESULTS and DISCUSSION

### Wisconsin Pickerel Frog Distribution

Pickerel frogs occur throughout much of Wisconsin, but appear to be most abundant in the southern and southwestern counties. Searches conducted in sections of 36 counties (Fig. 4), and questionnaire responses from reliable sources identified 61 active pickerel frog sites in 19 counties from May 1980 to October 1981 (Table 1, Fig. 5). Forty-two active sites (68%) were located in the driftless area of southwestern Wisconsin, an unglaciated region characterized by deep narrow valleys with many spring streams. Another 14 sites (23%) were distributed in 6 south and southeastern counties; 4 of these sites were in the Kettle Moraine, a region containing many deep spring pools and streams. The remaining 5 sites were located in central Wisconsin, the northernmost being in Chippewa county. Vogt (WDNR files) reported only 15 active pickerel frog sites in Wisconsin during 1971-1975; 40 historic sites were inactive during this period. Vogt's survey, however, occurred when massive die-offs and reductions in leopard frog populations were reported in Wisconsin and throughout the midwest (Hine et al. 1975), and pickerel frog populations might have been undergoing similar declines (Rittschof 1975). During this study, 8 sites reported as being active in central and northern Wisconsin could not be located from the scarce information provided. Pickerel frogs were found in 12 townships reported to contain inactive

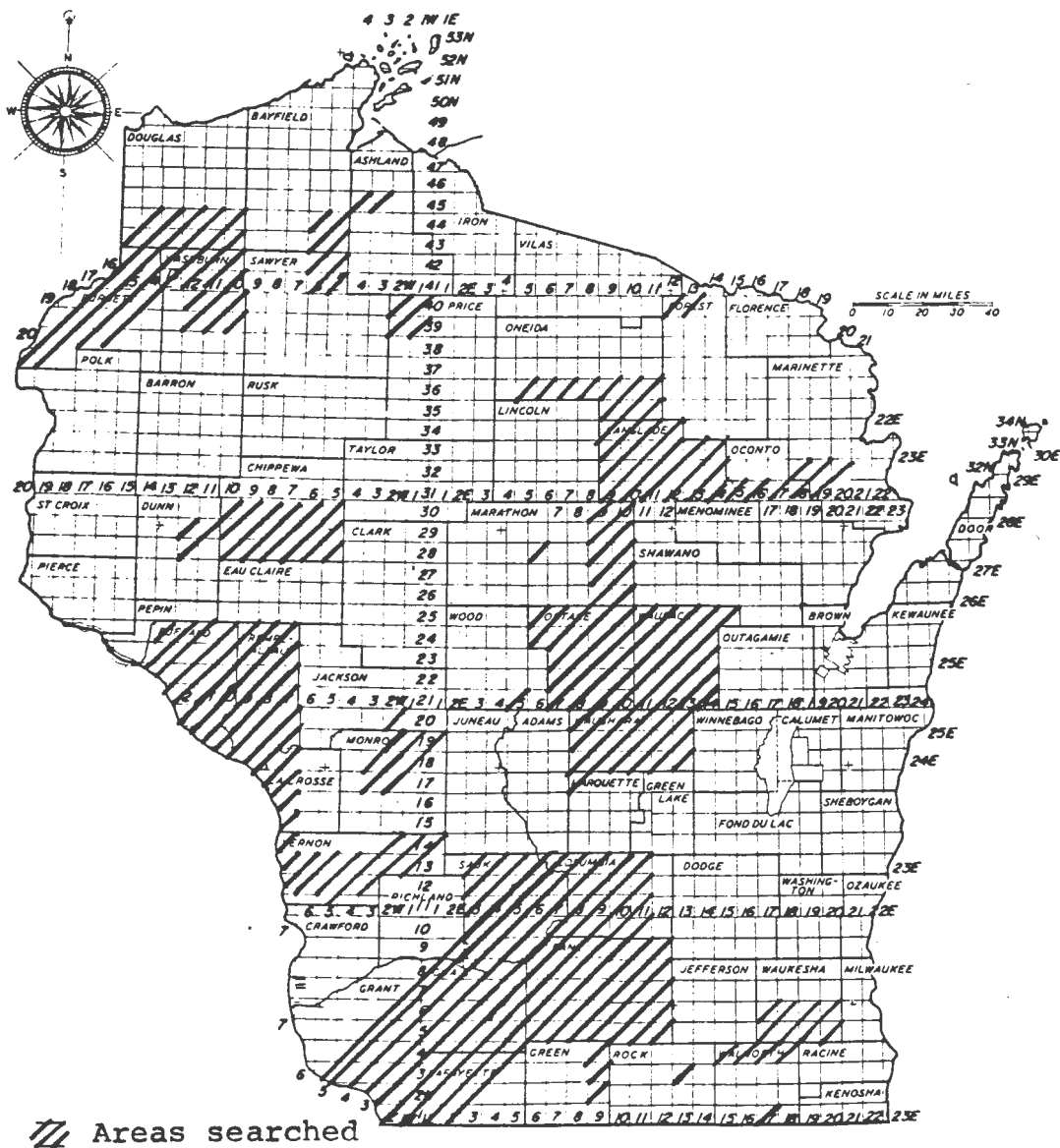


Fig. 4. Areas searched for pickerel frogs during the summers of 1980 and 1981.

Table 1. Verified locations of pickerel frogs (Rana palustris) in Wisconsin, summers of 1980 and 1981.

	Township	Range	Sec.	1/4 sec	1/4 1/4 sec
<u>Buffalo Co.</u>					
Eagle Creek	20N	11W	15	NE	SW
Hadley Creek	23N	11W	14	NW	NW
So. Branch Elk Creek	23N	10W	22	NE	SE
<u>Chippewa Co.</u>					
Jim Falls	30N	7W	30	SE	NW
<u>Columbia Co.</u>					
Rowan Creek	11N	9E	33	NE	SW
Spring Creek	10N	8E	21	NE	SW
Durwards Glen	11N	8E	18		
<u>Dane Co.</u>					
Dunlap Creek	9N	6E	33	NW	SE
9-Springs Creek	6N	9E	10	NE	NE
Wingra Springs	7N	9E	28	SW	
W. Branch Sugar River	6N	6E	24	SW	NW
<u>Grant Co.</u>					
Unnamed Creek	5N	3W	3	SW	NW
Rogers Brook	5N	3W	22	SW	SE
<u>Green Co.</u>					
Sylvester Creek	2N	9E	34	NW	SE
Cadiz Springs	1N	11E	27	SE	
<u>Iowa Co.</u>					
Sawle Creek	8N	5E	11	SE	SE
Harass's Pond	7N	3E	5	SE	NE
Ainsbrook Creek	7N	3E	13	SW	NE
Duesler's Creek	7N	5E	20	SW	NE
Arneson Creek	7N	5E	31	NE	SW
<u>Jackson Co.</u>					
Pigeon Creek Flowage	20N	2W	16		
<u>LaFayette Co.</u>					
Mounds Brook	4N	1E	19	NE	NE
Mud Brook	3N	5E	20	NE	NE
Otter Creek	3N	3E	11	SW	SW
<u>Marquette Co.</u>					
Lawrence Creek Sci. Area	17N	8E	31	S $\frac{1}{2}$	E $\frac{1}{2}$
Summerton Bay Sci. Area	15N	8E	26	SE	SW
<u>Monroe Co.</u>					
E. Branch Silver Creek and Silver Lake	17N	13W	13,14, and 15		
Tarr Creek	18N	3W	25	NW	N
Squaw Creek	18N	2W	5	SW	SW
Lemonwell Creek	17N	1W	8	NW	NE
Alderwood lake	19N	2W	30	SE	SE
Hazel Dell Lake	19N	2W	30	SW	S

Table 1. Continued.

	Township	Range	Sec.	1/4 sec	1/4 1/4 sec
<u>Portage Co.</u>					
Fountain Lake/Emmons Creek	21N	10E	11	SE	NE
Love Creek	23N	7E	26	NW	NW
<u>Richland Co.</u>					
Hawkins Creek	12N	2E	31	SE	
Unnamed Creek	11N	1W	3	SE	
<u>Rock Co.</u>					
Coon Creek	1N	11E	27	SE	
<u>Sauk Co.</u>					
Otter Creek	11N	6E	29	SE	
			32	NE	
			33	SW	
Messenger Creek	11N	6E	24	SW	
			25	NE	
N. Branch Honey Creek	10N	4E	2	SW	W
			11	E	
Leland Millpond	10N	5E	19	NW	NW
Bluff Rd. Trout Pond	10N	5E	7	SW	W
P F Farm Pond	10N	4E	12	SW	SE
Bluffview Court Pond	10N	6E	10	NW	NE
Griegels Gulch	11N	7E	17		
Parfrey's Glen Creek	11N	7E	21	SE	N
<u>Trempealeau Co.</u>					
French Creek	20N	8W	14	SW	SW
" "	19N	8W	16	SE	SE
Tamarack Creek	19N	9W	3	NE	NW
Plum Creek	21N	8W	8	NE	S
" "	22N	9W	36	SW	SW
Trempealeau Natl. Wildl. Ref.	18N	10W	36	NW	NE
<u>Vernon Co.</u>					
Hunder Coulee	14N	7W	36	NE	NE
N. Fork Bad Axe River	13N	6W	20	NE	SE
S. Fork Bad Axe River	12N	6W	15	SE	W
Otter Creek	13N	3W	24	SE	NW
W. Branch Baraboo River	14N	1E	28	SE	N
<u>Walworth Co.</u>					
Lulu Lake Fen	4N	17E	3	SE	
Bluff Creek	4N	15E	24	NW	
Williams Bay Wetland Complex	1N	17E	6	NW	
<u>Waukesha Co.</u>					
Genessee Fen	6N	18E	28	SW	E
Ottawa Fen Creek	6N	17E	34	NW	NE

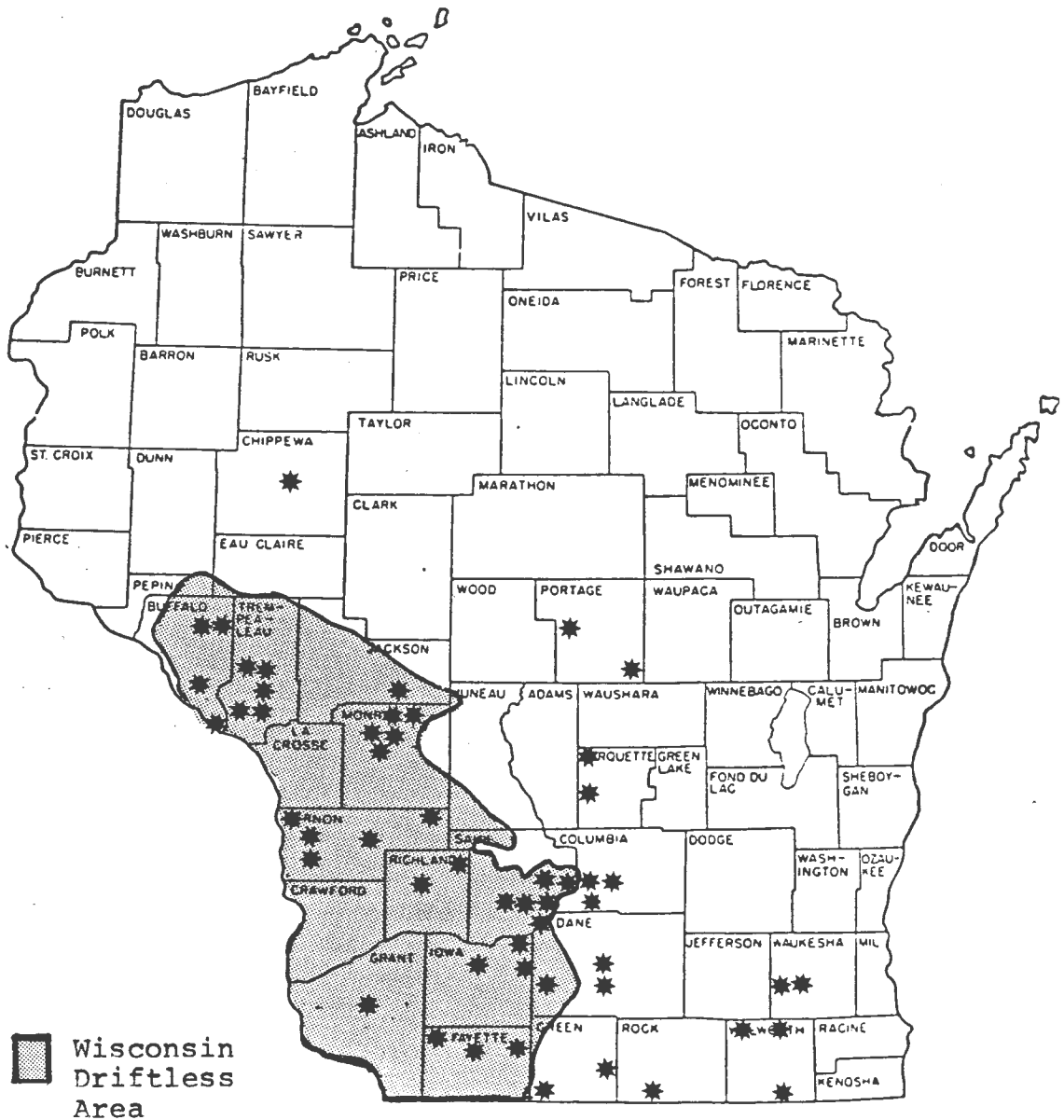


Fig. 5. Distribution of 61 active pickerel frog sites in Wisconsin during the summers of 1980 and 1981.

historic sites and in 9 additional areas that adjoined other inactive sites. Vogt (1981) reported that pickerel frogs only occur in isolated localities in Wisconsin; perhaps this is true in central and northern Wisconsin. In southern and southwestern Wisconsin however, they are more abundant and could even be considered common in some counties.

The sizes recorded for 428 Wisconsin pickerel frogs during this study (snout-urostyle range: 22-77 mm, Appendix C) were consistent with those reported for Wisconsin pickerel frogs by Vogt (1981). Frogs determined to be adult males ranged in size from 49.2-73.0 mm ( $\bar{x}$ =53.1 mm, SD=2.8, N=126), while those considered to be adult females ranged from 52.0-73.7 mm ( $\bar{x}$ =62.1 mm, SD=4.9, N=63) in size; this apparent sex dimorphism in size has also been reported by Wright (1914), Walker (1946) and others.

#### Habitat Characteristics

Water Quality. Water chemical analyses of 52 samples, collected at 38 sites where pickerel frogs were present, indicated that "high quality" water was not a prerequisite to pickerel frog existence (Appendices D and E). Water quality presumably affects various life stages of pickerel frogs differently, so water parameters were examined in relation to spring breeding sites (N=11), summer habitat (N=24), and over-wintering sites (N=3) (Table 2).

Pickerel frogs occurred in typically circum-neutral to moderately alkaline waters. The pH values for all water

Table 2. Seasonal ranges (mg/l) of water quality at active Wisconsin pickerel frog sites.

Parameter	Season					
	Breeding	N	Summer	N	Winter	N
Chemical						
pH	6.6-9.6	13	6.0-9.0	32	5.5-7.5	3
alkalinity	12-248	13	30-330	30	10-274	3
total hardness	24-224	13	10-410	34	11-326	3
calcium hardness	10-134	13	10-330	34	5.0-200	3
D.O.	8.6-10.6	3	8.2-10.2	3	6.0-8.0	3
$\bar{X}$ % O <sub>2</sub> saturation	97%	3	94%	3	61%	3
COD	7-310	13	3.0-53	29	2.5-6.5	3
BOD <sub>5</sub>	2-16	6	0.8-7.0	7	0.4-0.7	2
reactive P	.002-.04	13	.002-.275	30	.001-.05	4
total P	.03-.5	13	.01-.65	30	0.01	2
NH <sub>4</sub>	.01-.1	13	.01-.32	30	0.01-0.1	4
NO <sub>2</sub> +NO <sub>3</sub>	.01-.7	13	.05-9.2	30	0.1-2.0	4
TKN	.6-17	13	.1-2.6	30	0.1	2
Cl <sup>-</sup>	1-14	13	1-100	30	1-10	3
SO <sub>4</sub>			4-100	14		
Physical						
Cond. uhmos	55-430	13	80-1200	33	42-150	3
TSS	2-208	12	1-440	15		

samples, during all 3 seasons, were well above the 4.4 pH intolerance level reported for pickerel frogs by Gosner and Black (1957). Water pH at breeding sites also was above the acidic 5.0 level, a threshold below which significant embryonic mortality occurs in some common amphibians (Pough 1976, Karns 1981). Only 2 areas (1 summer and 1 winter site) had values below the circum-neutral pH of 6.5.

Pickerel frogs bred, remained near all summer, and over-wintered in soft ( $< 40$  mg of  $\text{CaCO}_3/\text{l}$ ), hard (40-100 mg of  $\text{CaCO}_3/\text{l}$ ), and very hard ( $> 100$  mg of  $\text{CaCO}_3/\text{l}$ ) water (Moyle 1946) (Table 2).

Wisconsin pickerel frog breeding sites and summer habitats had high DO levels, but those at winter sites were lower. DO would likely be a limiting factor during the embryonic stage only, because Rana tadpoles, even at very early stages of development were reported to "gulp" air as the water became oxygen deficient ( $< 50\%$   $\text{O}_2$  saturation) (Wasserug and Seibert 1975, Noland and Ultsch 1981). Three DO samples collected at breeding sites averaged  $97\%$   $\text{O}_2$  saturated. DO levels were also high ( $\bar{x} = 94\%$   $\text{O}_2$  saturation) at 3 summer sites; these probably reflected the increased solubility of  $\text{O}_2$  in cooler water and were not related directly to the frog's site selections. A considerable decrease in DO levels observed at 2 over-wintering sites ( $\bar{x} = 61\%$   $\text{O}_2$  saturation,  $N = 3$ ) was probably the result of poorly oxygenated ground water. Repeated use of 1 site in consecutive years suggests that lower DO levels were not affecting overwintering pickerel frogs.

Pickereel frogs were apparently unaffected by large concentrations of oxidizable material in the water. They typically bred in waters with low to moderate amounts of oxidizable material (COD range: 7-25 mg/l, BOD<sub>5</sub> range: 2-6 mg/l). However, at 1 site where a COD value of 310 mg/l and a BOD<sub>5</sub> value of 16 mg/l were recorded, a strong breeding chorus of 8-10 pickereel frogs was heard on 18 April 1981 while the water sample was being collected. Pickereel frog summer habitat also varied in range of COD from 3-52 mg/l and in BOD<sub>5</sub> from 0.87-7.0 mg/l. Pickereel frog winter sites were typically spring seeps or pools that received very little runoff and therefore had lower COD and BOD<sub>5</sub> values.

Pickereel frogs were present in both oligotrophic and eutrophic aquatic systems. Six of the 11 pickereel frog breeding sites had total P levels ( $\geq 0.1$  mg/l) sufficient to cause explosive phytoplankton growth in Wisconsin lakes year round (Lueschow et al. 1970). Reactive P and TKN also indicated moderately eutrophic conditions at breeding sites; 7 breeding sites had reactive P levels associated with excessive plant growth ( $\geq 0.01$  mg/l) (Curry and Wilson 1955, Sawyer 1947), and all 11 sites had TKN levels indicative of this condition ( $> 0.4$  mg/l) (Lueschow et al. 1970). Ranid frogs have been reported to breed more frequently in moderately eutrophic water in Netherland fens (Stribosch 1979); these areas would normally provide tadpoles with a constant food source during their developmental period.

Waters in which pickereel frogs were found during the summer and winter periods also varied in trophic condition.

Summer sites had total and reactive P, and TKN values that were similar to breeding sites (Table 2). Winter sites were the lowest in nutrient concentrations; again, this was a reflection of the specific habitat type used during winter dormancy.

Chloride levels at breeding and hibernation sites were normal for unpolluted waters, 1-14 and 1-10 mg/l, respectively. Chloride levels at summer habitat sites were mostly normal with the exception of 7 sites, where higher levels could have been attributed to runoff from roads that crossed or paralleled the site.

Pickerel frog abundance was also not related to either water conductance or TSS concentrations. Levels for both parameters were highest in the summer and lowest during the winter period (Table 2).

Analyses of water samples from 4 sites where pickerel frogs were absent, were within the ranges for all parameters observed at occupied pickerel frog sites (Table 3). Water quality was not limiting pickerel frog use of these summer areas, so their absence must have been related to some factor, or factors, other than measured water parameters.

It is also unlikely that water temperature limits pickerel frog breeding in Wisconsin. Water temperatures recorded at active pickerel frog sites during the breeding period (April-May, 1980-81) ranged from 6-22 C in streams, and from 11-29 C in ponds (Table 4). The survival of amphibian eggs is largely dependent on the ambient temperature of the water (Hassinger 1970). The embryonic temperature

Table 3. Ranges of water quality (mg/l) at 4 sites where pickerel frogs were absent during the summer 1980.

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<u>Parameter</u>	<u>Observed Value Range</u>
Chemical	
pH	7.8-8.6
alkalinity	137-277
total hardness	176-248
calcium hardness	118-176
COD	6.4-17.7
reactive P	.02-.19
total P	.045-.390
NH <sub>4</sub>	.02-.06
NO <sub>2</sub> +NO <sub>3</sub>	.20-4.4
TKN	.36-.86
Cl <sup>-</sup>	2.6-11
SO <sub>4</sub>	13.5-20
Physical	
Cond. uHmos	320-519

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Table 4. Water temperature summary from active Wisconsin pickerel frog sites, May 1980 - October 1981.

	<u>April-May</u>		<u>June</u>		<u>July</u>		<u>August</u>		<u>Sept.-Oct.</u>	
	streams	ponds	streams	ponds	streams	ponds	streams	ponds	streams	ponds
X water temperature	13.9 C	19.1 C	16.2 C	18.0 C	18.0 C	21.5 C	18.6 C		11.8 C	14.0 C
SD	3.7	4.0	3.3	1.6	3.3	4.9	6.7		1.9	
N samples	62	40	37	20	19	2	6		19	1
N sites	8	5	17	6	16	2	5		8	1

tolerance thresholds for the pickerel frog have been determined to be 7 and 30 C (Moore 1939). Amphibian species typically avoid their thermal limitations by restricting oviposition to times and sites where detrimental temperatures are unlikely to be encountered (Zweifel 1977).

Average water temperatures recorded at active pickerel frog sites during June-October 1980-81 (Table 4) indicated a preference for relatively cool waters. Cool water however, did not necessarily indicate suitable pickerel frog habitat. Water temperatures recorded during July-August 1980 at 65 streams that did not contain pickerel frogs, were similar ( $\chi^2 = 5.1$ ,  $P > 0.05$ ) to temperatures recorded at active pickerel frog sites during the same period. Other conditions at the unoccupied sites were similar to occupied pickerel frog habitat, yet none were found at these sites. This suggests that factors, other than water temperature, influence pickerel frog distribution in Wisconsin.

Water temperatures at 3 pickerel frog over wintering sites ranged from 6-8 C (Table 4). These temperatures were similar between years.

Vegetation. Pickerel frogs used a variety of habitats during the summer months as revealed by analysis of 11 active pickerel frog sites in southern Wisconsin (Tables 5 and 6, and Appendix F). Pickerel frogs were present in areas characterized by 2 different plant community structures; a canopied association, dominated by sugar maple, white oak and American elm, and an open or non-canopied association. Shrub-sapling and herbaceous species were categorized as

Table 5. Pickerel frog sites where vegetation was measured by relevé method.

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Relevé Number	Site <sup>a</sup>
1	Ottawa Fen Creek
2	Sawle Creek
3	Parfreys Glen Creek
4	Durwards Glen Creek
5	Otter Creek
6	Lulu Lake Creek
7	Dunlap Creek
8	Genesse Fen Creek
9	Bluff Creek
10	Lawrence Creek
11	Messenger Creek

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<sup>a</sup> See Table 1 for detailed description of location.

Table 6. Cover and abundance values of plant species at 11 Wisconsin pickerel frog sites, determined by relevé method.<sup>a</sup>

Canopy	Releve No.										
	1	2	3	4	5	6	7	8	9	10	11
<i>Acer saccharum</i>	5.4	.	3.1	2.1	2.1	.	.	.	.	.	.
<i>Quercus alba</i>	2.4	2.1	3.1	.	2.1	.	.	.	.	.	.
<i>Ulmus americana</i>	2.4	.	r.1	r.1	.	.	.	.	.	.	.
<i>Acer rubrum</i>	.	2.1	.	.	2.1	.	.	.	.	.	.
<i>Carya ovata</i>	.	.	2.1	.	2.1	.	.	.	.	.	.
<b>Shrub-sapling</b>											
<i>Cornus stolonifera</i>	3.4	3.2	.	.	.	1.1	.	.	1.2	2.2	.
<i>Salix</i> spp.	2.3	.	.	.	.	1.1	1.1	1.1	1.2	.	+2
<i>Alnus rugosa</i>	.	5.4	.	.	3.4	.	.	.	.	2.2	.
<i>Rubus</i> spp.	.	.	.	.	.	.	.	1.1	.	+2	.
<i>Rhamnus catharticus</i>	.	.	4.2	.	.	.	.	.	+2	2.2	.
<i>Corylus americana</i>	.	.	.	.	2.3	.	.	.	+1	.	.
<b>Herbaceous</b>											
<i>Phalaris arundinacea</i>	5.4	5.3	.	4.2	+2	.	5.5	5.2	.	5.4	3.3
<i>Solanum dulcamara</i>	+1	.	.	2.1	.	+2	.	+1	.	.	.
<i>Impatiens biflora</i>	5.2	3.2	5.4	5.2	2.3	1.3	3.4	5.1	.	3.3	2.3
<i>Urtica dioica</i>	+1	2.1	.	5.1	1.3	.	.	+1	.	.	2.5
<i>Lapotea canadensis</i>	1.2	2.1	3.1	5.1	.	+1	.	.	.	.	.
<i>Viola</i> spp.	+2	.	.	4.1	+1	.	.	.	.	.	.
<i>Pilea pumila</i>	+2	+1	.	3.1	.	.	.	.	.	.	.
<i>Aster</i> spp.	1.2	3.2	.	1.1	.	1.2	.	1.1	2.3	1.2	1.2
<i>Solidago</i> spp.	+1	.	.	.	.	1.2	3.1	.	.	2.2	.
<i>Asclepias incarnata</i>	.	.	.	.	.	+1	.	.	1.1	.	+1
<i>Solidago gigantea</i>	.	.	1.1	.	.	+2	.	.	.	.	.
<i>Eupatorium purpureum</i>	.	2.2	.	.	.	1.1	.	1.1	2.1	.	.
<i>Carex</i> spp.	.	.	.	.	1.2	5.4	3.3	.	5.4	.	.
<i>Typha latifolia</i>	.	.	.	.	.	2.2	.	.	.	.	+2
<i>Leersia oryzoides</i>	.	.	.	.	.	.	1.2	.	.	.	2.3
<i>Aster praealtus</i>	.	2.1	.	.	.	.	3.3	.	.	.	.
<i>Salix</i> spp.	.	1.2	.	.	.	.	1.3	.	1.2	.	+2
<i>Lycopus americanus</i>	.	.	.	.	.	.	1.2	.	.	.	+2
<i>Helianthus annuus</i>	.	2.1	.	.	.	.	3.2	+1	.	.	.
<i>Rubus</i> spp.	.	1.2	.	.	.	.	1.3	2.2	.	+2	.
<i>Ambrosia artemisiifolia</i>	.	1.1	.	2.1	.	.	.	.	.	.	.
<i>Vitis riparia</i>	.	+1	2.2	.	.	.	.	.	.	.	.
<i>Sonchus oleraceus</i>	.	.	.	.	.	.	2.1	1.1	.	.	.
<i>Sambucus pubens</i>	.	.	5.1	.	+1	.	.	2.2	+1	2.2	.
<i>Aster pilosus</i>	.	.	3.1	.	.	.	.	1.1	.	.	1.2
<i>Eupatorium perfoliatum</i>	.	.	.	.	.	.	.	.	1.2	.	2.1
<i>Solidago patula</i>	.	.	5.2	2.1	.	.	.	.	.	+1	.
<i>Nasturtium officinale</i>	.	.	2.3	.	.	.	.	.	.	3.4	.
<i>Cryptotaenia canadensis</i>	.	.	3.1	4.1	+1	.	.	.	.	.	.
<i>Aster macrophyllus</i>	.	.	3.1	.	1.2	.	.	.	.	.	.
<i>Desmodium</i> spp.	.	.	2.1	3.2	+1	.	.	.	.	.	.
<i>Polygonum hydropiper</i>	.	1.2	1.1	.	.	.	.	.	.	.	1.3
<i>Lysimachia nummularia</i>	.	.	.	2.2	.	.	.	.	.	.	1.3
<i>Carex vulpinoidea</i>	.	.	.	.	1.2	.	.	.	.	.	2.3
<i>Calamagrostis canadensis</i>	.	.	.	.	+1	.	.	.	.	.	1.2
<i>Fragaria virginiana</i>	.	.	.	4.2	.	.	.	.	.	.	+1
<i>Thalictrum polygamum</i>	.	.	.	3.1	1.1	.	.	.	.	.	.

- <sup>a</sup> **Cover/abundance Values**
- 5 Covering more than 3/4 of the sampled area
  - 4 Covering 1/2 to 3/4 of the sampled area
  - 3 Covering 1/4 to 1/2 of the sampled area
  - 2 With any number of individuals covering 1/20 to 1/4 of the sampled area, or very numerous individuals but covering less than 1/20 of the area
  - 1 Numerous, but covering less than 1/20 of the sampled area,
  - + Sparse and covering only a little of the sampled area
  - r Rare and covering very little of the sampled area (usually only 1 example)
- Sociability Estimates**
- 5 In large, solid stands; very dense populations
  - 4 In small colonies or larger mats; rather dense populations
  - 3 In small polsters or patches; distinct groups
  - 2 In small groups or clusters or tufts
  - 1 Growing singly
- The cover/abundance and the sociability estimate are grouped together with a period between, as 4.2. +1, etc.
- From Benninghoff (1966).

either: (1) characteristic species of the canopied sites, (2) characteristic species of the non-canopied sites, or (3) species which appeared to be ubiquitous. Species in categories 1 and 2 had a high fidelity (>60%) and constancy (occurred on 50% or more of the sites) (Table 7).

The vegetation at the canopied sites where pickerel frogs were present, was most like that described by Curtis (1959) as southern mesic, southern wet, and southern wet mesic forests. These shaded moist soil areas had a wide diversity of species and similarity indices ranged from 23.8 to 41.4% among the sites. The shrub layer of southern Wisconsin forests characteristically contain many species with low presence values (Curtis 1959). Twelve species occurred in this stratum at the canopied sites, but only red-osier dogwood and speckled alder were present at more than 1 site. Herbaceous species determined to be characteristic of this association (Table 7) included 3 that attained their maximum presence in southern mesic and wet forests; these were wood nettle, clearweed, and stinging nettle.

The species composition at the non-canopied sites where pickerel frogs were found was less homogenous than the wooded association; similarity indices ranged from 0-37.5% among these sites. The predominance of red-osier dogwood, willow, and buckthorn in the shrub-sapling stratum indicated that these areas could be classified as a shrub-carr community; however, characteristic herbaceous species were typical of both fen and sedge meadow communities (Curtis 1959).

Table 7. Characteristic species of wooded and open sites based on plant fidelity (F) and constancy (C) at 11 Wisconsin pickerel frog sites.

WOODED SITES	C	F
<u>Canopy</u>		
Acer saccharum	80	100
Quercus alba	80	100
Ulmus americana	60	100
<u>Herbaceous</u>		
Laportea canadensis	80	83
Viola spp.	60	100
Pilea pumila	60	100
Cryptotaenia canadensis	60	100
Desmodium spp.	60	100
OPEN SITES		
<u>Shrub-sapling</u>		
Salix spp.	83	80
Cornus stolonifera	50	60
<u>Herbaceous</u>		
Asclepias incarnata	50	100
Solidago spp.	50	80
Eupatoreum purpureum	50	80
Carex spp.	50	80
Salix spp.	50	80
Rubus spp.	50	80

Canopied areas and shrubby wet meadows with spring-fed streams, were equally used by pickerel frogs in this study. Vogt (1981) described Wisconsin pickerel frog habitat as densely canopied mesic forests associated with cool spring seeps and streams. Pope (1944) reported spring streams associated with wet meadows of abundant rank grass to be the most typical pickerel frog habitat in northern Illinois and southeastern Wisconsin. Schaaf and Smith (1970) reported northern populations of pickerel frogs occupied a variety of habitats if the water was cool and clear. The use of varied habitats appeared to be true for Wisconsin pickerel frog populations however, water quality data previously examined did not support the "cool and clear water" prerequisite of Schaaf and Smith (1970).

Pope (1944) reported on the occurrence of abundant thick grasses at pickerel frog sites. Pickerel frogs in this study were also present in dense vegetation. The vegetation density measured at 19 active pickerel frog sites during July-October 1981, ranged from 0-9.0 decimeters ( $\bar{x}$  = 3.2, n = 148) obstruction on a Robel pole. Pickerel frogs at 1 site were all within 2 m of a stream; the average vegetative obstruction on a Robel pole was 2.5 (n = 5) along this stream. Frogs were not present 5 m away from the stream where cattle grazing had significantly reduced the grass cover ( $\bar{x}$  Robel obstruction = 0.6, n = 5; t = 3.7, P < 0.05). Merrell (1977) reported that leopard frogs were often found in clumps of taller grass in closely grazed pastures.

The edge situation allowed the frogs to feed on the higher insect biomass associated with grazed areas and still have sufficient escape cover.

Land Use. Adjacent land use practices at 52 active pickerel frog sites did not influence pickerel frog occurrence (Table 8). Pickerel frogs were found only in 15 (29%) undisturbed areas of the 52 active sites. Wisconsin pickerel frog sites were most often in rural areas and land use disturbances were typically those associated with this life style. Livestock grazing, primarily cattle, accounted for the largest percentage of disturbance at frog sites; 16 pickerel frog locations were in pastures. Merrell (1977) reported pastures and hay meadows were important summer habitats for leopard frogs in Minnesota, possibly due to the higher insect populations associated with these areas (Tester and Marshall 1961). Cooke (1975) reported that 34% of the breeding sites used by Rana temporaria in Britain, from 1950-70, were on agricultural lands. Wisconsin pickerel frog sites however, were associated with croplands at only 4 sites; inadequate ground cover and pesticide use which decreases insect biomass, may have been reasons for this.

Wisconsin pickerel frog locations often received high human usage with 27 of the sites being within recreational or rural residential areas. Cold-water fish hatcheries, which had what appeared to be ideal pickerel frog habitat, did not have many pickerel frogs; only 2 active pickerel frog sites were located on these type of areas. The mowed grass adjacent to the streams at most hatcheries, probably limited

Table 8. Current land use patterns observed at 52 Wisconsin pickerel frog sites, 1980-81.

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<u>Land-use</u>	<u>Percentage of pickerel frog sites</u>
Undisturbed	29
Grazed	31
Plowed	8
Human compaction, mowed stream banks, and buildings	32

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cover for frogs, and predation by fish may have eliminated pickerel frog populations from most of these areas.

### Habitat Selection

Twenty-three pickerel frogs (8 males, 7 females, and 8 unknown sex) were captured, fitted with radio-transmitters, and monitored from 15 April - 1 November 1981; 10 at WFP study area and 13 at the MCR site. The frogs ranged in size from 51.0 - 72.0 mm snout-urostyle ( $\bar{x}$ =57.4, SD=5.4) and in weight from 14.5 - 48.0 g ( $\bar{x}$ =20.0, SD=7.6); attached radio-packages constituted 12-15% of the frogs body weight.

The radio-tagging technique had limited success. Radio packages had to be removed from 6 frogs during this study because of severe skin abrasions; 2 of these had completely healed and gained weight when recaptured at a later date. Eleven radio-tagged frogs died 2 to 70 days after release; 4 of these were apparently killed by predators. Radio contact was lost with 6 frogs; their fate is unknown. Radio-tagged frogs at WFP, however, migrated from the breeding pool in the same direction and to the same habitat types as 12 marked and recaptured frogs. Habitat use information from marked and recaptured frogs, and newly captured frogs at both sites was similar to habitat use by radio-tagged frogs (Tables 10, 11, and 12). Changes in the weight of radio-tagged frogs were also similar to toe-clipped and recaptured frogs (Table 9). Data from radio-tagged pickerel frogs which were monitored for at least 14 days (N=12), were used to describe habitat preferences.

Table 9. Weight changes in radio-tagged and toe-clipped pickerel frogs during spring and summer 1981 (N in parenthesis).

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	Radio-tagged	Toe-clipped recaptures
$\bar{X}$ weight gain	1.5 g (3)	1.8 g (15)
$\bar{X}$ No. days between measurements	13.2	14.1
$\bar{X}$ weight loss	2.43 g (5)	2.09 g (10)
$\bar{X}$ No. days between measurements	19.3	21.6
No weight change; $\bar{X}$ days between measurements	18.7 (3)	12.8 (6)

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Table 10. Habitat use by radio-tagged pickerel frogs at the WFP study site (T11N R6E Sec. 32, Sauk Co. Wisconsin).

Habitat Types	SEASON	
	Spring (15 April-May)	Summer (June, July, August)
	Proportion of observed locations	Proportion of observed locations
Water	0.408 <sup>a</sup>	0.297 <sup>a</sup>
Dry soil ≤ 2-m of stream	0.219	0.459 <sup>a</sup>
Undercut banks and roots	0.165	0.108 <sup>a</sup>
Muck soils	0.150	0.072 <sup>a</sup>
Dry soil > 2-m of stream	0.057 <sup>a</sup>	0.063 <sup>a</sup>
<u>N</u> frogs	5	3
<u>N</u> locations	333	111

<sup>a</sup> Percent of radio locations in habitat type is more or less than expected by chance alone (p < .10), using a 90% family confidence interval (Neu et al. 1974).

The first 2 days after release were considered to be an adjustment period; data from this period were not included in analyses.

Pickereel frogs were mostly sedentary after migration from breeding areas (Table 13). Spring and summer movements were infrequent at both study areas with some frogs remaining in the same general location for as long as 8 days. This observed reduction in movements did not appear to be unique to radio-tagged frogs, Martof (1953) and Dole (1965) reported similar movement patterns in green frogs (Rana clamitans) and leopard frogs in Michigan after their breeding periods. Fall movements were associated with frogs returning to their hibernacula.

Spring. WFP. Radio-tagged pickereel frogs at this site used water, or land that was within 2 m of it, more than any other habitat type (Table 10). Undercut banks, root tangles, and pieces of tree bark were also present within 2 m of the stream and seem to be important as retreats. Frogs were under rocks or stick piles in 77% of the in-stream locations. Dry soil sites farther than 2 m from the stream were rarely used.

MCR. Radio-tagged pickereel frogs at MCR used only the stream or land within 2 m of the stream (Table 11).

Summer. WFP. The summer habitat used by radio-tagged pickereel frogs at the WFP was similar to that of spring. Pickereel frogs were again in Otter Creek, or within 2 m of it, more times than expected (Table 10), and were under rocks or

Table 11. Habitat use by radio-tagged pickerel frogs at the MCR study site (T11N R6E Sec. 23, Sauk Co. Wisconsin).

Habitat Types	SEASON		
	Spring (May)	Summer (June, July, August)	Fall (Sept.-Oct.)
	Proportion of observed locations	Proportion of observed locations	Proportion of observed locations
Water	0.227	0.085 <sup>a</sup>	0.038 <sup>a</sup>
Dry soil ≤ 2-m of stream	0.773	0.500 <sup>a</sup>	0.642 <sup>a</sup>
Undercut banks and roots		0.368 <sup>a</sup>	0.321
Dry soil > 2-m of stream		0.047 <sup>a</sup>	
<u>N</u> frogs	1	5	2
<u>N</u> locations	22	106	53

<sup>a</sup> percent of radio locations in habitat type is more or less than expected by chance alone ( $p < .10$ ), using a 90% family confidence interval (Neu et al. 1974).

Table 12. Habitat use by toe-clipped pickerel frogs at the WFP and MCR study sites.

Habitat Types	<u>SEASON</u>		
	<u>Spring</u> (April-May)	<u>Summer</u> (June, July, August)	<u>Fall</u> (Sept.-Oct.)
	Proportion of observed locations	Proportion of observed locations	Proportion of observed locations
Water	0.171	0.429	
Dry soil < 2-m of stream		0.429	0.029
Muck soils	0.200		0.029
Dry soils > 2-m of stream		0.114	0.029
<u>N</u> frogs	11	16	3
<u>N</u> observations	13	19	3

stick piles in the creek 76% of the time. Undercut banks and root tangles appeared to be important refuges for the frogs during this period. Pickerel frogs that were more than 2 m from the stream were always found in semi-dense vegetation.

MCR. Radio-tagged frogs at MCR were in the stream, or within 2-m of it, more often than might be expected (Table 11). Pickerel frogs at MCR were found farther than 2 m away from the stream less than 5% of the time. Undercut banks and root tangles were also used at MCR during the summer period.

Pickerel frogs did not change habitat use between spring and summer periods; they were consistently found in or near the 2 streams. Pope (1944) and Vogt (1981) also reported that they remained close to water as adults. Undercut banks and roots, which were considered as a separate habitat type, were usually present along the streams or within 2 m of them.

Why pickerel frogs chose to remain close to the streams is unclear. Leopard frogs are often found far from any water during the summer (Dole 1965, Merrell 1977), and are apparently able to regain moisture lost to evaporation by absorption from wet soils and dew (Dole 1967). Amphibians vary in their ability to survive evaporative loss of body water and there is a direct correlation between this and the natural habitat a species occupies (Thorson and Svihla 1943). Pickerel frogs to my knowledge, have not yet been studied for evaporative water loss. The habitat they used in this study suggests that they cannot tolerate much of a water loss and therefore stay close to water.

Table 13. Post migratory movement patterns of 8 radio-tagged pickerel frogs during spring and summer, 1981.

No. of days radio-tagged	No. of radio-locations	$\bar{x}$ No. of movements/day	$\bar{x}$ distance moved, m
41	79	0.51	2.38
64	120	0.34	9.56
28	47	0.89	3.94
18	30	0.89	2.53
27	16	0.19	2.50
19	18	0.84	6.71
50	99	0.40	5.26
28	61	0.39	4.11

Availability of protected or secluded resting areas also appeared to be an important component of pickerel frog spring and summer habitat. Undercut banks and root tangles received considerable use by radio-tagged pickerel frogs. Martof (1953) found that green frogs in Michigan spend most of the day in these types of protected places.

Fall. WFP. Only 1 frog was radio-tagged during this period at the WFP area and it could not be followed for the 2-week minimal period. However, on 24 September 1981, during a light rainfall, it was followed 144.8 m as it moved from near its capture site to the hibernaculum at WFP; radio contact was lost the next day.

MCR. Two radio-tagged pickerel frogs continued to use only those areas within 2 m of the stream or stick piles in the stream and along the bank. Pickerel frogs at MCR used mostly dense cover within 2 m of the stream while moving upstream to overwinter. An undercut root area at MCR was used by 1 frog for 2 weeks accounting for the high number of locations in this habitat; this frog probably overwintered at this site.

### Breeding Behavior

Pickerel frog breeding calls were first heard at the WFP on 7 April, and at MCR on 24 April 1981. The earliest date previously reported for onset of pickerel frog breeding activity in Wisconsin was 10 April (Vogt 1981). Calling continued past the dates of last egg hatching at both sites,

lasting 35 days at the WFP (7 April - 12 May) and 27 at MCR (24 April - 1 June). Water temperatures, recorded while pickerel frogs were calling, ranged from 9.0-29 C ( $\bar{x}$ =18.6, N=54), air temperatures ranged from 3.0-26.5 C ( $\bar{x}$ =14.6, N=42).

Thirteen egg masses were found at the WFP in the abandoned pool; 6 were found at MCR in a shallow pocket of the stream where the current was sluggish. The egg masses at both areas were attached to dead or submerged vegetation just beneath, or at the water surface. The size of 14 egg masses ranged from 5.0-14 cm ( $\bar{x}$ =8.8 cm) by 5.0-13 cm ( $\bar{x}$ =8.1 cm); these were consistent with the range (9.0-11 cm diameter) reported for this species by Vogt (1981). Egg masses were deposited in shallow water, and were concentrated in portions of the breeding pool where they would receive the greatest amount of sunlight a factor that would allow for faster and longer warming and accelerated rate of development (Merrell 1977). Egg masses in the abandoned pool all hatched within a 24-day period (8 April-3 May). However, this temporary pool dried 21 days later, before any tadpoles metamorphosed. All egg masses at MCR hatched within an 18-day period (1 May-19 May), with tadpoles metamorphosing as early as 27 July, 75 days after the first hatch. Lengths (snout-urostyle) of 38 newly transformed individuals (tail remnants still present in some cases) captured on 3 August 1981, ranged from 22-36 mm ( $\bar{x}$ =27 mm). Wright (1914) reported a range of 19-28 mm ( $\bar{x}$ =24 mm) for 80 transforming pickerel frogs Manion and Cory (1957), however, reported a range of 31-38 mm ( $\bar{x}$ =34 mm) for 17 metamorphosing individuals in Michigan.

They suggested that this geographical variation was the result of "selective action by environmental factors". Water temperature and available food have been shown to control amphibian development and metamorphosis (Seale 1980 and Merrell 1977); I suspect that these environmental factors were responsible for the variation observed among these studies.

One-hundred-ninety pickerel frogs were captured at the WFP breeding pool during the 7 April-12 May calling period; 55 females (44 gravid), 134 males, and 1 immature. The total breeding population was estimated to be 381 frogs (95% C.I.=295-526; Table 14) as determined from mark-recapture data during the calling period. It is unlikely that this many frogs would normally breed in this small area; indeed only 13 pickerel frog egg masses were present. A 1.8-ha pond, a natural frog breeding site upstream from the pool area, had been drained in December 1980. The displaced breeders may have been attracted to the only pond available by the chorus of the few pickerel frogs which had probably bred at this site annually. The shrinking pool, high frog density, and resulting intraspecific competition may have forced frogs to seek another site rather than breed at that pool. The capture of a gravid pickerel frog at the dry pool on 26 May indicates that some frogs did not locate suitable breeding sites.

Ten pickerel frogs were captured at the MCR site during the 24 April-1 June calling period; 2 non-gravid females, 6 males, and 2 immatures. A minimum breeding population of

Table 14. Population estimate of pickerel frogs, at the Willis Forest Preserve, using mark-recapture data in a modified Schnabel formula (Ricker 1975).

Ct	um	Mt	Rt	CtMt	$\Sigma$ CtMt	$\Sigma$ Rt+1	$N = \frac{\Sigma CtMt}{\Sigma Rt+1}$
61	61						
41	36	61	5	2501	2501	5+1	416.83
48	40	97	8	4656	7157	13+1	511.21
60	30	137	30	8220	15377	43+1	349.48
8	6	167	2	1336	16713	45+1	363.33
29	18	173	11	5017	21730	56+1	381.23

Ct= No. of frogs captured during 1 trapping period.

um= No. of captured frogs that were unmarked.

Mt= No. of marked frogs released previously.

Rt= No. of captured frogs that have previously been marked (recaptures).

at least 22 frogs was determined by doubling the number of egg masses (6), and then, assuming males only breed once (Merrell 1977), a chorus of 10 frogs heard on 21 May must have represented unpaired, and uncounted males; the actual size of the population was probably larger.

Males outnumbered females at both the WFP and MCR sites during the breeding period, 2.4:1 and 3:1, respectively. Merrell (1968, 1977) suggested that sex ratios in leopard frog populations, equal at all other periods of the year, were probably equal at the breeding sites as well; he attributed their more active breeding behavior for the higher capture of males. This might explain the uneven sex ratios of captured pickerel frogs at the WFP and MCR sites.

Leopard frogs were typically absent from areas where pickerel frogs were abundant. Manion and Cory (1952) suggested that these 2 species replace each other locally according to some unknown environmental factors; larval ecology was suggested as a possibility. Sympatric tadpole species (Rana, Hyla and Acris) show a reduction in growth and survivorship as the food resource declines (Seale 1980). Separation of the breeding sites among closely related species would eliminate tadpole competition and possibly act as an isolating mechanism. Merrell (1977) reported that leopard frog populations were lower in the driftless area of Minnesota, possibly due to a lack of suitable breeding ponds. The adjoining driftless region of Wisconsin however, had abundant pickerel frog populations during this study. This suggests that separation of these 2 species is related to

breeding habitat. Water temperature appears to be a parameter which might separate the breeding sites of these 2 species. Data from this study however, has shown that areas with water temperatures similar to that of occupied pickerel frog sites do not always contain pickerel frogs. Wright (1914) reported that pickerel frogs bred in warmer water than leopard frogs, and Moore (1939) showed that pickerel frogs had a higher thermal tolerance than members of the leopard frog complex.

Differences in breeding sites and adult summer habitats between these 2 species in Wisconsin may be related to habitats they evolved from while allopatric, and not from direct competition between them. Pace (1974) stated that pickerel frogs apparently evolved in the southeastern United States, an area characterized by ravine and valley streams, and then invaded the northern regions of the U.S. after the last glaciers receded. The northern leopard frog on the other hand, evolved in the northwestern U.S., a region characterized by marshes and potholes, and invaded other regions from this direction. The abundant streams of the southeastern U.S. might have made it unnecessary for pickerel frogs to develop a system to cope with evaporative moisture loss; leopard frogs however, coming from the arid northwest, would need this ability. This might explain why pickerel frogs remain close to streams, which are permanent, while leopard frogs can forage as far as 2 miles away.

Breeding in a stream environment would pose additional disadvantages. Egg masses would be subjected to sudden

changes in current and water force along with predation by fish on all life stages. Perhaps, as a means to offset reductions in the population, pickerel frogs developed a distasteful skin secretion which they are often reported to possess (Wright 1914, Vogt 1981). This would be disadvantageous to leopard frogs occurring in the same area and could be why pickerel frogs outnumber them at sites where they are sympatric (Dunn 1935). Vogt (1981) suggested that leopard frogs at Otter Creek were mimicing the spot pattern of pickerel frogs because of this protection from predators.

Pickerel frogs were known to overwinter at 5 of the 61 Wisconsin sites. Although no detailed description of pickerel frog winter habitat has been reported, these 5 sites were similar to ones found by Sweet (pers. commun.) in Connecticut, in 1960. Typically these areas are in springs near the headwaters of a stream, with dormant frogs hiding under rocks, aquatic vegetation, or burrowed into the silty muck. Availability of these types of habitats for overwintering may limit which Wisconsin streams pickerel frogs will inhabit.

#### CONCLUSIONS

Distribution and habitat data collected during this study indicates that Wisconsin pickerel frogs prefer to breed in, and remain near stream habitats. These areas usually had spring-summer water temperatures ranging from 11-19 C; other tested parameters were also variable among

sites and did not appear to limit pickerel frogs to specific localities. Toner and St. Remy (1941) reported that pickerel frogs were a "stream" species, regardless of temperature; they reported specimens being taken from trout streams (12.8 C) as well as drainage creeks (26.7 C). Wright (1914) described the best pickerel frog breeding sites, near Ithaca, NY, as typically being associated with streams. Vegetation and adjacent land-use also does not influence pickerel frog distribution as long as sufficient cover is available. Land use practices that create small permanent ponds near streams (e.g., farm ponds, or private fish ponds) increase pickerel frog breeding sites. I do not believe that competition with leopard frogs influences pickerel frog distribution in Wisconsin.

The pickerel frog was removed from Wisconsin's Threatened Species List in November 1982. I recommend that further research be conducted to determine the role that winter habitat plays in the distribution of pickerel frogs in Wisconsin.

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**APPENDICIES**

Appendix A. Scientific and common names of plant species mentioned in the text.

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<u>Acer negundo</u>	Box elder
<u>Acer rubrum</u>	Red maple
<u>Acer saccharum</u>	Sugar maple
<u>Achillea millefolium</u>	Yarrow
<u>Agrostis alba</u>	Redtop grass
<u>Alnus rugosa</u>	Speckled alder
<u>Ambrosia artemisiifolia</u>	Ragweed
<u>Ambrosia trifida</u>	Giant ragweed
<u>Angelica atropurpurea</u>	Angelica
<u>Arisaema triphyllum</u>	Jack in the pulpit
<u>Asclepias incarnata</u>	Swamp milkweed
<u>Asclepias syriaca</u>	Common milkweed
<u>Aster laevis</u>	Smooth aster
<u>Aster macrophyllus</u>	Large-leaved aster
<u>Aster pilosus</u>	
<u>Aster praealtus</u>	Willow aster
<u>Aster spp.</u>	
<u>Betula lutea</u>	Yellow birch
<u>Bidens spp.</u>	Seed-tick sunflower
<u>Calamagrostis canadensis</u>	Blue-joint grass
<u>Caltha palustris</u>	Marsh marigold
<u>Carex pennsylvanica</u>	Pennsylvania sedge
<u>Carex spp.</u>	
<u>Carex vulpinoidea</u>	
<u>Carpinus caroliniana</u>	Musclewood
<u>Carya pallid</u>	Bitternut hickory
<u>Carya ovata</u>	Shagbark hickory
<u>Cornus stolonifera</u>	Red-osier dogwood
<u>Corylus americana</u>	American hazel
<u>Cryptotaenia canadensis</u>	Honewort
<u>Desmodium spp.</u>	Tick treefoil
<u>Elmyrus riparius</u>	Wild rye
<u>Equisetum spp.</u>	Horsetail
<u>Eupatorium perfoliatum</u>	Boneset
<u>Eupatorium purpureum</u>	Joe-pye-weed

## Appendix A. (Cont.).

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<u>Fragaria virginiana</u>	Wild strawberry
<u>Fraxinus nigra</u>	Black ash
<u>Gentian</u> spp.	gentian
<u>Glechoma hederacea</u>	Ground ivy
<u>Hamamelis virginiana</u>	Witchhazel
<u>Helianthus annuus</u>	Wild sunflower
<u>Hepatica acutiloba</u>	Sharp-lobed hepatica
<u>Hydrocotyl americana</u>	Water pennywort
<u>Impatiens biflora</u>	Jewelweed
<u>Laportea canadensis</u>	Wood nettle
<u>Leersia oryzoides</u>	Rice cut grass
<u>Lobelia inflata</u>	Indian tobacco
<u>Lobelia</u> spp.	
<u>Lycopus americanus</u>	Cut-leaf water hoarhound
<u>Lysimachia nummularia</u>	Moneywort
<u>Lythrum salicaria</u>	Purple loostrife
<u>Melilotus alba</u>	White sweet clover
<u>Mentha spicata</u>	Spearmint
<u>Miainthemum canadense</u>	Canada mayflower
<u>Mitchella repens</u>	Partidgeberry
<u>Monarda fistulosa</u>	Wild bergamont
<u>Oenothera biennis</u>	Evening primrose
<u>Osmorhiza claytoni</u>	Sweet cicely
<u>Nasturtium officinale</u>	Water cress
<u>Parthenocissus inserta</u>	Virginia creeper
<u>Phalaris arundinacea</u>	Reed canary grass
<u>Picea glauca</u>	White spruce
<u>Pilea pumila</u>	Clearweed
<u>Pinus strobus</u>	White pine
<u>Plantago major</u>	Common plantain
<u>Poa</u> spp.	Blue-grass
<u>Polygonatum biflorum</u>	Solomon seal
<u>Polygonum sagittatum</u>	Tearthumb
<u>Polygonum hydropiper</u>	Smartweed
<u>Polygonum virginianum</u>	Jumpseed
<u>Populus grandidentata</u>	Large-tooth aspen
<u>Populus tremuloides</u>	Trembling aspen

## Appendix A. (Cont.).

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<u>Potentilla fruticosa</u>	Shrubby cinquefoil
<u>Quercus alba</u>	White oak
<u>Quercus rubra</u>	Red oak
<u>Rhamnus catharticus</u>	Buckthorn
<u>Rhus radicans</u>	Poison ivy
<u>Rubus</u> spp.	Blackberries
<u>Salix</u> spp.	Willows
<u>Sambucus pubens</u>	Red-berried elder
<u>Sanguinaria canadensis</u>	Bloodroot
<u>Saponaria officinalis</u>	Bouncing bet
<u>Scirpus</u> spp.	Bulrush
<u>Silphium perfoliatum</u>	Cupplant
<u>Solanum dulcamara</u>	Nightshade
<u>Solidago flexicaulis</u>	Zig-zag goldenrod
<u>Solidago gigantea</u>	Late goldenrod
<u>Solidago patula</u>	Rough-leaved goldenrod
<u>Solidago</u> spp.	goldenrods
<u>Sonchus oleraceus</u>	Thistle
<u>Stellaria</u> spp.	White chicweed
<u>Symplocarpus foetidus</u>	Skunk cabbage
<u>Taraxacum officinale</u>	Common dandelion
<u>Thalictrum polgonum</u>	Tall meadowrue
<u>Thuja occidentalis</u>	White cedar
<u>Tilia americana</u>	Basswood
<u>Trifolium repens</u>	White clover
<u>Typha latifolia</u>	Cattail
<u>Ulmus americana</u>	American elm
<u>Ulmus rubra</u>	Slippery elm
<u>Urtica dioica</u>	Stinging nettle
<u>Verbascum thapsus</u>	Common mullein
<u>Viola</u> spp.	Violets
<u>Vitis riparia</u>	Wild grape

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Appendix B. Information request form mailed to WDNR  
personnel and other interested individuals.



university of wisconsin/stevens point • stevens point, wisconsin 54481

Greetings:

I am a graduate student at the University of Wisconsin-Stevens Point, working on a Wisconsin DNR-funded Pickerel Frog study, and would like your help.

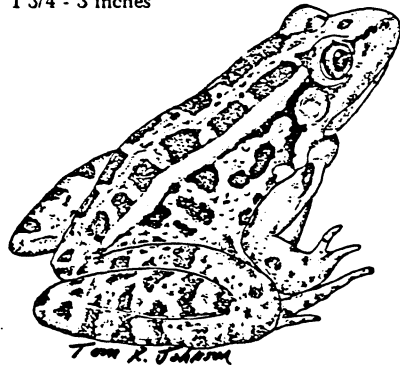
The pickerel frog, a Wisconsin Threatened species, is associated with cool, spring-fed, trout waters and the open grassy banks adjacent to them. Would you please be alert to the presence of these frogs while you are working (shocking, etc.) in trout streams, springs, spring-fed lakes, and other similar habitat? The frogs are often in the water and will respond to electro-fishing. They can also be found in the grassy openings adjacent to the trout streams and spring-fed lakes during the day. A pickerel frog resembles the common Leopard Frog but can be distinguished from it as follows:

A small to medium sized, tan or gray colored frog, with distinct, square or rectangular brown blotches arranged in two more or less rows between the dorsolateral folds; dorsolateral folds are yellow/bronze, extending to the hip region. The inside of the hind legs and often the sides are washed in a bright yellow-orange.

Leopard frogs are normally green (but sometimes tan), with rounded spots in no definite pattern and with no yellow wash on the underside of legs.

**PICKEREL FROG**

*Rana palustris*  
 1 3/4 - 3 inches



You need not collect any specimens although it would help to make a positive identification if you are able to preserve a specimen by freezing or by placing in a liquid preservative. Otherwise, simply record the location on the enclosed report form and return it to me. I would appreciate receiving the report as soon as possible after you find them. I will then be able to visit the location and collect habitat and population data. With your help, I will be able to cover a wider range of the state and determine the distribution and relative abundance of this threatened species.

Thank you for your cooperation and assistance with this study.

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Appendix C. Pickerel frog measurement data, 1980-82.<sup>a</sup>

Frog Capture										No.		
No.	Loc.	Date	Time	S-U	Tib.	Hd.	Tym.	Wt.	SS.	Spt.	S.A.	
1	4201	5/28/80	11:00	52.1	33.5	18.3	4.0	12.5	1	13	1	3
2	4201	5/30/80	8:30	52.3	31.9	19.5	4.5	12.5	1	13	1	3
3	4203	6/10/80	14:00	44.6	27.7	16.2	3.0	8.5	1	11	9	9
4	4203	6/10/80	15:00	25.7	16.7	12.0	2.0	1.5	1	10	9	9
5	4203	6/10/80	15:00	27.3	15.1	12.0	2.0	1.9	0	8	9	9
6	4202	6/10/80	16:00	45.7	31.0	17.6	4.5	9.2	1	16	9	9
7	4202	6/10/80	16:30	42.3	26.9	17.5	3.5	6.9	1	13	9	9
8	4202	6/10/80	16:30	42.0	27.1	17.0	3.5	6.5	1	13	9	9
9	4202	6/10/80	16:30	46.7	31.3	19.5	4.0	13.0	1	12	9	9
10	4202	6/10/80	17:30	35.7	22.1	15.0	3.0	4.5	0	11	9	9
11	4201	6/11/80	15:30	41.1	26.9	15.7	3.5	6.5	1	11	9	9
12	4202	6/11/80	16:30	44.0	27.9	16.0	4.0	9.9	0	11	9	9
13	4203	6/13/80	11:00	30.6	19.1	12.5	3.0	3.1	0	10	9	9
14	4203	6/13/80	11:00	39.6	25.5	12.0	4.0	7.2	0	11	9	9
15	4204	6/17/80	12:00	54.3	34.1	20.7	5.5	14.5	0	14	9	9
16	4204	6/17/80	12:30	60.1	39.6	24.0	6.0	21.9	1	15	9	9
17	4204	6/17/80	13:00	37.3	22.6	19.1	3.5	4.2	1	7	9	9
18	4204	6/17/80	13:00	48.4	30.2	20.5	4.0	11.5	1	14	9	9
19	4204	6/17/80	13:00	45.5	27.0	17.1	3.5	9.1	1	15	9	9
20	4204	6/17/80	13:00	54.5	33.6	21.2	5.0	17.3	0	12	9	9
21	4204	6/17/80	13:30	37.1	22.6	15.5	3.0	4.5	1	13	9	9
22	4204	6/17/80	12:30	39.3	25.7	15.2	4.5	6.9	1	14	9	9
23	5702	6/20/80	12:05	39.5	99.9	99.9	9.9	99.9	0	11	9	9
24	5702	6/20/80	12:10	42.0	99.9	99.9	9.9	99.9	0	9	9	9
25	5702	6/20/80	12:15	43.0	99.9	99.9	9.9	99.9	1	11	9	9
26	5702	6/20/80	12:15	40.0	99.9	99.9	9.9	99.9	0	10	9	9
27	5703	6/20/80	18:15	37.9	25.5	15.6	3.6	6.2	1	11	9	9
28	5703	6/20/80	18:30	36.0	23.9	15.4	3.0	4.5	1	16	9	9
29	5703	6/20/80	18:30	50.9	32.3	20.2	4.5	17.0	1	13	1	3
30	5703	6/20/80	18:30	31.2	20.9	14.6	3.0	4.2	0	9	9	9
31	5703	6/20/80	18:30	53.6	35.4	19.4	4.2	17.0	1	16	1	3
32	5703	6/20/80	18:30	37.3	23.1	15.8	3.7	5.7	1	16	9	9
33	5703	6/20/80	18:30	40.8	26.1	16.6	3.9	9.4	1	13	9	9
34	5703	6/20/80	18:30	38.4	23.5	15.6	3.5	5.6	0	12	9	9
35	5703	6/20/80	18:30	38.4	23.9	15.5	3.3	4.9	1	15	9	9
36	5703	6/20/80	18:30	38.9	24.1	15.6	3.4	7.1	1	13	9	9
37	5703	6/20/80	18:30	34.6	21.8	15.0	3.8	3.8	0	9	9	9
38	5703	6/20/80	18:30	38.9	25.5	15.7	3.5	9.9	1	15	9	9
39	5703	6/20/80	18:30	37.5	23.6	15.5	4.0	5.6	1	15	9	9
40	5703	6/20/80	18:30	35.6	22.2	14.5	3.0	4.2	1	12	9	9
41	5703	6/20/80	18:30	30.6	19.5	13.2	2.4	3.1	1	12	9	9
42	5703	6/20/80	18:30	39.6	25.1	16.2	3.4	6.2	1	13	9	9
43	5703	6/20/80	18:30	37.4	22.6	15.2	3.0	5.3	1	13	9	9
44	5703	6/21/80	11:00	42.9	20.9	17.5	3.5	8.0	1	15	9	9
45	5703	6/21/80	11:00	41.4	26.9	15.0	4.0	7.9	1	17	9	9
46	5703	6/21/80	11:00	40.0	26.0	14.0	3.5	7.5	1	12	9	9
47	5703	6/21/80	11:00	33.9	23.0	14.0	3.0	5.0	1	15	9	9
48	5703	6/21/80	11:00	38.1	25.2	16.1	3.5	6.5	1	9	9	9
49	5703	6/21/80	11:00	39.2	25.5	16.5	3.0	5.9	1	14	9	9
50	5703	6/21/80	11:00	40.9	25.7	14.5	3.0	7.2	1	16	9	9
51	5703	6/21/80	11:00	38.4	24.0	15.5	3.8	9.9	1	12	9	9
52	5703	6/21/80	11:00	42.6	25.2	17.5	3.5	7.8	1	15	9	9
53	5703	6/21/80	11:00	41.4	24.9	16.0	4.0	6.0	1	17	9	9
54	5703	6/21/80	11:00	43.0	26.0	16.0	4.0	7.5	0	12	9	9
55	5703	6/21/80	11:00	32.4	21.0	13.0	2.5	3.4	1	16	9	9
56	5703	6/21/80	11:00	34.9	21.9	16.0	3.0	4.9	0	13	9	9
57	5703	6/21/80	11:00	36.3	22.9	12.5	3.0	5.0	1	14	9	9
58	5703	6/21/80	11:00	35.2	23.1	12.5	3.5	4.5	1	11	9	9
59	5703	6/21/80	11:00	43.1	28.1	12.0	4.5	9.3	1	15	9	9
60	5703	6/21/80	11:00	38.0	24.3	17.0	3.5	5.7	1	15	9	9
61	1303	6/21/80	13:45	47.1	30.3	17.0	3.5	10.3	1	8	9	9
62	1303	6/21/80	13:45	40.3	24.4	16.5	3.5	6.1	0	14	9	9
63	1303	6/21/80	14:00	56.9	35.7	21.0	5.0	21.5	1	13	9	9

## Appendix C. Cont.

153	5701	4/28/81	8:30	51.5	32.0	17.5	4.0	13.0	0	9	1	3
154	5701	4/28/81	8:30	52.0	31.0	13.0	4.0	13.0	0	10	1	3
155	5701	4/28/81	8:30	48.5	32.0	15.5	3.5	13.0	1	12	1	3
156	5701	4/28/81	8:30	64.3	41.0	21.0	4.0	32.0	1	18	2	3
158	5701	4/28/81	8:30	52.5	34.0	19.0	4.0	15.5	1	16	1	3
159	5701	4/28/81	8:30	55.0	32.0	17.0	4.0	15.5	1	33	1	3
160	5701	4/28/81	8:30	59.0	34.0	22.0	4.5	25.5	0	11	2	3
190	5701	4/28/81	8:30	99.9	99.9	99.9	9.9	99.9	9	99	1	3
999	9999	99/99/99	99:99	52.0	32.0	17.0	4.0	15.3	1	13	9	9
999	9999	99/99/99	99:99	58.0	36.0	19.0	4.0	21.0	0	11	1	3
13	5703	6/28/81	13:15	42.0	23.0	16.6	3.0	12.0	1	20	9	9
101	5703	6/29/81	12:00	53.0	34.0	18.0	4.0	16.5	1	15	1	3
161	5701	4/28/81	10:00	62.1	36.9	22.0	4.5	28.0	0	11	2	3
162	5701	4/28/81	10:00	51.0	31.4	16.5	3.5	13.5	0	16	1	3
163	5701	4/28/81	10:00	51.5	31.8	17.0	4.0	16.5	1	12	1	3
164	5701	5/ 3/81	13:00	73.7	47.0	26.0	5.5	43.0	1	18	2	3
165	5701	5/ 3/81	13:00	63.0	37.0	22.5	5.0	32.0	1	24	2	3
168	5701	5/ 4/81	9:35	66.5	35.0	20.0	4.5	28.5	1	18	2	3
169	5701	5/ 4/81	10:00	49.9	29.5	17.0	3.5	11.0	0	16	1	3
170	5701	5/ 4/81	10:00	49.0	23.5	17.0	3.5	13.0	0	7	1	3
171	5701	5/ 4/81	10:00	63.0	35.0	20.0	4.0	22.0	1	19	2	3
172	5701	5/ 4/81	10:00	50.3	29.0	16.0	3.5	12.5	0	13	1	3
173	5701	5/ 4/81	10:00	64.0	38.0	22.0	4.5	26.0	0	11	2	3
174	5701	5/ 5/81	10:00	48.3	23.0	16.0	3.5	10.0	0	10	1	9
175	5701	5/ 5/81	10:00	65.0	37.0	22.0	5.0	29.0	1	17	2	3
177	5701	5/ 5/81	10:00	50.0	29.0	16.5	2.5	15.5	1	11	1	9
4	5703	6/ 1/81	16:15	32.2	22.0	14.0	3.4	4.0	1	14	9	9
5	5703	6/ 1/81	16:15	36.7	22.1	13.5	3.0	5.0	1	19	9	9
6	5703	6/ 1/81	16:15	54.1	33.7	20.0	4.0	18.0	1	12	2	3
8	5703	6/ 1/81	16:15	58.0	36.0	19.5	4.9	18.0	1	16	2	3
9	5703	6/ 1/81	16:15	54.6	33.0	18.0	4.5	16.0	1	20	1	3
10	5703	6/ 1/81	16:15	53.0	32.0	18.0	4.0	14.0	1	16	1	3
210	5701	6/28/81	18:15	46.0	28.0	16.3	3.6	10.5	0	14	9	9
999	5703	8/19/81	11:10	34.0	17.5	13.0	3.0	3.5	0	14	9	4
999	5703	8/19/81	11:10	28.0	16.0	10.0	1.5	2.0	1	13	9	4
999	5703	8/19/81	11:10	29.5	16.0	11.0	2.0	2.5	0	15	9	4
999	5703	8/19/81	11:10	34.0	19.5	13.0	3.0	3.5	1	13	9	4
999	5703	8/19/81	11:10	26.0	14.0	10.5	2.0	2.0	0	16	9	4
999	5703	8/19/81	11:10	27.0	15.0	11.0	2.5	2.0	1	15	9	4
999	5703	8/19/81	11:10	35.0	20.0	15.0	3.0	4.3	1	12	9	4
999	5703	8/19/81	11:10	25.0	11.0	10.0	2.0	2.0	1	17	9	4
1	3901	5/19/81	11:00	99.9	99.9	16.0	4.0	99.9	1	23	2	4
1	1102	5/20/81	99:99	53.1	32.0	17.0	4.5	99.9	1	17	1	3
14	5703	6/26/81	99:99	71.5	41.0	22.0	5.3	26.0	1	17	2	3
11	5703	6/26/81	99:99	41.6	30.0	15.0	4.0	11.0	1	13	9	9
190	5701	5/ 5/81	10:00	51.6	33.0	18.0	3.5	15.0	1	13	1	3
185	5701	5/ 5/81	10:00	51.9	28.5	16.5	4.0	15.0	0	14	1	3
189	5701	5/ 5/81	10:00	54.0	35.0	16.0	3.0	16.0	1	38	1	3
186	5701	5/ 5/81	10:00	62.0	36.0	21.0	4.5	25.0	1	16	2	3
187	5701	5/ 5/81	10:00	52.6	32.0	16.0	3.0	15.0	1	22	1	3
70	5701	5/ 5/81	10:00	53.0	32.0	20.0	4.3	14.5	1	16	1	3
182	5701	5/ 5/81	10:00	51.5	30.5	17.0	3.5	13.3	1	12	1	3
189	5701	5/ 5/81	10:00	50.5	30.3	17.0	4.0	13.5	1	16	1	3
191	5701	5/ 5/81	10:00	64.5	36.0	20.5	4.5	30.0	1	33	2	3
200	5701	5/ 5/81	10:00	99.9	99.9	99.9	9.9	99.9	9	99	2	3
999	5703	8/ 3/81	13:30	28.0	15.0	8.0	2.0	1.7	1	20	9	4
999	5703	8/ 3/81	13:30	26.0	15.0	10.0	1.5	2.0	0	11	9	4
999	5703	8/ 3/81	13:30	27.5	9.0	8.0	1.5	1.5	1	12	9	4
999	5703	8/ 3/81	13:30	27.0	14.0	10.0	2.0	1.5	1	15	9	4
999	5703	8/ 3/81	13:30	22.0	12.0	7.0	1.5	1.4	0	10	9	4
999	5703	8/ 3/81	13:30	26.0	15.5	11.0	2.0	2.3	1	15	9	4
999	5703	8/ 3/81	13:33	25.0	8.0	10.0	2.0	1.5	1	11	9	4
999	5703	8/ 3/81	13:30	28.5	15.0	10.0	2.0	2.5	1	16	9	4
999	5703	8/ 3/81	13:30	31.0	15.0	11.0	2.0	2.9	1	17	9	4
999	5703	8/ 3/81	13:30	24.0	13.0	7.5	1.5	1.2	0	10	9	4
999	5703	8/ 3/81	13:30	24.5	14.0	9.0	1.5	1.2	0	14	9	4

## Appendix C. Cont.

64	1303	6/21/80	14:15	49.9	31.6	18.3	5.0	11.0	1	11	9	9
65	1303	6/21/80	14:15	51.2	33.1	19.8	5.0	12.8	1	16	9	9
66	5701	6/22/80	15:00	48.2	30.2	18.4	4.4	11.2	1	11	9	9
67	1303	6/21/80	14:45	49.9	30.9	22.0	5.0	13.4	1	20	9	9
68	5701	6/22/80	15:30	37.1	23.4	14.5	3.7	99.9	0	10	9	9
69	5701	6/22/80	16:15	38.2	23.8	15.3	3.5	5.3	1	11	9	9
70	5701	6/22/80	16:15	39.8	25.0	15.2	3.4	6.5	0	9	9	9
71	5701	6/22/80	15:30	41.6	26.2	16.5	3.6	7.9	0	11	9	9
72	5701	6/22/80	15:30	40.0	24.9	16.2	3.8	6.3	1	13	9	9
73	5701	6/22/80	15:30	45.5	29.1	17.5	3.5	11.3	0	15	9	9
75	5701	6/22/80	15:30	40.5	26.6	15.1	3.2	6.3	1	17	9	9
76	2501	6/24/80	12:20	49.3	31.8	13.2	3.9	12.2	1	17	9	9
77	2501	6/24/80	12:20	58.2	36.3	20.6	4.6	21.8	1	13	9	9
78	2501	6/24/80	12:20	57.3	33.1	21.1	4.5	19.6	1	22	9	9
79	2501	6/24/80	13:00	51.2	30.8	19.2	4.0	11.8	1	16	9	9
80	2501	6/24/80	13:00	37.7	22.7	14.7	3.2	4.4	1	14	9	9
81	2501	6/24/80	13:30	64.8	39.4	22.9	5.1	26.9	1	15	9	9
82	2502	6/24/80	14:40	60.4	40.2	22.8	5.5	28.7	1	19	9	9
83	1301	6/25/80	10:30	43.7	27.9	16.6	3.3	9.3	9	59	9	9
84	1301	6/25/80	10:30	40.0	22.8	15.3	3.2	6.2	1	14	9	9
85	1301	6/25/80	10:45	39.6	23.2	15.3	9.9	6.7	0	10	9	9
86	1302	6/25/80	13:40	40.8	25.7	16.3	3.5	7.3	1	16	9	9
87	5704	6/25/80	19:30	34.7	21.2	14.0	3.7	4.2	1	13	9	9
88	5704	6/25/80	19:30	54.1	34.3	19.8	5.0	18.9	1	13	9	9
89	5701	6/22/80	18:30	39.7	26.1	16.4	3.5	6.2	1	14	9	9
90	5701	6/22/80	18:30	45.0	29.1	16.9	3.8	8.0	1	55	9	9
91	5701	6/22/80	18:30	46.1	29.3	17.9	3.3	10.5	1	38	9	9
95	6202	6/27/80	16:30	41.1	25.9	15.2	3.2	6.5	1	13	9	9
96	6202	6/27/80	17:00	41.2	23.8	15.2	3.4	6.8	0	10	9	9
97	6201	6/28/80	11:00	43.2	27.1	16.2	3.9	8.6	1	15	9	9
99	601	6/30/80	12:30	57.2	33.2	20.9	4.0	20.9	1	13	9	9
100	601	6/30/80	12:45	51.9	31.1	18.2	3.5	14.1	1	21	9	9
101	6301	7/ 1/80	10:45	40.0	23.2	16.0	3.3	6.2	1	14	9	9
102	6301	7/ 1/80	11:00	55.0	33.4	19.2	4.2	18.0	0	12	9	9
103	6305	7/ 1/80	12:10	46.3	28.8	18.1	3.5	12.5	1	13	9	9
104	6302	7/ 3/80	11:00	43.7	27.6	15.8	3.5	8.0	1	17	9	9
105	6302	7/ 3/80	11:00	48.7	32.2	18.7	3.7	12.5	1	14	9	9
106	6302	7/ 3/80	11:00	44.5	28.7	17.1	3.5	10.3	1	21	9	9
107	6303	7/ 3/80	12:15	43.6	27.9	16.4	3.8	9.6	1	13	9	9
108	6304	7/ 3/80	13:00	47.9	29.2	19.4	3.5	10.9	1	12	9	9
109	5001	7/ 9/80	11:15	41.9	27.8	14.6	3.4	7.9	1	17	9	9
110	5001	7/ 9/80	11:15	50.1	32.6	19.3	3.9	12.8	1	24	9	9
0	601	6/30/80	12:15	47.8	31.3	18.6	4.2	99.9	9	59	9	9
0	2501	6/24/80	13:00	43.6	28.4	16.5	3.5	8.8	9	59	9	9
3	5002	8/ 2/80	16:00	48.4	31.2	17.8	3.8	12.5	0	16	9	9
4	5002	8/ 2/80	16:10	45.6	30.1	17.6	3.5	9.7	1	15	9	9
1	901	8/15/80	18:20	35.9	21.9	13.5	3.0	4.9	0	12	9	9
2	901	8/15/80	18:40	35.2	22.1	13.2	3.2	4.2	1	17	9	9
1	6801	8/24/80	15:17	59.3	36.3	21.2	4.7	22.9	1	19	9	9
1	6802	8/24/80	18:30	36.3	22.1	14.4	3.0	4.7	1	10	9	9
98	601	6/30/80	12:15	47.8	28.6	17.6	3.5	9.9	1	12	9	9
137	5701	4/27/81	11:00	47.2	30.5	17.0	3.5	12.0	0	9	1	3
139	5701	4/28/81	8:30	52.6	32.7	19.5	4.0	14.5	1	14	1	3
136	5701	4/27/81	11:00	60.0	35.2	21.0	4.0	27.0	0	12	2	3
140	5701	4/28/81	8:30	49.6	31.9	17.0	3.5	13.0	1	12	1	3
141	5701	4/28/81	8:30	51.4	29.6	16.5	3.5	14.0	0	8	1	3
143	5701	4/28/81	8:30	48.1	30.6	16.0	3.0	11.5	0	10	1	3
142	5701	4/28/81	8:30	61.3	36.0	19.0	4.0	24.3	0	14	2	3
144	5701	4/28/81	8:30	68.0	39.8	20.5	5.0	34.5	1	14	2	3
145	5701	4/28/81	8:30	51.5	32.2	19.0	4.0	19.0	1	17	1	3
147	5701	4/28/81	8:30	64.1	38.0	17.5	4.0	31.5	0	23	2	3
148	5701	4/28/81	8:30	46.4	29.3	14.5	3.0	11.0	1	13	1	3
149	5701	4/28/81	8:30	50.3	31.1	16.0	3.5	13.5	0	15	1	3
150	5701	4/28/81	8:30	68.7	42.2	22.0	5.5	39.5	1	13	2	3
151	5701	4/28/81	8:30	49.1	29.9	16.0	3.3	12.0	0	10	1	3
152	5701	4/28/81	8:30	52.1	33.5	16.5	4.0	17.5	0	14	1	3

## Appendix C. Cont.

85	5701	4/16/81	20:00	51.3	37.2	19.0	4.0	21.5	0	25	2	3
86	5701	4/16/81	20:00	50.3	39.2	19.0	4.7	17.0	0	17	1	3
88	5701	4/17/81	10:00	49.1	31.3	15.0	3.0	11.6	1	16	1	3
87	5701	4/17/81	10:00	51.3	33.2	17.0	3.5	17.0	0	12	1	3
81	5701	4/17/81	10:00	60.8	37.6	17.0	4.5	19.5	0	11	2	3
95	5701	4/17/81	10:00	50.6	32.3	19.0	4.0	12.2	0	13	1	3
22	5701	4/14/81	8:00	63.9	39.7	22.5	4.5	30.3	1	15	2	3
94	5701	4/17/81	10:00	49.9	33.4	16.0	3.3	14.3	1	16	1	3
93	5701	4/17/81	10:00	49.9	29.6	16.0	4.0	12.0	1	18	1	3
92	5701	4/17/81	10:00	49.2	31.3	17.0	3.5	14.5	1	14	1	3
91	5701	4/17/81	10:00	51.9	31.7	17.5	4.5	13.5	1	12	1	3
90	5701	4/17/81	10:00	51.4	33.2	17.0	4.0	14.3	1	15	1	3
99	5701	4/20/81	8:00	59.0	33.2	18.0	3.5	21.5	0	13	2	3
97	5701	4/20/81	8:00	60.5	36.4	20.0	5.0	19.0	0	11	2	3
96	5701	4/20/81	8:00	51.9	31.4	18.0	4.0	15.0	1	14	1	3
102	5701	4/23/81	9:00	59.2	37.7	20.0	4.5	25.5	0	13	2	3
101	5701	4/23/81	9:00	51.1	30.3	17.0	4.0	13.5	0	11	1	3
98	5701	4/23/81	9:00	59.9	37.6	20.0	4.5	25.3	0	10	2	3
105	5701	4/23/81	9:00	66.2	38.0	20.0	4.0	35.5	1	25	2	3
104	5701	4/23/81	9:00	57.3	37.1	20.0	4.5	22.0	1	18	2	3
103	5701	4/23/81	9:00	48.9	31.0	16.5	4.0	12.6	1	21	1	3
108	5701	4/23/81	9:00	46.0	29.9	15.0	3.5	11.5	0	10	1	3
117	5701	4/23/81	9:00	48.2	30.0	17.0	4.0	12.3	0	10	1	3
118	5701	4/23/81	9:00	49.6	31.0	16.5	4.0	14.0	1	12	1	3
143	5701	4/23/81	9:00	51.3	31.6	17.5	4.0	13.5	1	12	1	3
115	5701	4/23/81	9:00	52.5	31.7	19.0	4.0	15.0	0	14	1	3
114	5701	4/23/81	9:00	51.1	31.1	17.0	4.0	12.0	0	10	1	3
107	5701	4/23/81	9:00	54.1	32.2	17.3	4.0	16.0	1	35	1	3
106	5701	4/23/81	9:00	50.0	31.8	17.0	4.0	14.5	1	17	1	3
130	5701	4/23/81	9:00	46.6	29.9	17.0	3.0	11.3	1	13	1	3
110	5701	4/23/81	9:00	51.9	30.9	18.0	4.0	16.5	0	11	1	3
109	5701	4/23/81	9:00	63.6	36.8	20.5	4.5	29.0	1	13	2	3
116	5701	4/23/81	9:00	52.8	33.6	17.5	4.0	14.3	0	11	1	3
202	5701	5/24/81	14:00	33.5	19.0	11.5	2.0	2.5	1	13	9	4
201	5701	5/24/81	14:00	34.0	20.0	12.0	2.0	3.0	0	11	9	4
270	5701	5/24/81	14:00	51.9	31.2	18.0	4.0	13.5	1	22	1	3
199	5701	5/20/81	9:00	54.1	31.4	18.0	4.0	13.5	1	15	1	3
203	5701	5/26/81	18:45	62.5	40.3	22.0	5.0	32.0	1	23	2	3
63	5701	4/15/81	14:00	49.3	31.6	16.5	4.5	13.0	1	11	1	3
62	5701	4/15/81	14:00	49.5	30.9	16.5	3.5	13.5	1	12	1	3
61	5701	4/15/81	14:00	51.7	32.8	17.5	3.5	14.5	0	11	1	3
60	5701	4/15/81	14:00	60.7	39.9	21.0	5.0	24.5	1	32	2	3
100	9999	99/99/99	99:99	99.9	99.9	99.9	9.9	11.9	9	99	1	3
121	9999	99/99/99	99:99	99.9	99.9	99.9	9.9	13.3	9	99	9	9
120	5701	4/23/81	9:00	60.0	38.2	21.0	5.0	26.5	0	16	2	3
999	5703	8/12/81	15:15	45.0	27.0	16.0	5.0	2.0	0	10	9	9
1	5703	8/12/81	15:40	35.0	20.0	13.0	3.0	4.0	1	15	9	4
25	5701	4/14/81	8:00	60.9	36.2	21.0	4.5	27.5	1	22	2	3
23	5701	4/14/81	8:00	48.3	31.5	17.0	3.5	13.0	0	15	1	3
21	5701	4/14/81	8:00	53.6	31.9	18.0	4.0	17.5	1	13	1	3
20	5701	4/14/81	8:00	53.3	32.6	18.5	4.0	17.0	1	21	1	3
19	5701	4/14/81	8:00	48.2	31.0	17.5	3.5	14.0	0	10	1	3
18	5701	4/14/81	8:00	62.5	38.2	20.5	4.0	29.0	1	14	2	3
26	5701	4/14/81	8:00	57.6	34.0	21.0	4.0	20.0	1	16	1	3
27	5701	4/14/81	8:00	56.8	35.4	20.5	4.5	26.0	1	30	2	3
28	5701	4/14/81	8:00	51.3	30.9	17.5	4.0	18.0	0	9	1	3
29	5701	4/14/81	8:00	52.8	32.5	19.0	3.5	16.5	0	12	1	3
31	5701	4/14/81	8:00	54.3	33.6	18.5	3.0	16.5	0	11	1	3
32	5701	4/14/81	8:00	50.5	30.4	18.5	3.9	15.0	0	7	1	3
33	5701	4/14/81	8:00	51.1	30.0	17.0	4.0	12.5	1	18	1	3
34	5701	4/14/81	8:00	53.9	34.6	19.0	4.8	17.3	0	13	1	3
35	5701	4/14/81	8:00	51.1	31.5	17.0	3.5	16.0	0	14	1	3
38	5701	4/14/81	8:00	99.9	40.0	23.0	5.0	99.9	0	99	2	3
37	5701	4/14/81	8:00	62.0	37.7	21.5	4.0	26.3	1	16	2	3
100	5701	4/14/81	8:00	50.0	33.1	17.5	3.5	99.9	1	17	1	3
170	5701	4/14/81	8:00	50.9	31.0	17.5	3.5	99.9	1	13	1	3

## Appendix C. Cont.

999	5703	8/ 3/81	13:30	25.0	13.0	10.0	1.5	1.2	1	11	9	4
999	5703	8/ 3/81	13:30	24.0	13.0	10.0	2.0	1.2	0	10	9	4
999	5703	8/ 3/81	13:30	28.0	14.5	11.0	2.0	1.7	0	13	9	4
999	5703	8/ 3/81	13:30	26.0	15.0	10.3	2.0	1.7	1	12	9	4
999	5703	8/ 3/81	13:30	24.0	13.5	10.0	2.0	1.0	1	12	9	4
999	5703	8/ 3/81	13:30	24.0	14.0	10.0	1.5	1.2	1	12	9	4
999	5703	8/ 3/81	13:30	24.0	13.0	9.0	1.5	1.2	0	12	9	4
999	5703	8/ 3/81	13:30	22.0	13.0	9.8	1.5	1.2	1	15	9	4
999	5703	8/ 3/81	13:30	24.0	13.0	10.0	2.0	1.3	0	12	9	4
999	5703	8/ 3/81	13:30	24.0	12.0	9.0	1.0	1.2	0	11	9	4
999	5703	8/ 3/81	13:30	27.0	15.0	11.0	2.0	1.3	0	13	9	4
999	5703	8/ 3/81	13:30	27.0	14.0	11.0	2.0	1.5	0	12	9	4
999	5703	8/ 3/81	13:30	24.5	13.5	10.0	1.5	1.3	0	16	9	4
999	5703	8/ 3/81	13:30	36.0	16.0	12.0	2.0	2.2	1	17	9	4
999	5703	8/ 3/81	13:30	27.0	15.0	10.0	1.5	1.5	0	12	9	4
999	5703	8/ 3/81	13:30	30.0	16.3	12.0	2.0	2.7	1	14	9	4
999	5703	8/ 3/81	13:30	27.0	14.0	10.0	1.5	2.9	0	10	9	4
182	5701	5/ 5/81	10:00	44.0	32.0	15.3	3.5	11.5	0	12	9	9
123	5701	5/ 5/81	10:00	66.1	33.0	19.0	4.0	24.0	1	17	2	3
12	5703	6/26/81	99:99	45.5	26.0	16.0	3.0	9.0	0	16	1	9
151	5703	6/29/81	13:00	43.0	24.0	12.3	2.0	22.9	0	11	9	9
152	5703	6/29/81	13:00	44.0	27.0	16.0	3.5	22.9	1	14	1	4
102	5703	7/ 1/81	17:10	42.0	29.0	15.0	3.0	10.3	1	15	9	9
154	5703	7/12/81	14:30	47.0	30.0	17.4	3.0	9.5	0	19	9	9
61	5703	7/29/81	99:99	58.5	37.0	19.0	4.0	20.0	1	13	1	9
62	5703	7/29/81	99:99	56.0	34.0	19.0	4.0	18.0	1	13	9	9
999	5703	8/19/81	12:00	29.5	18.0	12.5	2.5	3.0	1	16	9	4
41	5703	8/10/81	17:00	44.0	27.0	17.0	3.5	10.0	1	16	1	4
22	5703	9/16/81	99:99	63.0	33.0	20.0	4.0	30.0	1	12	2	3
23	5703	9/16/81	99:99	72.0	39.0	21.0	6.0	48.0	1	13	2	3
1	1301	6/ 3/81	11:00	55.1	33.5	18.3	3.5	13.5	1	15	1	3
2	1301	6/ 3/81	11:00	52.0	31.7	17.0	4.0	14.5	1	16	2	9
6	1301	6/ 3/81	11:00	34.0	17.3	11.7	2.0	3.3	1	13	9	9
3	1301	6/ 3/81	11:00	51.6	31.7	16.3	3.5	13.0	0	15	1	3
1	1304	6/ 3/81	14:30	73.0	43.0	23.0	5.2	33.3	0	12	1	3
179	5701	5/ 5/81	10:00	52.0	34.3	17.3	3.0	15.0	1	19	1	3
180	5701	5/ 5/81	10:00	47.3	29.8	15.0	3.0	12.0	1	13	1	3
181	5701	5/ 5/81	10:00	55.0	35.0	19.5	4.0	15.3	1	12	2	3
184	5701	5/ 5/81	10:00	72.3	38.5	23.0	5.0	34.0	1	19	2	3
1	5703	8/12/81	15:40	31.0	19.0	12.0	2.0	3.5	1	17	9	4
112	5701	4/23/81	9:00	45.2	31.3	16.0	4.0	6.5	0	10	1	3
119	5701	4/23/81	9:00	52.3	31.7	19.0	4.0	14.0	0	15	1	3
125	5701	4/23/81	9:00	52.3	31.9	18.0	4.0	15.0	1	16	1	3
124	5701	4/23/81	9:00	48.2	29.5	17.0	3.0	12.5	0	12	1	3
123	5701	4/23/81	9:00	57.6	34.6	20.0	4.5	24.0	1	13	2	3
122	5701	4/23/81	9:00	59.1	37.3	20.5	5.0	29.6	1	12	2	3
121	5701	4/23/81	9:00	50.6	30.7	18.0	4.0	13.5	1	20	1	3
129	5701	4/23/81	9:00	63.0	37.7	20.0	4.0	27.0	1	21	2	3
128	5701	4/23/81	9:00	63.0	36.2	22.0	5.0	31.0	1	29	2	3
127	5701	4/23/81	9:00	59.1	36.0	20.0	4.0	25.5	1	15	2	3
126	5701	4/23/81	9:00	50.9	30.6	18.0	4.0	14.0	0	10	1	3
135	5701	4/23/81	9:00	49.9	29.9	19.0	3.5	13.3	0	9	1	3
134	5701	4/23/81	9:00	59.6	35.7	19.0	4.0	26.5	1	20	2	3
133	5701	4/23/81	9:00	58.8	35.2	20.0	4.0	26.0	1	14	2	3
132	5701	4/23/81	9:00	64.0	38.7	22.0	5.5	31.9	1	15	2	3
131	5701	4/23/81	9:00	55.1	33.9	19.0	4.0	21.0	1	16	1	3
130	5701	4/23/81	9:00	49.0	31.9	16.0	3.5	15.0	1	14	1	3
157	5701	4/28/81	8:30	50.0	31.0	18.0	3.5	13.0	1	14	1	3
999	5703	8/19/81	11:10	28.0	15.5	10.0	2.0	2.0	0	14	9	4
7	5703	6/ 1/81	16:15	54.0	36.0	19.3	4.2	15.3	1	14	1	3
178	5701	5/ 5/81	10:00	50.5	30.5	17.0	3.0	12.0	0	12	1	9
999	5701	5/22/81	99:99	99.9	99.9	99.9	9.9	23.0	9	99	2	3
89	5701	4/16/81	20:00	65.7	39.1	20.5	5.0	24.6	1	14	2	3
82	5701	4/16/81	20:00	53.4	32.5	17.5	4.0	15.5	1	14	1	3
83	5701	4/16/81	20:00	64.1	36.5	20.0	5.0	34.0	0	11	2	3
84	5701	4/16/81	20:00	53.1	33.4	18.0	4.0	17.3	1	21	1	3

## Appendix C. Cont.

64	5701	4/15/81	20:00	60.9	35.7	19.0	4.5	19.9	1	14	2	3
65	5701	4/15/81	20:00	49.3	29.8	18.5	3.0	15.0	0	10	1	3
66	5701	4/15/81	20:00	48.9	31.7	18.0	4.0	12.5	1	13	1	3
67	5701	4/15/81	20:00	51.8	32.9	17.0	3.5	15.9	0	12	1	3
68	5701	4/15/81	20:00	50.2	32.6	16.0	3.5	7.2	1	14	1	3
69	5701	4/15/81	20:00	53.2	32.2	19.0	4.0	18.0	1	12	1	3
70	5701	4/15/81	20:00	49.9	30.4	17.0	4.0	15.0	0	11	1	3
71	5701	4/15/81	20:00	54.7	33.4	20.0	4.5	13.0	1	16	1	3
72	5701	4/15/81	20:00	55.5	32.0	17.0	4.0	16.5	1	12	1	3
73	5701	4/15/81	20:00	48.2	31.5	17.5	4.5	14.0	1	15	1	3
74	5701	4/15/81	20:00	54.1	32.8	19.0	4.0	15.0	1	16	1	3
75	5701	4/15/81	20:00	48.1	29.4	17.5	3.3	12.6	1	14	1	3
76	5701	4/15/81	20:00	52.5	32.5	16.0	3.5	14.5	0	9	1	3
77	5701	4/15/81	20:00	53.3	32.1	17.0	4.0	16.3	0	15	1	3
78	5701	4/15/81	20:00	52.3	32.2	19.0	4.0	15.9	0	10	1	3
79	5701	4/16/81	10:00	53.2	32.2	19.5	4.5	15.0	1	13	1	3
80	5702	4/16/81	14:00	46.9	29.0	15.5	3.5	10.3	1	14	1	3
40	5701	4/14/81	13:00	53.2	34.5	17.0	3.5	16.0	1	17	1	3
41	5701	4/14/81	13:00	52.6	31.1	17.5	4.5	14.0	0	11	1	3
43	5701	4/14/81	13:00	56.6	33.9	18.5	4.5	20.0	1	17	1	3
45	5701	4/14/81	13:00	49.8	30.6	15.0	3.5	14.3	0	9	1	3
46	5701	4/14/81	13:00	50.0	30.8	18.0	3.5	13.3	1	12	1	3
47	5701	4/14/81	13:00	62.7	37.9	22.0	5.0	24.0	1	19	2	3
49	5701	4/14/81	13:00	54.1	32.7	19.0	4.5	15.6	1	19	1	3
50	5701	4/14/81	13:00	51.1	30.9	16.5	3.5	13.2	1	12	1	3
51	5701	4/14/81	13:00	51.9	31.9	13.0	4.5	14.5	0	12	1	3
52	5701	4/14/81	13:00	52.0	31.9	16.0	4.0	99.9	1	12	1	3
53	5701	4/14/81	13:00	54.6	32.6	19.5	4.5	15.0	1	13	1	3
54	5701	4/14/81	13:00	52.3	31.2	17.0	4.0	14.0	0	13	1	3
55	5701	4/14/81	13:00	49.3	31.0	18.0	4.0	12.6	1	13	1	3
56	5701	4/14/81	13:00	51.1	30.3	18.0	3.5	14.9	0	11	1	3
57	5701	4/14/81	13:00	55.0	30.6	19.0	4.0	13.9	1	14	1	3
58	5701	4/14/81	13:00	51.1	32.5	17.0	3.0	12.5	1	15	1	3
59	5701	4/14/81	13:00	52.1	32.2	19.5	4.0	14.0	0	10	1	3
144	5701	4/14/81	13:00	51.1	31.3	18.0	4.0	12.0	0	10	1	3
2	5703	5/15/81	10:00	57.1	37.7	18.3	4.3	20.0	1	21	1	3
3	5703	5/15/81	10:00	53.9	34.4	19.0	4.0	17.0	1	18	1	3
1	5704	5/11/81	15:15	40.8	21.7	7.7	2.0	5.5	0	15	9	4
2	5704	5/11/81	15:25	54.0	32.0	19.0	4.5	15.0	1	13	2	9
2	5701	4/10/81	19:00	51.9	31.9	18.0	4.0	14.5	1	27	1	3
4	5701	4/11/81	12:45	60.2	30.9	20.0	4.5	30.0	1	15	2	3
5	5701	4/11/81	14:00	51.7	33.0	19.0	4.0	16.0	1	14	1	3
6	5701	4/14/81	8:00	52.8	33.0	19.5	3.5	17.0	0	15	1	3
7	5701	4/14/81	8:00	52.0	31.6	17.0	3.0	15.0	1	15	1	3
8	5701	4/14/81	8:00	57.6	34.5	18.0	4.0	23.5	1	15	2	3
9	5701	4/14/81	8:00	48.8	32.0	15.0	3.5	15.5	1	15	1	3
10	5701	4/14/81	8:00	50.8	33.7	17.0	3.5	16.0	0	19	1	3
11	5701	4/14/81	8:00	48.4	31.1	16.5	3.5	14.5	0	11	1	3
12	5701	4/14/81	8:00	49.5	31.1	13.0	3.7	15.5	1	12	1	3
163	5701	4/14/81	8:00	53.9	32.4	20.0	4.0	17.5	1	13	1	3
14	5701	4/14/81	8:00	54.5	32.9	18.5	3.5	16.5	1	16	1	3
15	5701	4/14/81	8:00	65.0	38.3	24.0	4.0	31.5	1	16	2	3
16	5701	4/14/81	8:00	64.6	32.0	22.0	5.0	37.0	1	28	2	3
17	5701	4/14/81	8:00	53.5	32.9	19.0	4.0	15.5	0	11	1	3
1	5701	9/24/81	99:99	77.0	41.0	22.0	5.0	44.0	1	13	2	3
2	5701	9/24/81	99:99	55.0	32.0	16.5	4.0	18.5	0	11	1	3
3	5701	10/ 5/81	99:99	58.7	34.2	19.3	3.0	22.5	1	20	1	3
4	5701	10/ 5/81	99:99	52.0	32.0	17.0	4.0	16.5	1	16	1	3
5	5701	10/ 5/81	99:99	35.0	20.0	12.0	2.0	4.5	1	12	9	4
5	5703	10/ 5/81	99:99	40.0	25.0	16.0	3.0	8.0	1	17	1	4
5	5703	10/ 5/81	99:99	39.0	21.0	14.0	2.0	5.5	9	99	9	4
6	5703	10/ 5/81	99:99	36.0	23.0	14.0	2.5	5.5	0	12	9	4
7	5703	10/ 5/81	99:99	35.0	20.0	14.0	2.0	5.5	1	13	9	4
8	5703	10/ 5/81	99:99	34.0	29.0	14.0	2.0	4.0	0	15	9	4
52	5701	10/11/81	99:99	57.0	32.0	18.0	3.0	19.0	0	99	9	9
53	5701	10/11/81	99:99	37.0	23.0	13.0	2.0	99.9	1	16	9	4

## Appendix C. Cont.

54	5701	10/11/81	99:99	53.0	32.0	19.0	3.0	16.0	0	8	1	9
<del>55</del>	<del>5701</del>	<del>10/11/81</del>	<del>99:99</del>	<del>49.0</del>	<del>27.0</del>	<del>13.0</del>	<del>2.5</del>	<del>10.0</del>	<del>9</del>	<del>99</del>	<del>1</del>	<del>9</del>
51	5701	10/11/81	99:99	40.0	21.5	13.0	2.0	5.0	9	99	9	4
999	5701	10/11/81	99:99	60.0	37.0	22.9	3.9	22.5	0	17	2	3
1	3302	7/ 2/81	15:00	44.3	22.0	16.0	3.0	99.9	1	17	9	9
1	3301	7/ 3/81	11:30	56.0	32.0	21.0	4.0	99.9	1	13	9	9
1	2201	7/ 3/81	13:00	54.0	30.0	17.0	4.0	15.0	1	23	1	9
1	2202	7/ 3/81	15:00	57.0	32.0	17.0	4.0	22.0	1	16	9	9
1	5709	7/21/81	13:00	32.0	12.0	10.5	2.0	99.9	0	15	2	9
1	6203	7/25/81	99:99	61.0	35.0	20.0	4.0	21.0	1	13	1	9
1	6204	7/25/81	99:99	57.0	35.0	19.0	4.0	21.0	1	13	1	9
1	6202	7/25/81	99:99	60.0	35.0	19.5	4.0	24.5	1	18	1	3
1	602	7/25/81	99:99	51.0	33.0	17.0	4.0	14.0	0	10	9	9
3	5710	10/ 4/81	99:99	37.0	21.0	12.0	2.0	5.0	1	14	9	4
2	1103	9/12/81	16:00	38.0	21.0	13.0	3.0	5.0	1	15	9	4
1	1103	9/12/81	16:00	35.0	20.0	13.0	2.0	4.5	1	12	9	4
1	5710	9/14/81	99:99	44.0	22.0	15.0	2.5	6.5	1	18	9	4
138	5701	4/27/81	11:00	48.8	29.7	19.0	4.0	14.0	1	14	1	3
1	5703	5/13/81	11:00	55.3	31.5	13.0	4.0	15.0	1	14	1	3
44	5701	4/14/81	13:00	48.7	31.7	17.6	3.0	13.0	1	16	1	3
42	5701	4/14/81	13:00	52.6	33.0	13.5	4.5	14.3	0	12	1	3
39	5701	4/14/81	13:00	54.1	30.7	13.5	4.0	14.6	1	15	1	3
111	5701	4/23/81	9:00	47.1	29.6	15.5	4.0	12.0	0	11	1	3
3	5701	4/10/81	19:00	49.5	29.0	17.5	3.5	11.0	0	5	1	3
30	5701	4/14/81	8:00	50.8	31.1	19.0	3.5	15.0	0	9	1	3
36	5701	4/14/81	8:00	51.8	33.2	19.0	4.0	19.0	0	27	2	3
1	5701	4/10/81	19:00	55.9	34.0	12.5	4.0	18.5	0	12	1	3
94	5701	4/14/81	8:00	56.6	33.6	19.5	4.0	22.0	0	15	2	3
0	2503	10/12/81	99:99	51.0	22.0	15.0	3.0	13.5	1	13	9	9
0	2503	10/12/81	99:99	40.0	21.0	14.0	2.0	6.0	1	12	9	4
0	5701	2/ 1/82	15:30	55.0	32.0	19.5	4.0	99.9	1	12	1	3
0	4204	3/17/82	16:45	37.0	22.0	13.0	2.0	99.9	0	11	9	9
0	6802	2/28/82	99:99	34.0	20.0	12.0	2.0	5.5	1	18	9	9

<sup>a</sup>No. Loc. Identification number assigned to a particular frog.

Date Date of capture

Time Time of capture

S-U Snout-Urostyle length

Tib. Tibia length

Hd. Head length

Tym. Tympanum diameter

Wt. Weight in grams

SS. Presence (1) or Absence (0) of a snout spot

No. Spt. Number of dorsal spots

S. Sex: 1=male, 2=female

A. Age: 3=adult, 4=immature

All measurements in mm unless noted.

## Appendix D. Location of water sample collection sites

Site	Name	Township	Range	Sec.	County
1	Alderwood Lk.	19N	2W	30	Monroe
2	Sylvester Cr.	2N	9E	34	Green
3	Messenger Cr.	11N	6E	23	Sauk
4	Nine springs Cr.	6N	9E	10	Dane
5	Arneson Cr.	7N	5E	31	Iowa
6	Otter Cr.	11N	6E	32	Sauk
7	Dunlap Cr.	9N	6E	33	Dane
8	Wingra springs	7N	9E	28	Dane
9	Honey Cr.	10N	4E		Sauk
10	Duesler Cr.	7N	5E	19	Iowa
11	Plum Cr.	21N	8W	8	Tremp.
12	Eagle Cr.	20N	11W	15	Buff.
13	Tamarack Cr.	19N	9W	3	Tremp.
14	Fountain Lk.	21N	10E	11	Portg.
15	Ottawa fen Cr.	6N	17E	34	Wauke.
16	Genessee fen Cr.	6N	18E	28	Wauke.
17	Klondike springs	11N	6E	32	Sauk
18	Klondike breeding pool	11N	6E	32	Sauk
19	Bluffview Ct. pond	10N	6E	10	Sauk
20	Faussett's pond	11N	6E	32	Sauk
21	Harrass's pond	7N	3E	7	Iowa
22	Bluff Rd. trout pond	10N	5E	7	Sauk
23	PF-Lynns Rd. farm pond	10N	4E	12	Sauk
24	Leland milpond	10N	5E	19	Sauk
25	Spring Cr.	10N	8E	21	Colum.
26	Sawle Cr.	8N	5E	31	Iowa
27	Lawrence Cr.	17N	8E	26	Marq.
28	Rowan Cr.	11N	9E	33	Colum.
29	Rogers Br.	5N	3W	22	Grant
30	Unnamed Cr.	5N	3W	3	Grant
31	East silver Cr.	17N	3W	13	Monroe
32	Lemonwell Cr.	19N	1W	8	Monroe
33	French Cr.	20N	8W	15	Tremp.
34	French Cr.	19N	8W	16	Tremp.
35	Hadley Cr.	23N	11W	14	Buff.
36	So. Br. Elk Cr.	23N	10W	22	Buff.
37	Tarr Cr.	18N	2W	30	Monroe
38	Hazel Dell Lake	19N	2W	30	Monroe
39	Elk Creek				Tremp.
40	Marmon Cr.				LaCros.
41	Perrot Cr.				Tremp.
42	Medary Cr.				LaCros.

Appendix E. Water quality data (mg/l) collected at 38 active, and 4 inactive, Wisconsin pickerel frog locations, May 1980 - March 1982.

Seasons	Site	Date	Temp C	pH	Cond uMOHS	Alk	Total Hard	Ca++ Hard	D.O.	C.O.D.	BOD <sub>5</sub>	Reactive P	Total P	NH <sub>4</sub> N	NO <sub>2</sub> <sup>+</sup> NO <sub>3</sub>	TKN	CL-	TSS	SO <sub>4</sub>
	1	5-21-80		6.9	55	16	24	10		13.4		0.035	0.08	0.04	0.24	0.62	1.0		
	18	4-08-81	14	7.4	123	56	62	56	8.68	28.0	4.5	0.016	0.270	0.10	0.40	2.4	1.0	185	
	20	4-20-81	24	6.8	83	16	51	16		8.5	2.5	0.002	0.035	0.04	0.04	0.42	1	9	
	21	4-20-81	24	9.1	300	134	166	91		24.9	4.8	0.012	0.07	0.04	0.05	0.74	2.4	11	
Spring	10	4-20-81	29	9.6	265	146	145	64		309.6	16	0.002	0.55	0.02	0.01	16.8	2.3	76	
	3	5-26-81	11	7.2	78	30	34	20		14.1		0.012	0.160	0.01	0.01	1.12	1.6	10	
	3	4-08-81	14	6.7	65	12	26	20		19.8	2.9	0.012	0.20	0.01	0.66	0.90	1.44	208	
	22	5-26-81	23	8.4	360	180	176	108		21.2		0.02	0.11	0.02	0.01	1.2	14	27	
	23	5-26-81	23	9.6	237	130	134	56		14.9		0.02	0.05	0.01	0.01	0.88	5.5	2	
	24	5-26-81	23	8.6	300	166	162	102		12.5		0.004	0.13	0.10	0.03	0.60	3.1	21	
	25	5-26-81	19	8.3	400	248	224	134		7.8		0.002	0.07	0.02	0.43	0.96	3.3	29	
	9	4-08-81	15	6.7	58	12	20	26	10.6	18.8		0.12	0.10	0.16	0.62	0.80	1	77	
	9	5-26-81	12	7.1	63	24	24	16		2.35		0.01	0.03	0.01	0.09	0.36	1	5	
	7	4-08-81	14	7.7	445	232	246	242	8.28	38.8	6.8	0.078	0.65	0.2	0.66	2.6	6.7	440	
	19	4-20-81	24	8.1	610	34	56	38		25.6	4.6	0.005	0.075	0.20	0.13	0.13	100	18	
	6	5-26-81	14	7.9	440	214	228	140	8.58	3.2		0.005	0.20	0.01	5.2	0.48	7.3	13	
	26	5-26-81	17	8.7	330	186	180	112		3.9		0.015	0.045	0.01	0.26	0.60	4.8	1	
	9	5-26-81	14	8.2	320	172	170	106		3.9		0.002	0.025	0.01	1.2	0.68	1.5	6	
	28	5-26-81	15	8.2	510	272	272	168		5.5		0.036	0.10	0.01	2.1	0.49	9.2	1	
	29	7-06-81	12	7.36	565	272	247	242		2.9	1.3	0.015	0.020	0.02	2.5	0.19	8.1	8	
	30	7-06-81	22	7.94	800	326	395	328		13.6	5.1	0.171	0.23	0.32	9.15	2.02	42.2	25	
	31	7-25-81	16	7.25	80	39	52	26		8.4		0.060	0.070	0.01	0.13	0.14	1.5	5	
	32	7-25-81	20	7.56	224	132	144	82		34.8	1.9	0.050	0.095	0.01	0.80	0.52	8.3	13	
Summer	33	7-25-81	15	8.02	311	196	230	140		32	3.1	0.275	0.310	0.01	0.90	0.40	3.8	84	
	34	7-25-81	17	8.14	340	247	266	164		15.3		0.130	0.155	0.04	0.72	0.39	4.1	70	
	35	7-25-81		8.26	335	218	248	150		51.5		0.145	0.155	0.01	2.70	0.16	10.5	42	
	36	7-25-81		8.14	305	206	228	174		13.9		0.150	0.175	0.01	1.21	0.42	4.4	32	
	37	7-25-81	12	7.88	176	91	114	70		27.8		0.167	0.195	0.01	0.11	0.22	2.7	2	
	11	7-07-80		7.45	282	90	148	93		7.6		0.045	0.105	0.06	0.40	0.44	6.5		46.0
	15	8-26-80	12	7.78	625	268	328	204		3.7		0.005	0.020	0.02	1.9	0.20			
	16	8-26-80	10	7.38	1050	312	408	262		3.06		0.005	0.005	0.02	6.1	2.8	54.9		
	12	7-07-80		8.31	485	263	290	192		12.9		0.040	0.095	0.04	0.50	0.60	6.8		10.8
	13	7-07-80		7.89	565	282	327	201		8.4		0.085	0.155	0.14	1.10	0.94	22.0		17.1
	2	6-26-80	19	8.16	800	304	375	210		15.3		0.005	0.135	0.02	4.4	0.64	16.7		18.5
	3	6-26-80		7.38	94	27	30	14		4.8		0.020	0.045	0.02	0.14	0.20	1.4		5.2
	4	6-26-80	14	7.62	850	264	322	186		13.7		0.015	0.180	0.14	4.7	1.48	18.9		16.5
	5	6-26-80	19	8.47	710	266	310	86		8.4		0.040	0.80	0.06	1.64	0.28	8.0		16.0
	6	6-26-80	16	7.12	83	28	31	24		6.8		0.010	0.040	0.02	0.14	0.18	1.0		5.7
	7	6-26-80	15	8.10	700	275	303	176		7.3		0.010	0.050	0.04	1.16	0.34	6.0		6.5
	8	6-26-80	11	7.5	1200	297	368	236		5.6		0.01	0.015	0.02	3.4	0.10	47.2		16.3

Appendix E. Continued.

Seasons	Site	Date	Temp C	pH	Cond uMOHS	Alk	Total Hard	Ca++ Hard	D.O.	C.O.D.	BOD <sub>5</sub>	Reactive P	Total P	NH <sub>4</sub> N	NO <sub>2</sub> + NO <sub>3</sub>	TKN	CL-	TSS	SO <sub>4</sub>
	10	6-26-80	23	8.5	495	198	226	140		8.8		0.05	0.08	0.04	0.36	0.64	5.7		9.9
	14	7-21-80	23	9.0	225	136	164	66	10.2		.85	0.005	0.009	0.12	0.05	0.36	3.0		
	1	6-09-80		6.0												30.3			100
Summer	37	7- 81			116		70	35											
	38	7- 81					11	11											
	31	7- 81			105		60	27											
	31	9-22-81		7.9	103		56	32											
Winter	17	1-19-81q	8	5.8	46	10	15	12	8.0	4.1		0.002		0.02	0.05			1.0	
	17	2-01-82	8	5.8	42	10	12	5.4	7.5	6.4	0.4	0.001	0.01	0.01	0.13	0.14		1.0	
	15	3-01-82	8	7.4	150	274	326	199	6.1	2.4	0.7	0.002	0.011	0.02	1.86	0.12		10.5	
	31	3-17-82	6									0.05		0.12	0.73				
Summer sites none found	39	7-07-80		8.2	410	188	232	134		17.7		0.19	0.39	0.06	2.3	0.86	11		20
	40	7-07-80		8.4	519	277	314	176		7.6		0.04	0.10	0.02	0.40	0.36	10		17
	41	7-07-80		7.8	320	137	176	118		17.3		0.04	0.15	0.04	4.4	0.80	2.6		14
	42	7-07-80		8.6	415	222	248	142		6.4		0.02	0.05	0.02	0.20	0.49	4.5		14

<sup>a</sup> See appendix D above for specific location.

Appendix F. Plant species which occurred at only 1 pickerel frog site (site indicated in parenthesis), and were not used for differentiating plant communities.

#### CANOPY

*Acer negundo* (1) 2.4  
*Populus grandidentata* (3) 3.1  
*P. tremuloides* (3) 2.2  
*Prunus serotina* (3) 1.1  
*Betula lutea* (4) 4.1  
*Picea glauca* (4) r.1  
*Pinus strobus* (4) 4.1  
*Thuja occidentalis* (4) r.1  
*Alnus rugosa* (5) 5.4  
*Carya pallida* (5) +.1  
*Corylus americana* (5) 3.3  
*Ulmus rubra* (5) r.1

#### SHRUB-SAPLING

*Acer saccharum* (1) 1.3  
*Betula lutea* (4) 2.1  
*Carya ovata* (4) r.1  
*Carya pallida* (4) 1.1  
*Hamamelis virginiana* (4) 4.2  
*Picea glauca* (4) r.1  
*Carpinus caroliniana* (5) +.2  
*Populus tremuloides* (6) 1.2  
*Sambucus pubens* (10) +.2

#### HERBACEOUS

*Lobelia* spp. (2) +.1  
*Parthenocissus inserta* (2) 1.1  
*Aster laevis* (3) 2.1  
*Equisetum* spp. (3) 5.3  
*Lobelia inflata* (3) 1.1  
*Ambrosia trifida* (4) 2.1  
*Arisaema triphyllum* (4) 2.1  
*Hepatica acutiloba* (4) 2.2  
*Osmorhiza claytoni* (4) 2.1  
*Polygonatum biflorum* (4) r.1  
*polygonum virginianum* (4) r.1  
*Sanguinaria canadensis* (4) 2.1  
*Verbascum thapsus* (4) r.1  
*Acer saccharum* (5) 1.1  
*Alnus rugosa* (5) 1.3  
*Caltha palustris* (5) 3.2  
*Carex pennsylvanica* (5) 2.3  
*Elmys riparius* (5) +.2  
*Hydrocotyl americana* (5) 1.2  
*Maianthemum canadense* (5) 1.1  
*Mitchella repens* (5) 1.2  
*Polygonum arifolium* (5) +.1  
*Solidago flexicaulis* (5) +.1  
*Symplocarpus foetidus* (5) 4 4

*Achillea millefolium* (7) 1.3  
*Angelica atropurpurea* (7) 1.2  
*Asclepias syriaca* (7) +.1  
*Bidens* spp. (7) +.1  
*Glechoma hederacea* (7) 2.3  
*Lythrum salicaria* (7) 2.3  
*Saponaria officinalis* (7) 1.3  
*Silphium perfoliatum* (7) 1.3  
*Stellaria* spp. (7) +.2  
*Gentian* spp. (8) +.1  
*Mentha spicata* (8) +.1  
*Monarda fistulosa* (8) 1.1  
*Oenothera biennis* (8) +.1  
*Potentilla fruticosa* (8) 1.2  
*Rhus radicans* (10) 2.2  
*Scirpus* spp. (10) 2.3  
*Agrostis alba* (11) 2.2  
*Melilotus alba* (11) 1.2  
*Plantago major* (11) 1.2  
*Poa* spp. (11) 2.2  
*Taraxacum officinalis* (11) +.1  
*Trifolium repens* (11) +.1

#### Value

5	Covering more than 3/4 of the sampled area
4	Covering 1/2 to 3/4 of the sampled area
3	Covering 1/4 to 1/2 of the sampled area
2	With any number of individuals covering 1/20 to 1/4 of the sampled area, or very numerous individuals but covering less than 1/20 of the area
1	Numerous, but covering less than 1/20 of the sampled area, or fairly sparse but with great cover value
+	Sparse and covering only a little of the sampled area
r	Rare and covering only a very little of the sampled area (usually only 1 example)

The cover/abundance and the sociability estimate are grouped together with a period between, as 4.2, +.1, etc.

5	In large, solid stands; very dense populations
4	In small colonies or larger mats; rather dense populations
3	In small polsters or patches; distinct groups
2	In small groups or clusters or tufts
1	growing singly

From Benninghoff(1966)