

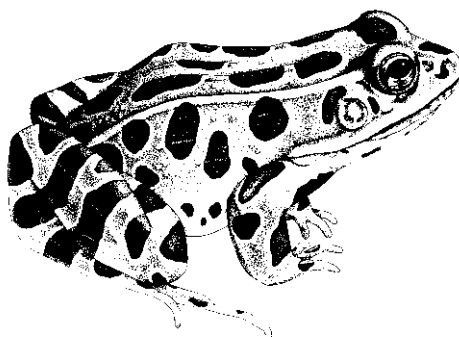
COSEWIC
Assessment and Status Report

on the

Northern Leopard Frog
Rana pipiens

in Canada

Southern Mountain population
Prairie population



ENDANGERED 2000
Southern Mountain population

SPECIAL CONCERN 1998
Prairie population

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE
IN CANADA



COSEPAC
COMITÉ SUR LA SITUATION DES
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AU CANADA

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COSEWIC 2000. COSEWIC assessment and update status report on the northern leopard frog *Rana pipiens* (Southern Mountain and Prairie populations) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 40 pp.

Seburn, C.N.L., and D.C. Seburn. 1998. COSEWIC status report on the northern leopard frog *Rana pipiens* (Southern Mountain and Prairie populations) in Canada, in COSEWIC assessment and status report on the northern leopard frog *Rana pipiens* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-40 pp.

Production note:

The 2000 assessment (Southern Mountain population) and the 1998 assessment (Prairie population) are based on the 1998 status report on the Northern Leopard Frog. The COSEWIC assessment and update status report were subsequently finalised in 2000.

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Également disponible en français sous le titre Rapport du COSEPAC sur la situation de la grenouille léopard (*Rana pipiens*) au Canada

Cover illustration:
Northern leopard frog — illustration by Andrée Jenks, Owen Sound, Ontario

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Catalogue No. CW69-14/85-2002E-IN
ISBN 0-662-31690-8



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COSEWIC Assessment Summary

Assessment Summary – May 2000

Common name

Northern leopard frog

Scientific name

Rana pipiens

Status

Southern Mountain Population: Endangered

Reason for designation

Southern Mountain Population: Although previously widespread and abundant, this frog has suffered severe declines in both distribution and abundance, and is now known from only a single site in the Southern Mountain region.

Occurrence

Southern Mountain Population: British Columbia

Status history

Southern Mountain Population: Designated Endangered in April 1998. Status re-examined and confirmed in May 2000. May 2000 assessment based on new quantitative criteria applied to information from the existing 1998 status report.

Assessment Summary – April 1998

Common name

Northern leopard frog

Scientific name

Rana pipiens

Status

Prairie Population: Special Concern

Reason for designation

Prairie Population: This frog has undergone a widespread contraction of its range in the prairies, particularly in the west, accompanied by increased isolation of its remaining populations. The cause of the range contraction is unknown. There is no sign of recolonization of lost populations in the western prairie areas.

Occurrence

Prairie Population: Alberta, Saskatchewan, Manitoba

Status history

Prairie Population: Designated Special Concern in April 1998.



COSEWIC
Executive Summary

Northern Leopard Frog
Rana pipiens

Declines in *Rana pipiens* populations were first noticed in the early 1970s. Prior to that, this medium-sized frog was widespread and locally common to very abundant across its range, which comprised most of central North America except for the west coast (although it had been introduced to Vancouver Island). Over the following decade, most western populations suffered varying degrees of decline while eastern populations remained intact. Because there was very little monitoring during that time period the spatial and temporal spread of the decline is unclear. The western populations in Canada are the subject of this status report.

Proper assessment of the current status in Manitoba, Saskatchewan and the Northwest Territories is hampered by a lack of information on both the historic and present distribution of the species. Declines in Manitoba *R. pipiens* were first noted in 1975. By 1976 they were virtually eliminated from many areas. Some populations have begun to recover but, in general, densities remain low. There is little information about Saskatchewan declines although it is believed that populations reached a low in the early to mid 1970s and are recovering. *Rana pipiens* vanished from much of their range in Alberta in 1979, although the apparent suddenness of this decline may reflect a prior lack of widespread monitoring. Little or no range recovery has occurred since then. Alberta populations were recently declared provincially endangered. It is unclear when declines in British Columbia populations occurred, but *R. pipiens* have been rare for several years. The only remaining population is at Creston Valley Wildlife Management Area. Declines have also been reported in adjacent U.S. states: Washington, Idaho and Montana as well as elsewhere in the west and mid-west. *Rana pipiens* also appears to be less abundant in northern Ontario than in the past.

Breeding occurs in the spring in temporary ponds. Females can lay up to 7000 eggs. Hatching success is high unless the pond dries up prematurely. Survivorship from oviposition to metamorphosis is often less than 10%. Tadpoles transform in late July or early August. These frogs can disperse up to 8 km by the following spring. Males mature at a smaller size than females. During the summer *R. pipiens* make use of a variety of habitats but, compared with eastern Canada, in the west they tend to be found relatively close to water. Winter habitat requirements include a well-oxygenated water body that does not freeze solid. *Rana pipiens* can overwinter in water bodies with fish if refugia are present.

Many populations occur on private land although they also occur in many provincial and national parks. In Alberta, none of the seven main breeding populations are on protected land although one site is a candidate Natural Area. In British Columbia, the remaining population is at a Wildlife Management Area.

The cause of the historic decline is unknown. Potential causes may include wetland drainage, drought, habitat modification, game fish introduction, pesticide use, disease, wetland eutrophication and/or response to ultraviolet radiation.



COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determines the national status of wild species, subspecies, varieties, and nationally significant populations that are considered to be at risk in Canada. Designations are made on all native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fish, lepidopterans, molluscs, vascular plants, lichens, and mosses.

COSEWIC MEMBERSHIP

COSEWIC comprises representatives from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biosystematic Partnership), three nonjurisdictional members and the co-chairs of the species specialist groups. The committee meets to consider status reports on candidate species.

DEFINITIONS

Species	Any indigenous species, subspecies, variety, or geographically defined population of wild fauna and flora.
Extinct (X)	A species that no longer exists.
Extirpated (XT)	A species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A species facing imminent extirpation or extinction.
Threatened (T)	A species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Not at Risk (NAR)**	A species that has been evaluated and found to be not at risk.
Data Deficient (DD)***	A species for which there is insufficient scientific information to support status designation.

* Formerly described as “Vulnerable” from 1990 to 1999, or “Rare” prior to 1990.

** Formerly described as “Not In Any Category”, or “No Designation Required.”

*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list.



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COSEWIC Status Report

on the

Northern Leopard Frog

Rana pipiens

in Canada

Southern Mountain population
Prairie population

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1998

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INTRODUCTION

Rana pipiens, the Northern Leopard frog or *grenouille léopard* (Fig. 1) is a member of the family Ranidae – or "true frogs" – which is composed of 46 genera and approximately 560 species (Hillis and Davis, 1986). All North American members of the family belong to the genus *Rana*. The species name "*pipiens*" is believed to come from the observation of an early collector who heard a bird-like peeping when he collected *R. pipiens* and assumed the call went with the frog (Pace, 1974). In all likelihood, the call was a different frog, *Pseudacris crucifer* (Spring Peeper). Other common names for *R. pipiens* include the meadow frog, grass frog and laboratory frog (Breckenridge, 1944).



Figure 1. Northern Leopard frog, *Rana pipiens* (David M. Green photo).

Rana pipiens from North and Central America was once considered to be one wide-ranging species with considerable geographic variation (Moore, 1944). The complex was later recognized to be composed of several species, based primarily on differences in call structure (Littlejohn and Oldham, 1968; Pace, 1974) and morphology (e.g. Post and Pettus, 1966, in Hillis *et al.*, 1983; Pace, 1974). *Rana pipiens* is the only member of the complex found in Canada. The species complex is commonly divided into four groups: 1) *R. areolata* group (Crawfish Frogs); 2) *R. berlandieri* group (Rio Grande Leopard Frogs); 3) *R. montezumae* group, including other Mexican species, and 4) *R. pipiens* group (Northern Leopard Frogs; Frost, 1985; Hillis and Frost, 1985, both in Hillis and Davis, 1986). A phylogenetic tree based upon ribosomal DNA for 32 species of *Rana* suggests (Hillis and Davis, 1986) that *R. pipiens*' closest relatives are *R. magnaocularis*, *R. palustris* (Pickerel Frog) and *R. sphenocéphala* (Southern Leopard Frog).

Rana pipiens is a medium-sized, semi-terrestrial frog characterized by conspicuous dark dorsal spots bordered with light coloured rings. It has a whitish belly and prominent light coloured dorsolateral folds. *Rana pipiens* is polymorphic for the background colour of the dorsum. It is commonly green, but may be brown. Background colour is inherited through a simple Mendelian system of two alleles at one locus with green dominant to brown; dorsal coloration is not sex-linked (Fogleman *et al.*, 1980). The polymorphism has been recognized for over 100 years (Cope, 1889, in Corn, 1981). The brown morph can make up 2-68% of a given population (Corn, 1981;

Schueler, 1982; Seburn *et al.*, 1997). In general, green frogs appear to be more common in forested areas and brown in areas of extensive marsh and lakes (Schueler, 1982). Dark spotting appears to be more extensive in warmer, moister climates as compared with cooler, dryer climates and may result from selection for crypsis by matching backgrounds (*Ibid.*). Two rarer colour morphs, “burnsi” and “kandiyohi”, were originally thought to be separate species (Weed, 1922; Merrell, 1972, in Schueler, 1982). Burnsi *R. pipiens* have few or no spots on their dorsum, while kandiyohi have dark interspot reticulations. The two variants are dominant to the normal *R. pipiens* pattern (Moore, 1942; Volpe, 1955). Burnsi and kandiyohi morph frequencies can be as high as 10% in some populations but are generally less than 5% (Merrell, 1970). The distribution of both forms appears to be centered in Minnesota and confined to recently glaciated areas (*Ibid.*), although speckled *R. pipiens* have been reported from Manitoba (Browder, 1968).

Females are larger than males with adults ranging from 50-100 mm svl. Maximum known size is 111 mm svl (Conant and Collins, 1991). Like most anurans *R. pipiens* is sexually dimorphic for forelimb musculature (Yekta and Blackburn, 1992). Although females are larger, most of the forelimb muscles are significantly heavier in males, particularly those involved in clasping the female during amplexus.

Despite the wide geographic range of *R. pipiens* in Canada there have been few in-depth studies of Canadian populations. The largest geographic study examined variation in skin pigmentation across Canada (Schueler, 1982). Other studies have been conducted in Nova Scotia (Gilhen, 1984), New Brunswick (McAlpine and Dilworth, 1989), Quebec (Leclair and Castanet, 1987; Leclair, 1990; Gilbert *et al.*, 1994), Ontario (Emery *et al.*, 1972; Cunjak, 1986; Licht, 1991; Pope, 1996), Manitoba (Eddy, 1976), and Alberta (Seburn *et al.*, 1997).

DISTRIBUTION

Rana pipiens is found throughout most of central and northeastern North America (Fig. 2). A preliminary national range map of *Rana pipiens* was first assembled in the 1940s (Mills, 1948, in Bleakney, 1958) and a dot distribution map appeared about a decade later (Logier, 1955, in Bleakney, 1958).

In Manitoba, *R. pipiens* was historically widespread west and south of Lake Winnipeg (Fig. 3). A subsequent record has been reported east of Lake Winnipeg along the Berens River (Preston, pers. comm.). The northern limit is Southern Indian Lake (57° 10' 00" N, 98° 29' 58" W). *Rana pipiens* was abundant in the marshes along the southern shores of both Lake Winnipeg and Lake Manitoba up until 1975 (Eddy, 1976). It was found in lower density throughout the Interlake area and the rest of the southern portion of the province. Eddy (1976) suggested that *R. pipiens* along the shores of Lake Manitoba comprise a single population.



Figure 2. Distribution of *Rana pipiens* in North America.
(Source: Russell and Bauer, 1993).

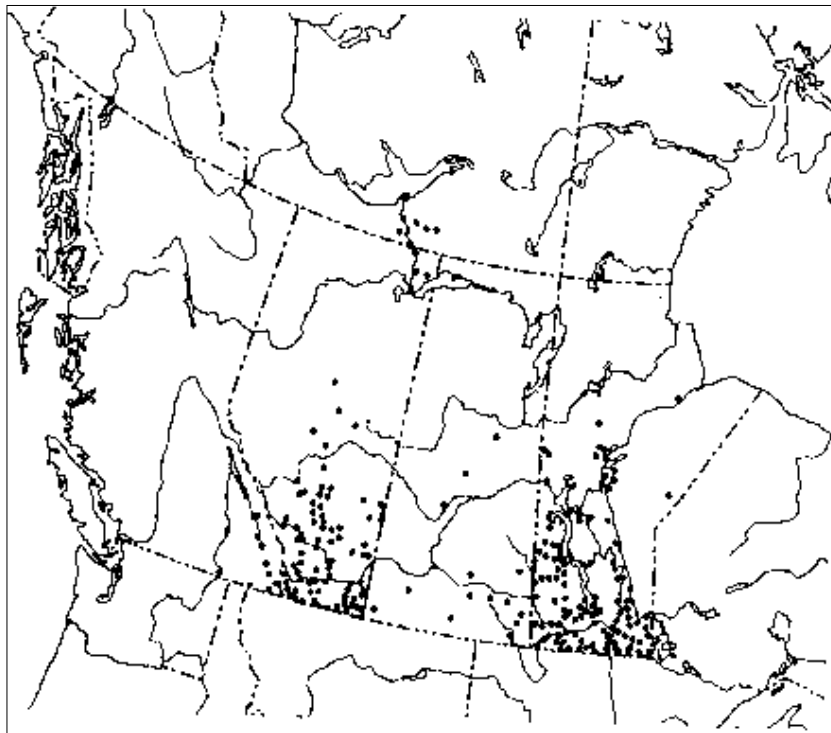


Figure 3. Historic distribution of *Rana pipiens* in western Canada. Data are from various sources — Manitoba: Preston (1982), Saskatchewan: Secoy and Vincent (1976), Alberta: Wagner (1997), British Columbia: (Green and Campbell, 1984), Northwest Territories: M. Fournier (pers. comm.).

In Saskatchewan, *R. pipiens* was widespread and had been described as occurring "in all of Saskatchewan, except the northeast corner" (Secoy, 1987). Except for one location on Lake Athabasca (Secoy, 1987) and a report from between Black and Bompas Lakes, east of Athabasca Lake (Heard, 1985) *R. pipiens* ranged across the province south of about 55° (Lac la Rouge; Fig. 3). In Manitoba and Saskatchewan, the distribution of *R. pipiens* roughly coincides with the transition in the boreal forest from predominantly forest to forest and barrens (Rowe, 1972). This division is not true for Ontario, where *R. pipiens* is found along the coast of James and Hudson Bay (Schueler, 1973).

Rana pipiens in Alberta ranged widely south of 55° (Fig. 3). The historic western limit is the foothills and lower reaches of the mountains. The distribution north of 55° is unclear, although there are records north of Lake Athabasca and in the adjacent Northwest Territories (Fournier, 1997). *Rana pipiens* was found along the Milk, South Saskatchewan, Red Deer, Battle, North Saskatchewan, and Athabasca Rivers (Seburn, 1992c).

Rana pipiens has historically had a limited distribution in British Columbia (Fig. 3). It could be found in the southern Rocky Mountain Trench, near the headwaters of the Kootenay and Columbia river valleys and also in the vicinity of Creston at the southern end of Kootenay Lake (Orchard, 1991). A population at Osoyoos was reported (Carl, 1949, in Orchard, 1991) and *R. pipiens* has been introduced onto Vancouver Island (Green, 1978).

Rana pipiens has a limited distribution in the Northwest Territories (Fournier, 1997), where there are nine known sites. The earliest report is from 1901; three of the sites have recent reports (since 1980).

PROTECTION

The Nature Conservancy has assigned *R. pipiens* a global rank of G5, Very Common, meaning the species as a whole is secure (Oldham, 1996).

The Manitoba provincial Conservation Data Centre assigned *R. pipiens* a rank of S4, Common (Duncan *et al.*, 1994). In Manitoba, *R. pipiens* is first mentioned by name in the Wildlife Act, July 19, 1980, under Division 5 of Schedule A — Amphibians and Reptiles. Before that, it was included in the Wildlife Act under the general definition of wildlife, with "some specific protection by regulation under the Act" (R. Larche, pers. comm.). A permit for collecting was required after September 1971. In April 1973 a quota and season were instigated whereby "a resident holder of an amphibian and reptile picker's licence may hunt, take and sell northern leopard frogs and northern leopard frog tadpoles" for any purpose from August 1 to October 31 and for sale as sport fishing bait only, from May 1 to August 1. A limit of 50 tons, max., of adult northern leopard frogs taken within a calendar year was imposed. Although a commercial season for fish bait exists in Manitoba, few dealers have been active in this business (R. Larche, pers. comm.).

Legislation varies in other jurisdictions. No Saskatchewan amphibians have any legislative protection (Seburn, 1992a) and permits are not required to collect, study, hunt or keep captive any amphibian in the province (Russell, 1996). *Rana pipiens* has a rank of S4, Common, in Saskatchewan (Oldham, pers. comm.). In January 1997, *R. pipiens* was designated "endangered" by the government of Alberta (Wagner, 1997). There is no Conservation Data Centre in Alberta and hence no S-rank. In British Columbia, *R. pipiens* is legally protected from killing or collecting by the provincial wildlife act (L. Friis, pers. comm.). *Rana pipiens* in British Columbia is ranked S1 — Extremely Rare, usually five or fewer populations and especially vulnerable to extirpation (Oldham, pers. comm.). It is designated as "wildlife" in the N.W.T. and may be captured or killed for management or research with a permit (Russell, 1996). There is no S-rank for the N.W.T. In adjacent U.S. states, *R. pipiens* has the following ranks: Washington, S1, Extremely Rare; Idaho, S5, Very Common; Montana, S3/4, Rare to Uncommon and/or Common; North Dakota, no rank (Oldham, pers. comm.). These ranks do not necessarily reflect current distributions. In western Montana *R. pipiens* has "nearly disappeared" although it was once common (J. Reichel, pers. comm.).

POPULATION SIZE AND TREND

Population size

Because amphibian populations fluctuate dramatically from one year to the next, based on stochastic factors such as the weather, the number of populations is a more important criterion for stability than population size (Green, 1997). The number of extant populations is unknown. Although *R. pipiens* is frequently reported at ponds across western Canada many of these sites are not breeding ponds, but sinks for dispersing young of the year (Seburn *et al.*, 1997).

Although data on the number of extant populations in Manitoba is not available, *R. pipiens* were heard calling at between 27-40% of monitored sites from 1993 to 1997 (R. Larche, pers. comm.). These sites were monitored as part of an annual volunteer "backdoor" survey of calling frogs. Results to date: 1993, 25 of 63 (40%) sites reported calling *R. pipiens*; 1994, 20 of 51 (39%) sites; 1995, 13 of 49 (27%) sites; 1996, 30 of 109 (28%) sites (R. Larche, pers. comm.). Unfortunately geographic distribution of these records is not currently available.

The number of remaining Saskatchewan populations is unknown. Based on a lack of recent sightings, populations have greatly declined in number since the late 1970s (Didiuk, 1997). Reports to the Saskatchewan atlassing program indicate *R. pipiens* is still widespread (A. Didiuk, pers. comm.; Fig.4) although there is no information on the size of any of these populations. Given the preliminary nature of the atlassing program it is quite probable that additional populations will be recorded. Volunteer amphibian monitoring in Saskatchewan began in 1993 (SAMP, 1994). Nine of 35 (26%) survey routes reported *R. pipiens* calling that year. *Rana pipiens* was reported from Saskatoon (three routes), Regina, Alvena, Canwood, Conquest, Paddockwood and Perdue. Only

two of the routes reported *R. pipiens* from more than one pond per route. *Rana pipiens* may be under-represented in the surveys as their calling is not always easy to detect. The current distribution map (Fig. 4) implies a wide range, although populations tend to be in isolated drainages or waterbodies (Didiuk, 1997).

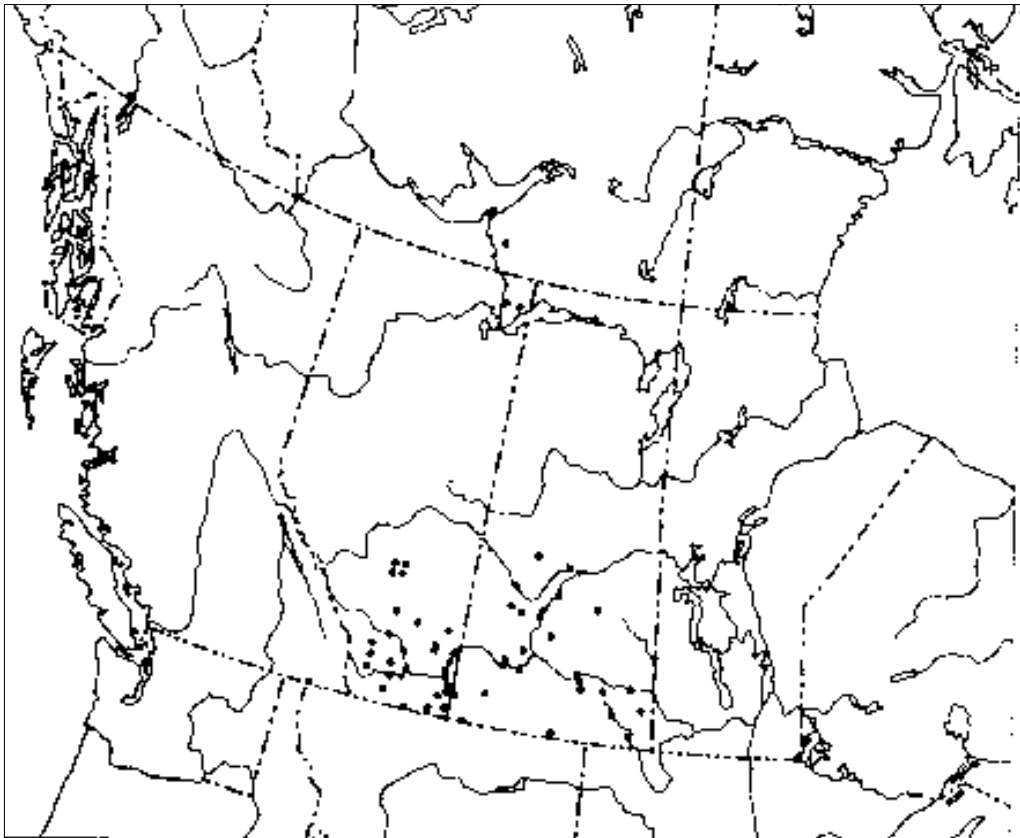


Figure 4. Current distribution of *Rana pipiens* in western Canada. Data are from various sources — Saskatchewan: Andrew Didiuk (pers. comm.) and Saskatchewan Herpetofaunal Atlas Project, Alberta: Wagner (1997), British Columbia: Ohanjian and Teske (1996), Northwest Territories: M. Fournier (pers. comm.). Current distributional data are not available for Manitoba (R. Larche, pers. comm.). Data for Saskatchewan include both historic and current records, some of which have not recently been confirmed.

Of 74 historically known breeding populations in Alberta only 26 remain, with breeding confirmed at only 12 (Fig. 4; Seburn, 1992c). With the exception of one population in the extreme northeast of Alberta (Boquene Lake), all known extant populations are south of the Battle River and all known populations with evidence of successful breeding are south of Drumheller, the majority in the extreme southeastern corner of the province. The maximum number of adults observed at any breeding pond is 40 (Seburn, 1992c). There are seven known major populations. Other sites with confirmed breeding are Milk River Natural Area, Little Bow River, Bow City (Bow River), South Gleichen (Bow River), Coaldale, and Kennedy's Coulee. Recently, *R. pipiens* has been reported to be abundant in Kin Coulee Park in Medicine Hat (Powell *et al.*, 1996). Alberta Fish and Wildlife has been monitoring one population of *R. pipiens* at Prince's

Spring since 1990 (E. Hofman, pers. comm.) and large numbers of young of the year have been seen each year.

Rana pipiens is virtually extirpated in British Columbia. During the mid-1970s, *R. pipiens* at the Creston area in southeastern British Columbia was described as being "numerous" (Ohanjanian, 1996). It was considered uncommon by 1981 and staff at the Creston Valley Visitor's Centre have not seen *R. pipiens* since the mid-1980s. Surveys for *R. pipiens* from 1988-1990 were unsuccessful (Orchard, 1992). In 1991 four *R. pipiens* were located north of Creston at the Duck Lake Nesting Area within the Creston Valley Wildlife Management Area, near the U.S. border. None were located in surveys conducted in 1995, in the Southern Interior Mountains Ecoprovince from Bush Arm, north of Golden, south to the U.S. border at Grasmere and west to Creston (Ohanjanian and Teske, 1996). Neither were they located at Waneta and along Highway 3 west of Creston (Ibid). Calling surveys in 1996 detected a total of only 3-4 males at only one location in the Creston Valley Wildlife Management Area (Ohanjanian, 1996). No egg masses or tadpoles were observed. Summer surveys found no young of the year *R. pipiens*. However, the presence of one sub-adult indicates recent successful breeding. *Rana pipiens* was found at Creston again in 1997 (L. Friis, pers. comm.).

Rana pipiens in the NWT is limited to a small area of "boreal plain" between the Alberta border and Great Slave Lake (Fournier, 1997). There are few observations and no estimates of population sizes. There are reports from this area as recently as 1995.

Population distribution and persistence

Throughout western Canada, the distribution of *Rana pipiens* appears to be more closely tied to major river drainages than is the case in eastern Canada. This may reflect the distribution of suitable breeding and especially hibernation sites as well as the relatively drier climate of the west.

In Manitoba, *R. pipiens* began dying off in 1975 and by the next year was "virtually gone from the major centres of population" (Koonz, 1992). Unlike in some areas, large numbers of dead frogs were found. "Piles of dead and dying frogs were reported from many Lake Manitoba shorelines, whereas heaps nearly a metre high were recorded from the major frog hole area" (Koonz, 1992). Virtually all frogs were wiped out in the densest areas. "Large marshes along Lake Manitoba were silent of Northern Leopard Frog calls, and egg masses were absent" (Koonz, 1992). Small, isolated populations survived. Some recovery was noticed in 1983 and currently *R. pipiens* has reoccupied much of its historic range, and although densities are far below previous levels, at some sites recovery has been "dramatic" (R. Larch, pers. comm.).

There is little information about *R. pipiens* in Saskatchewan. Populations appear to be associated with major river drainages, particularly the North Saskatchewan, South Saskatchewan, Qu'Appelle, Frenchman and Souris Rivers. Anecdotal information suggests that populations reached a low in the early to mid 1970s but are recovering (Seburn, 1992a; Weller *et al.*, 1994). *Rana pipiens* has been tentatively labelled "secure"

in the province (Secoy, 1987). Although populations were acknowledged to fluctuate greatly in size their wide geographic distribution is considered sufficient to classify them as secure. Secoy highlighted two possible factors affecting *R. pipiens*: a decade-long drought and the modification of wetlands in the southern portion of the province. Sloughs and other wetlands are being or have been drained and many streams and rivers are being channelized for irrigation. Because of these factors Secoy argued that *R. pipiens* and other "secure" species may in fact be threatened in the long term.

Rana pipiens vanished from much of its range in Alberta by 1979 (Roberts, 1981, 1992). Subsequently, some additional populations have disappeared (Roberts, 1991). Loss of spawning and overwintering sites does not appear to be a factor (Roberts, 1992). High mortality (attributed to "red leg" disease) was locally evident in 1976. No populations are believed to have been wiped out as a result of this, but it may have been a factor in the decline.

In British Columbia, *R. pipiens* is now quite rare (Orchard, 1992). Alteration of waterways and introduction of predatory fish are two possible causes of the decline. Fish introductions have been implicated in anuran declines in the Sierra Nevada of California (Drost and Fellers, 1996) and in the southern portion of the province "game fish have been introduced into virtually every water body that can support them" (Orchard, 1991).

Rana pipiens declines are not confined to western Canada. In eastern Canada, there is some evidence to indicate that *R. pipiens* is not as common in northern Ontario as it was historically (Weller *et al.*, 1994). A recent survey of areas from Sudbury to Geraldton failed to locate any *R. pipiens* north of Sault Ste. Marie (Seburn and Seburn, 1997). In Washington state, *R. pipiens* has "been extirpated from most of its historic range" (Leonard and McAllister, 1996). *Rana pipiens* was found in only two of 15 known historic locations surveyed between 1992 and 1995. The cause of the decline is unknown, although *Rana catesbeiana* (Bullfrog) introductions (*R. catesbeiana* was not found in the two remaining *R. pipiens* sites), game fish introductions, wetland modification and pollution have been suggested. In western Montana, *R. pipiens* "has nearly disappeared" from where it was once common (J. Reichel, pers. comm.). Declines may have begun as early as 1970. The current distribution in eastern Montana is poorly known, although *R. pipiens* appears to be declining. Declines have been reported from southern Idaho and eastern Oregon (Koch *et al.*, 1996). There has been some evidence of increasing numbers of *R. pipiens* in eastern Idaho in recent years. Nine populations studied in Colorado from 1973-1982 all went extinct (Corn and Fogleman, 1984). Five populations were eliminated because of the ponds drying up in the mid-1970s as a result of drought. It is unknown why the others were wiped out. Examination of 13 historic sites in Arizona from 1983-1987 failed to locate any *R. pipiens* (Clarkson and Rorabaugh, 1989). One previously unreported population was found. *R. catesbeiana* was present at only one of the 13 sites.

Trends

There has been a significant and widespread decline of *Rana pipiens* throughout the western portion of its range in Canada and the United States. While declines in Manitoba and Wisconsin were accompanied by evidence of dead frogs this was not generally so. In British Columbia and Alberta the decline has resulted in a significant range contraction with more southern populations faring better than those at the northern limit (with the exception of the N.W.T. and extreme northeastern Alberta). In Saskatchewan and Manitoba, however, the historic range appears to be intact although the number of populations reduced. There is some evidence that numbers have rebounded moderately within the extant range but there is no evidence of recolonization in the broader areas where the species completely disappeared. Although precise dating of the decline is not possible, except in Manitoba, the data are consistent with the decline having occurred during the mid-late 1970s.

Further detail on historic events is hampered by a lack of data. Volunteer monitoring programs may eventually determine the number of extant populations in Saskatchewan and Manitoba. Thus, while it is clear that a dramatic decline occurred it is unclear if *R. pipiens* continues to decline, is currently stable or increasing. For example, the Manitoba Conservation Data Centre lists the population trend for *R. pipiens* as either Stable or Declining (Duncan *et al.*, 1994).

HABITAT

Habitat definition

Rana pipiens breeds in a variety of wetland types including ponds, quiet backwaters of streams (Merrell, 1977; Seburn, 1992b), roadside ditches, borrow pits, channels and permanently flooded meadows (Eddy, 1976). Breeding has been reported in the backwaters of creeks or rivers, oxbows, upland ponds and in upland spring-fed wetlands in Alberta (Wershler, 1991). The typical breeding site, as noted in Minnesota, is a temporary pond 30-60 m in diameter, with a depth of 1.5-2 m, which does not support a fish community (Merrell, 1968). Water depth of 1.5 m or more appears to be more important than pond area, in Wisconsin (Hine *et al.*, 1981). In shallow temporary ponds there is a greater risk of eggs and larvae dying as water levels drop during the summer (Eddy, 1976; C. Seburn, pers. obs.). In dry years successful breeding may be limited to areas with permanent water (Eddy, 1976). Nevertheless, Merrell (1968) described breeding ponds as typically not connected to other water bodies and drying up every few years. This characteristic prevents the establishment of significant fish populations which might prey on eggs or larvae.

Aquatic vegetation is also an important characteristic of breeding sites. Breeding sites in Wisconsin have emergent vegetation covering approximately two-thirds of the edge and submergent vegetation is present on roughly 50% of the surface area in May (Hine *et al.*, 1981). Breeding ponds tend to have gradual slopes allowing for more space

for emergent vegetation and are in open areas that receive plenty of sunlight. The habitat surrounding breeding ponds is usually inland fresh meadow, shallow marsh, unmowed pasture or hayfield. Emergent vegetation at Alberta sites often include *Typha latifolia* (Cattail), *Scirpus* spp. (Bulrushes) and *Carex* spp. (Sedges) either separately or together (Wershler, 1991). Most breeding sites have a large amount of open water but at least two were almost solid marsh. In Alberta, almost all ponds with *Rana pipiens* are not silty (Seburn, 1992b). Pond substrate is highly variable although breeding sites tend to have substrates overlain with decomposing vegetation.

In examining water quality variables (conductivity, pH, alkalinity, SO_4 , Cl, NA, CA, MG, K, HCO_3 and CO_3) at 23 breeding, non-breeding (but *R. pipiens* present) and historic (no frogs present) sites in southern Alberta in 1991, Seburn (1992b) found significantly higher levels of CO_3 at historic sites compared to 1990 breeding sites. Water quality at four breeding sites in southern Alberta in 1992 (C. Seburn, 1993) had pHs ranging from 8.5 - 9.5, dissolved oxygen from 8.8 - 16.3 ppm, CO_2 from 0-29.6 ppm, hardness from 151 - 342 ppm, alkalinity ($CaCO_3$) from 305 - 470 ppm and turbidities (dimensionless description of water cloudiness) from 40 - 42, except of one site where turbidity ranged up to 90.

Rana pipiens tends to be widely dispersed in the summer in a variety of terrestrial habitats. Merrell (1977) found it easier to describe those which are rarely used. *Rana pipiens* is generally not found in heavily treed areas, in grass more than a metre tall, or on open sandy areas lacking vegetation, although it is found in sandy areas at night at Long Point, Ontario (D. Green, pers. comm.). It is rarely found in heavily grazed pasture or places where the grass has been closely cropped. Preferred habitat seems to be in vegetation 15-30 cm tall (Merrell, 1977). In taller vegetation, insects are more apt to be out of reach. Edges between habitats are often preferred because of their higher structural diversity. Juveniles are rarely found far from water, likely because of the risk of dehydration (Whitaker, 1961). In Alberta, summer habitat was found to be quite diverse (Wershler, 1991), including shorelines with little or no vegetation such as badlands along grassland and parkland rivers, shorelines with abundant vegetation including grasses, sedges and willows, and open areas away from shorelines. Unusual habitats include the shores of larger lakes in the Boreal-Mixed Wood forest and fens and swamps. Most frogs are found close to water, allowing easy escape when approached. *Rana pipiens* also has been found around no human-made ponds at a golf course in Medicine Hat (Seburn, 1992b). It may be confined to areas close to water except during rain showers (C. Seburn, 1993). In New Brunswick, the mean height of vegetation where *R. pipiens* is found was 32.0 cm, with a range of 9-85 cm (McAlpine and Dilworth, 1989). This is similar to *Rana clamitans* (Green Frog) which was found in vegetation averaging 55.2 cm. *R. pipiens* selected denser vegetation: average of 2288.8 stems/m², whereas *R. clamitans* averaged only 481.6 stems/m².

Because *R. pipiens* requires a variety of habitat types throughout the year (breeding, foraging and hibernation sites) the proximity and connectedness of these habitats is also important (Seburn *et al.*, 1997). For example, in Wisconsin, breeding ponds are within 1.6 km of hibernacula (Hine *et al.*, 1981).

Habitat trends

Wetland loss is one of the most devastating pressures on amphibian populations. It is estimated that over half of historical wetlands in southern Canada have been drained, mostly for agriculture (Biodiversity Science Assessment Team, 1994). Up to 70% of prairie wetlands have been lost this century. In Manitoba, circa 1950, there were approximately 2000 km² of prairie wetlands (Bethke and Nudds, unpublished manuscript, in Sinclair *et al.*, 1995). By 1990 roughly 20% of these wetlands had been lost. The amount of wetlands has apparently stabilized since the early 1980s. During the same time period, Alberta lost 50% of its 4000 km² of wetlands. Unlike Manitoba, the loss of wetlands in Alberta accelerated during the 1980s. It is estimated that 59% of all wetland basins and 78% of all wetland margins in southern Saskatchewan have been affected by agriculture (Turner *et al.*, 1987, in Didiuk, 1997). Wetlands may also be lost through drought. Even if the drought is temporary, dry sloughs may be brought into cultivation and not be regained when the drought ends.

Habitat protection

Too little is known about the present distribution of *R. pipiens* in Manitoba to speculate on the amount of suitable habitat protected (Duncan *et al.*, 1994). Although *R. pipiens* "occurs in Riding Mountain National Park and most provincial parks, wildlife management areas and refuges, this does not mean that habitat is protected from industrial development or that commercial or personal harvest is prohibited" (R. Larche, pers. comm.). The major population studied by Eddy (1976) occurred on the University of Manitoba Field Station property at Delta Marsh, on Lake Winnipeg. *Rana pipiens* has been reported from Grasslands National Park in southern Saskatchewan (Seburn, 1992a). *Rana pipiens* has been observed on Battle Creek near Cypress Hills Inter-Provincial Park near the Saskatchewan-Alberta border, and a large population is within 8 km of the park (Seburn, 1992c). Another protected population is at the Milk River conservation area in Alberta (Seburn, 1992c).

A management plan for *R. pipiens* in Alberta determined there are seven major populations. None are protected, although some are public land leased for grazing. One of the sites (Old Channel Lake) is adjacent to the Suffield National Wildlife Area which is protected. Recent surveys indicate that *R. pipiens* is present in Suffield (L. Powell, pers. comm.). In addition, a population is known from Kin Coulee Park, a municipal park in Medicine Hat (Powell *et al.*, 1996). Although the park is protected from commercial development, it is unclear how much "beautifying" the city does (e.g. spraying of weeds, lawn maintenance).

The remaining known *R. pipiens* population in British Columbia is in the Creston Valley Wildlife Management Area (Ohanjanian, 1996). The wildlife area is 7,000 hectares of dykes, ponds and marshes, and is excellent *R. pipiens* habitat. This area is protected by the British Columbia government and by the RAMSAR International Convention on Wetland Protection (I. Ohanjanian, pers. comm.).

GENERAL BIOLOGY

Reproduction

Rana pipiens emerges from overwintering ponds when the water temperature rises to 7-10° C (Licht, 1991). Adults emerge before juveniles (Dole, 1967a). Migration to breeding ponds can occur on warm, rainy nights (e.g. Michigan, Dole, 1967a), but in those areas where the nighttime temperature is substantially lower than the daytime temperature it can occur during the day (e.g. Minnesota, Merrell, 1977; Alberta, C. Seburn, pers. obs.). Breeding generally occurs during late April and the first three weeks of May in Manitoba (Eddy, 1976) and in early May in Alberta (C. Seburn, 1993).

R. pipiens calls at water temperatures of 10°C and air temperatures of 15°C (Seburn, 1992b). Males float on the surface, often clustered in the warmest part of the pond, (Merrell, 1977). Males have been observed calling from beneath the water's surface (C. Seburn pers. obs.). Such calls can only be heard a few metres away. In some prairie sites hibernation and breeding occur in the same waterbody (C. Seburn, pers. obs.) which may explain calling from under water.

Typically the call of *R. pipiens* is made up of three components in sequences of ABBCBCBC or AB(B) or AB(B)C(CCCC), where A is a long, multiple pulsed trill, B a shorter trill with a faster pulse rate and C a shorter trill with a slow pulse rate (Pace, 1974). Playback experiments with the call suggest that A acts as a long distance attracting call, B helps females to orient after entering the pond and C is a spacing or aggression call. Both males and unreceptive females will give a release call (McClelland and Wilczynski, 1989). The male call is more complex because of more highly developed vocal chords (Ibid.).

Females arrive at the breeding pond 3-14 (usually 5-7) days after calling begins in Wisconsin (Hine *et al.*, 1981). In Manitoba, most of the later migrators were female supporting this as a widespread phenomenon (Eddy, 1976). Even when present, females often tend to conceal themselves in the vegetation in the water near the calling males (Merrell, 1977). Because of this, observed sex ratios during the breeding season are generally strongly male skewed, up to 9:1 (Merrell, 1968). Sex ratios at other times are approximately 1:1 (Merrell, 1968; Hine *et al.*, 1981; and Leclair, 1983, in Gilbert *et al.*, 1994).

Males are not discriminating in mate selection. They have been observed in amplexus with females of three other species of ranids and even with a *Bufo americanus* (American Toad) female (Wright, 1914, in Merrell, 1977). Males have been seen in amplexus or attempted amplexus with an *Amia* sp. (Bowfin) in an aquarium and even with a floating beer can (Merrell, 1977).

When clasped by a male, a female remains silent although she may struggle. This effort is usually unsuccessful because the male's thumb pads are enlarged during the breeding season, allowing him to clasp the female firmly. Such struggling may dislodge small males. Occasionally males may intercept and mount females while still on land

(Merrell, 1977; Schueler and Karstad, 1996). Multiple males have been observed attempting to mate with a single female (Eddy, 1976). Once frogs are in amplexus, oviposition and fertilization proceed quickly (Merrell, 1977). A female mates only once and lays all her eggs in a single egg mass. The male releases her within a minute after oviposition and the female leaves the pond (Noble and Aronson, 1942; Aronson and Noble, 1945; both in Merrell, 1977). If warm weather persists all mating can be completed within 2-7 days (Hine *et al.*, 1981). If cold weather interrupts the breeding season, breeding will resume once warm weather returns, up to 2 weeks later.

Egg-laying sites are often concentrated. Up to 23 egg masses/10 m² have been observed in Quebec (Gilbert *et al.*, 1994). Egg masses are attached to submerged vegetation or laid at the surface (Merrell, 1977; Hine *et al.*, 1981; Gilbert *et al.*, 1994). Egg masses from Manitoba have been reported from the bottom of flooded areas, 31-38 cm under water (Eddy, 1976). In Alberta, egg masses were observed in a flooded pasture that dried before hatching could occur (C. Seburn, pers. obs.). A variety of plant species are used to attach the egg mass, including *Carex* spp. (Hine *et al.*, 1981; Corn and Livo, 1989), *Typha* spp. (Eddy, 1976; Hine *et al.*, 1981) or *Scirpus* spp. (Corn and Livo, 1989). The density of egg masses varies from 12-1075 egg masses per hectare with a mean of 277/ha (Hine *et al.*, 1981).

Individual females have been recorded to lay up to 7000 eggs in Nebraska (Hupf, 1977, in Corn and Livo, 1989), although half this number is more common (Corn and Livo, 1989). The number of ovarian eggs is positively correlated with body length (Gilhen, 1984; Gilbert *et al.*, 1994). Egg masses average 87 mm long (range: 40-150 mm), by 63 mm wide (30-100 mm), by 69 mm deep (40- 110 mm; Hine *et al.*, 1981) and range in volume from 50-180 ml, with an average of 90 ml (Eddy, 1976). Egg density averages 21.3 embryos/ml. Using this density, Eddy estimated over one million *R. pipiens* eggs were laid at one of her study sites only 60 x 80 m in size.

The eggs themselves are small (1.5 mm in diameter) and velvety black (Dickerson, 1907). The underside of the eggs is white in colour. The eggs can hatch in 9 days or less. Hatching of eggs in Manitoba has been reported from May 7-29 and May 17-25 during two consecutive years (Eddy, 1976). For the two years, hatching occurred on average 11 and 10 days after deposition, respectively. For the same two years, cumulative degree-days (calculated as degrees above 4°C) varied from 131.7 to 104.3, from deposition to hatching. *Rana pipiens* eggs, from an unspecified source (likely eastern US), were killed by temperatures of 2.5°C (Moore, 1939). Eggs survived exposure to 5.0° and normal development occurred above 8.4°. The thermal maximum is approximately 28°, although embryos have developed normally at 30°. Egg development has been described in detail by (Dickerson (1907).

Physiology

Adult *R. pipiens* can tolerate levels of salinity as great as 6.0 parts per thousand for at least three months (Ruibal, 1959). Frogs die within three hours of exposure to concentrations of 13 parts per thousand. For embryos, the minimum lethal

concentration is 5.0 parts per thousand (Ruibal, 1959). Between 3.8 and 4.6 parts per thousand, development is usually successful, although abnormalities such as enlarged yolk-plugs and small tadpoles are common. Below 3.8 parts per thousand, development is always successful although abnormalities are still present at concentrations as low as 2.5 parts per thousand. Yolk-plug size is positively correlated with salinity.

A number of studies have examined the effect of acidity on the life cycle of *R. pipiens*. One study found that fertilization of eggs at pH below 6.5 was reduced (Schlichter, 1981). However, Freda (1986) questioned the validity of this result because toxic sodium acetate/acetic acid buffers were used in the study. pH does not influence fertilization of eggs (Karns, 1983 in Freda 1986; Andren *et al.*, 1988) and embryos can survive in relatively acidic water. Over 50% of embryos survive in water with a pH of 4.4 (Freda and McDonald, 1990), but at pH 4.2 mortality is almost 100%.

Water absorption rates of amphibian skin varies with the species. *Rana pipiens* skin has a permeability of about 10 mg of water hour⁻¹ cm⁻² (Schmid, 1965), in contrast to *Bufo americanus* with an absorption rate of about 18 mg of water hour⁻¹ cm⁻². Typically there is 0.814 g of water for every gram of body mass (Churchill and Storey, 1995) in *R. pipiens*. Frogs from Michigan dehydrated to 65- 75% of their normal weight could completely rehydrate within 48 hours simply by sitting on sand with a moisture content of 20% (Dole, 1967b). On sand with a moisture content of 10%, frogs regain almost 60% of the lost water in 48 hours. When forced to remain in very arid conditions frogs bury themselves in the soil. In nature, frogs would most likely move to moister areas.

Rana pipiens can survive loss of up to 50% of the total body water (approximately 40% of body mass) at 5°C (Churchill and Storey, 1995). Water loss is concentrated in skeletal muscles, whereas internal organs lose only 3-8% of their wet mass (Churchill and Storey, 1995). Dehydration provokes a rapid increase in blood glucose from conversion of glycogen to glucose in the liver. Both the brain and the kidney display increased levels of glucose. As this procedure is similar to freeze tolerance initiation in *R. sylvatica* (Storey and Storey, 1984; 1986), Churchill and Storey theorized that freeze tolerance is a specialized adaptation of the more general dehydration response. *R. pipiens* is not freeze-tolerant (Churchill and Storey, 1995).

Food habits

Rana pipiens is an indiscriminate predator, eating anything of appropriate size that moves. Foraging involves orienting, approaching slowly and then making a terminal leap of 15-40 cm (Wiggins, 1992). The success rate drops when the frog has to move more than 40 cm before lunging. The success rate is higher when the nearest neighbouring frog is more than 240 cm away.

Rana pipiens feeds primarily upon arthropods and to a lesser extent earthworms, snails and slugs (Moore and Strickland, 1954). All 20 stomachs examined contained insects of some kind. Over half yielded coleopterans (beetles), dipterans (true flies) and homopterans (leafhoppers). Less commonly found insects included hymenopterans

(bees and ants), hemipterans (true bugs), orthopterans (grasshoppers), lepidopterans (moths and butterflies) and odonatans (dragonflies). Similar results were found for 11 adults from Wisconsin (Hine *et al.*, 1981). Prey items include nocturnal and diurnal species suggesting that frogs feed both day and night.

There is marked seasonal variation in stomach contents corresponding to prey abundance in Manitoba (Eddy, 1976). For example, insects are found in 50% of stomachs in early fall and 96.5% in the spring. During a chironomid midge hatch one year the stomach contents examined were 100% chironomid remains. The average prey length found in stomachs of 42 *R. pipiens* from New Brunswick was 13.2 mm (range 3.0-55.0; McAlpine and Dilworth, 1989).

Unusual prey items recorded include a small *Thamnophis* sp. (Garter Snake), 3 separate cases of *Archilochus colubris* (Ruby-throated Hummingbird), *Dendroica petechia* (Yellow Warbler; Breckenridge, 1944), *Clethrionomys gapperi* (Red-backed Vole) and *Microtus pennsylvanicus* (Meadow Vole; Eddy, 1976). Most prey are terrestrial in origin (Walker, 1967). Feeding by tadpoles has not been examined intensively. Although tadpoles are primarily herbivorous they also feed on dead animals, including other tadpoles (Merrell, 1977). Adult *R. pipiens* will also consume frogs, including small conspecifics (Eddy, 1976; Merrell, 1977). At least 10% of the frogs examined from Manitoba had consumed recently transformed frogs (Eddy, 1976). Up to three frogs were detected per stomach. Larger *R. pipiens* are more apt to be cannibalistic, however cannibalism occurs in all age classes older than one year. Males and females are equally prone to cannibalism. *Rana pipiens* tadpoles also are eaten.

Growth and survivorship

Upon hatching, *R. pipiens* tadpoles are approximately 7.75 mm long, slender and black (Dickerson, 1907). They cling to the jelly mass or the aquatic vegetation by means of two "suckers" that secrete a sticky substance. After 2-3 days of rapid development the tadpoles become free-swimming organisms. As Dickerson puts it: "Their life for the next few weeks seems to have only four needs: to swim rapidly, to eat almost constantly, to rest a little sometimes, and to grow." Tadpole development and the average size at each stage have been summarized (Taylor and Kollros, 1946). At a constant temperature of 20°C, it takes approximately 90 days for larvae to complete growth and development. The average length of the larval period ranges from 68.2-86.0 days in Colorado (Corn, 1981). A variety of factors influence the rates of growth and development and the resulting size at metamorphosis (Werner, 1986).

Tadpole studies in Alberta provide some information on body size and geographic variation. By the end of June, tadpoles at a site near Empress, Alberta (east of Calgary on the Saskatchewan border) averaged 11 mm svl and 59 mm total length (C. Seburn, 1993). The modal developmental stage was 36 of 46 stages; first and second toes on hind limbs still joined (Porter, 1972). When only stage 36 tadpoles were compared it was found that tadpoles from Empress were significantly smaller than those from a site in the Cypress Hills in southeastern Alberta: 27.1 vs. 31.5 mm svl.

Tadpole body length is highly correlated with cumulative degree-days since hatching for a given pond during a particular year (Eddy, 1976). However, the growth rate with respect to the cumulative-degree days (slope of the regressions) significantly differs among ponds and for the same pond over time. Eddy attributed this to variation in productivity over time and between the sites.

Crowding is well known to inhibit growth in tadpoles (Wilbur, 1976). *Rana pipiens* tadpoles kept in aquaria with partial dividers creating "rooms" the tadpoles could freely move around in, grow larger than tadpoles kept in open aquaria (John and Fenster, 1975). It was speculated that growth was tied more to the frequency of physical interactions with other tadpoles than with the actual space available per tadpole.

Colour morph may be correlated with important developmental characteristics. Research in Colorado indicates that embryos that will become brown frogs have higher developmental rates than those embryos that become green frogs (Corn, 1982). "Brown" tadpoles have a shorter larval period than "green" tadpoles (Corn, 1981). After transformation the green frogs grow faster than the brown ones (Corn, 1982).

Rana pipiens tadpoles depress the growth of *R. sylvatica* tadpoles at low food levels (Werner, 1992). This effect is reduced when *R. sylvatica* tadpoles are larger than *R. pipiens* tadpoles. *Rana pipiens* tadpoles grow faster when kept with *R. sylvatica* tadpoles than with an equal number of conspecifics. *Rana pipiens* tadpoles are more active than *R. sylvatica* tadpoles and may eat the food faster. However, a series of experiments conducted in enclosures in a large pond found variable results (DeBenedictis, 1974). When food and predator levels were altered, both species show reduced growth in mixed populations.

In Alberta, tadpoles transform in late July or early August (C. Seburn, 1993). Average size at metamorphosis varies from 31-40 mm svl. Tadpoles from Manitoba transform at an average size ranging from 33-37 mm svl (Eddy, 1976). Premature drying of ponds may encourage rapid transformation of late stage tadpoles. Metamorphs under such conditions are only 25-30 mm svl compared with the usual size range of 35-40 mm svl in Minnesota (Merrell, 1977).

Size at metamorphosis can have long term implications. At low density, tadpoles metamorphose at 48-50 mm svl in Minnesota (Merrell, 1969, in Merrell, 1977). By the end of summer frogs are more than 55 mm svl, the approximate size of sexual maturity. Usually, young of the year *R. pipiens* would not attain this length until the next year. *Rana pipiens* from Manitoba also have been reported to attain large size during their first year (Eddy, 1976). Young of the year frogs from 1974 were larger than in previous years, despite the fact that metamorphosis was late that year. Eddy reports that several frogs grew "nearly to the size of mature frogs in one season" (p. 38) and that a few males possessed characteristics of maturity: nuptial pads and vocal sacs. If rate of development is consistently related to larval density, then populations may have some self-regulating capability — adults would be recruited into the population more rapidly after poor breeding years.

In the first few days of terrestrial life, newly transformed *R. pipiens* stop growing (Hine *et al.*, 1981). Young of the year lose 1.5-2.5 g during their first four days (*Ibid.*). However, after one month, juveniles grow from 39 mm svl (8.0 g mass) on average to 50 mm svl (11.6 g mass). Temperature effects growth rates of newly transformed frogs as well as tadpoles. Young of the year *R. pipiens* from Colorado raised at different temperatures with unlimited food grow faster at warmer temperatures (Corn, 1982). Growth ceases below 11.6°C.

Skeletochronology has been used to model growth rates in a Quebec population of *R. pipiens* (Leclair and Castanet, 1987). Estimated length at first winter is 45.8 mm svl (range: 31-56 mm svl). By the second winter estimated body length is 65.7 mm and by the third winter it is 78.4 mm. Despite the apparent size differential, there is great overlap between age classes. Hence, size alone cannot be used to differentiate one and two year old frogs.

Sexual maturity is more likely size-dependent than age-dependent, as is the case for most ectotherms. Females reach this size at 55 (Hine *et al.*, 1981; Merrell, 1977) to 60 mm svl (Gilbert *et al.*, 1994). Just over half of one year old males are mature at 51 mm svl (*Ibid.*).

The maximum known longevity of *R. pipiens* in captivity is 9 years (Froom, 1982). Based on skeletochronology, the oldest *R. pipiens* from Quebec was found to be 4 years old (Leclair and Castanet, 1987).

Rates of survivorship and sources of mortality vary greatly over the life cycle. Hatching success is generally high, averaging 70-99% in Colorado (Corn and Livo, 1989). Approximately 5% of Wisconsin eggs are lost to parasitism, disease, or other factors (Hine *et al.*, 1981). Of those egg masses laid on the surface of the water 15-20% appear to be lost to desiccation. Mortality at one site in Manitoba was estimated to be 50% (Eddy, 1976). Failure to develop accounts for 20% of the mortality and physical displacement and/or breaking up of the egg mass the remainder. Complete reproductive failure can occur if the pond dries up before metamorphosis (Merrell, 1977). Repeated premature drying of ponds can lead to extinction of the population (Corn and Fogleman, 1984). The only predators of *R. pipiens* eggs mentioned in the literature are newts (Wright, 1914, in Merrell, 1977).

Most mortality occurs in the tadpole stage. Estimates of survivorship from embryo to metamorphosis range from 1-6% (Wisconsin; Hine *et al.*, 1981), <2% (Michigan; DeBenedictis, 1974), 2.3-7.5% (Colorado; Corn, 1982), and 3.3% (Minnesota; Merrell, 1977). The highest survival in Wisconsin occurred in the largest pond and the one least affected by agriculture (Hine *et al.*, 1981). The lowest survival was in small ponds surrounded by agricultural land. In predator-free enclosures survivorship to transformation range from 1.3-26.8% (DeBenedictis, 1974).

One indication of predation levels on tadpoles is the incidence of non-lethal encounters evident from tail damage. Two areas of a wetland near Empress, Alberta were compared and it was found that rates of tail injury varied from 39-88% (C. Seburn, 1993).

A variety of predators on tadpoles have been reported, including waterfowl, fish, and aquatic insects (Dickerson, 1907). Insect predators include odonata larvae include Phryganeidae (Caddis-fly larvae), adult and larval Dytiscidae (diving beetles), *Notonecta* spp. (Back-swimmers) and *Belostoma* spp. (giant waterbugs). *Batrachobdella picta* (a leech) is also a common predator (DeBenedictis, 1974). Other predators include *Thamnophis* and *Nerodia* spp. (Pope, 1964) and adult *R. pipiens* (Eddy, 1976). *Rana catesbeiana* is a confirmed predator of its own larvae (McAlpine and Dilworth, 1989) and probably other species of tadpoles as well.

In Manitoba, "large numbers of dead but uninjured tadpoles" were found at one site in 1973 (Eddy, 1976). The tadpoles were similar in size to living tadpoles indicating that there was no difference in growth. Eddy proposed over-production of algae could have resulted in anoxia killing the tadpoles. Dissolved oxygen content of the water was approximately 3 ppm. The previous year the plant growth was slower and the tadpoles had transformed before the channel became choked with vegetation. In 1974, the year after the mass mortality, plant growth was again slow and dissolved oxygen was never less than 7.5 ppm, but adults and sub-adults "were extremely scarce in the spring" (p. 61).

After transformation, young of the year frogs can comprise up to 98% of the population (Eddy, 1976). The ratio of young of the year to sexually mature frogs varies from 15:1 to 20:1 in Minnesota (Merrell, 1977). Annual adult mortality was estimated at about 60% (Merrell and Rodell, 1968, in Merrell, 1977). Overwintering mortality at one site, in Alberta, in 1994 was estimated at 93% (Yaremko, 1994) although this value includes dispersal as well as mortality (Wagner, 1997).

Mortality can occur during overwintering, dispersal or at other times. Overwintering mortality may result from anoxia, freezing, lack of sufficient fat stores, or disease spread by crowding (Hine *et al.*, 1981). Possible sources of mortality during dispersal include increased risk of predation, desiccation, inability to find an appropriate habitat or traffic mortality. The effect of traffic mortality is considerable. Over 1000 young *R. pipiens* were found dead on a road one morning in Minnesota (Merrell, 1970). The road had been paved the day before so the frogs were killed in an exodus from the breeding pond the previous night. Unfortunately it is unclear how far the road was from the pond.

Juvenile and adult *R. pipiens* are preyed upon by a large variety of predators. Predation is a potential threat at all stages although *R. pipiens* may be most vulnerable when active. Eddy (1976) observed that predators are only abundant when *R. pipiens* can be found at high densities. Predators apparently shift to other prey when frogs are less active or more dispersed. A total of 20.6% of identifiable *Rana* remains from *R. catesbeiana* stomachs from Nova Scotia are recently transformed *R. pipiens* (McAlpine and Dilworth, 1989). Predators on *R. pipiens* include *Thamnophis* and

Nerodia spp., turtles, and leeches (Merrell, 1977), herons (Ardeidae), *Procyon lotor* (Raccoons), and owls (Oldfield and Moriarty, 1994), as well as *Heterodon* spp. (Hognose Snakes), *Coluber constrictor* (Racers), *Pituophis melanoleucus* (Gopher Snakes), *Podilymbus podiceps* (Pied-billed Grebes), mergansers, hawks and fish (Breckenridge, 1944). *Salvelinus fontinalis* x *S. namaycush* (Splake) and *S. fontinalis* (Brook Trout) eat *R. pipiens* during the winter and *S. namaycush* (Lake Trout) eat them in the spring (Emery *et al.*, 1972). In addition, large numbers of juveniles are used every year as bait by fishermen. *Rana pipiens* has been described as being commonly eaten by people (Pope, 1964).

Hibernation

Hibernation occurs in a well-oxygenated water body that does not freeze solid and is likely triggered by temperature, because *R. pipiens* select water over land at air temperatures of 1.5°C (Licht, 1991). *Rana pipiens* overwinters in springs in the gravelly floodplain of the Clearwater and Milk rivers, in Alberta (Roberts, 1981, 1990 in Wershler, 1991) and the bottom of Lake Manitoba (Eddy, 1976). Overwintering in a cave has been reported from Indiana (Rand, 1950, in Emery *et al.*, 1972).

Rana pipiens often overwinters in water bodies other than breeding ponds. Pond selection may be by temperature because large ponds stay warm longer than small ones (Merrell, 1977). Dissolved oxygen may be a critical factor. Most overwintering sites are associated with springs in southern Alberta (Wershler, 1991). Elsewhere they are found in streams, spillways below dams and in deeper lakes and ponds (Cunjak, 1986; Emery *et al.*, 1972; Merrell, 1977; Roberts, 1981), areas where dissolved oxygen is likely to be relatively high. *Rana pipiens* can successfully overwinter in fish-bearing ponds where the water temperature on the bottom is approximately 2.5° C and oxygen content is about 7 ppm (Emery *et al.*, 1972). In a 10-hectare pond containing predatory fish *R. pipiens* was found in the centre of small circular excavations at the surface of the mud (*Ibid.*). The excavations typically are 8-13 cm across and 2.5-8 cm deep and as much as 3.1 m below the ice. Frogs are capable of some slow spontaneous movements.

Behaviour

Home ranges of adults vary from 15-615 m² and of subadults from 23-515 m², in Michigan (Dole, 1965a). Larger frogs tend to have larger home ranges. Adult females (the largest frogs) tend to have the driest areas for home ranges and subadults the moistest. Some adults occupy the same home range they did as subadults. In contrast, *R. pipiens* in Kansas show no tendency to maintain a home range (Fitch, 1958).

Rana pipiens typically spend more than 95% of the day sitting in a "form," a small clearing of damp soil in the leaf litter (Dole, 1965b). Frogs whose home ranges are in forested habitats make use of cavities and crevices rather than making forms. Movements are usually from one form to another and rarely more than 5-10 m. Two-thirds of such movements occur at night. On rainy nights adults move up to 160 m, often in a relatively straight line. Frogs travel up to 46.6 m/hr on such forays. Frequently these

animals return to their home range after the rain. Pitfall trapping in South Carolina revealed that *R. pipiens* activity is positively correlated with rain and that the number of captures increased with the amount of rain (Gibbons and Bennett, 1974).

A laboratory study found both seasonal and diurnal variation in general activity of *R. pipiens* (Robertson, 1978). From April to June there is an apparent sinusoidal pattern in peak activity, which matched the cycle of the lunar month. Frogs are most active at night during the new moon and earlier in the evening at the full moon. From July to October frogs are most active at dawn with a secondary peak around midnight. Activity from October to March is not significantly different from random. Daily activity is also positively correlated with barometric pressure. Robertson hypothesized that *R. pipiens* could be responding to various tidal forces.

Rana pipiens tadpoles do not exhibit kin recognition through spatial affinity under the same conditions in which *R. sylvatica* tadpoles do (Fishwild *et al.*, 1990). Although this does not preclude kin recognition, it is unlikely because *R. pipiens* tadpoles do not school as *R. sylvatica* tadpoles do. *Rana pipiens* tadpoles are also larger than other tadpoles that show kin recognition and school. Hence they may rely on size rather than schooling to avoid predation.

Movement and migration

In spring, adults emerge from wintering ponds before subadults (Dole, 1967a). Migration to breeding sites occurs when the air temperature at 1 m above ground is at least 13° C (Merrell, 1977). Both adults and subadults appear to be restricted to ponds in the spring (Dole, 1967a). Subadults may remain at the winter site (Merrell, 1977) although they may be found at breeding ponds (Merrell, 1968). Pond environments may be preferred because they provide a refuge from predators whereas in spring terrestrial habitats may lack cover vegetation. In addition, seasonal variation in hormonal balances may influence the ability of subadults and adults to maintain a proper water balance, requiring them to stay near water. After breeding, frogs move to their summer ranges.

Males and females may differ in their post-breeding activities. Males leave the breeding area to feed near permanent water, whereas females remain there, in Manitoba (Eddy, 1976). In July, males return to the breeding area where both sexes may cannibalize young of the year as they emerge.

Rana pipiens exhibits good homing ability. Adults can orient correctly towards home after being displaced up to 1 km (Dole, 1968). Blinded frogs orient just as well and actually move farther than sighted frogs.

In the fall, *R. pipiens* begins moving toward overwintering sites. This begins in early August, in Manitoba, even though *R. pipiens* is active at overwintering sites until October (Eddy, 1976). It is unclear if this late summer movement is the beginning of the fall migration or really dispersal of young of the year. Large numbers of frogs migrate to the lake on warm nights after a cold spell, during or after rain. Migration tends to be

concentrated during the first hour of darkness. Late migrators move in large numbers at temperatures as low as 4°C. Young of the year frogs appear to begin the migration (Merrell, 1977). Because overwintering sites may be some distance from breeding ponds and summer habitat, a given *R. pipiens* may move 3-6 km during one year.

Recently transformed *R. pipiens* disperse in all directions from the breeding pond (Bovbjerg and Bovbjerg, 1964; Dole, 1971; Seburn *et al.*, 1997). Although migrating juveniles in Iowa (Bovbjerg, 1965) and Michigan (Dole, 1971) include those that still had tailbuds, this was not observed in Minnesota (Merrell, 1977). Dispersal does not appear to be triggered by rain events in Iowa or Alberta (Bovbjerg and Bovbjerg, 1964; Seburn *et al.*, 1997). Movements by newly metamorphosed *R. pipiens* were compared between artificial ponds in a laboratory and those out-of-doors (Bovbjerg, 1965). From 70-100% of frogs "disperse" out of the artificial ponds. Dispersal occurs at the same time under both conditions. It was concluded that dispersal is not weather-dependent or density-dependent but rather determined internally during metamorphosis; however dispersal could also have been initiated by changes in barometric pressure. Immigration of juveniles equals or surpasses the number of emigrants, in Michigan (Dole, 1971). Immigrants are likely dispersers from neighbouring ponds. Emigration takes place mainly on rainy nights with commensurate drop in air pressure. Three males from Michigan were caught over 5 km from their natal pond 2 years after metamorphosis (Dole, 1971). The dispersal must have been overland.

The only detailed study of *R. pipiens* dispersal in western Canada occurred in the Cypress Hills of south-eastern Alberta (Seburn *et al.*, 1997). Dispersal occurs equally during the day and night and rainfall has little effect. Unlike in other studies, dispersal was mainly along aquatic corridors. Hundreds of young frogs dispersed up to 1 km within 3 weeks of metamorphosis, some had dispersed up to 2.1 km within 6 weeks and a few had dispersed up to 8 km downstream by the following spring. Dispersal along aquatic corridors may offset the benefits of dispersing on warm rainy nights when the risk of desiccation is minimal, or the arid nature of the environment may encourage aquatic dispersal. If aquatic dispersal is widespread in western populations then modifications to streams from channelization may affect dispersal potential.

Vulnerability

Because *R. pipiens* has declined so dramatically over much of its western range in both Canada and the US that it is clearly vulnerable to some factor or suite of factors. As the cause of the decline is uncertain, it is difficult to assess the current vulnerability. One of the main threats to habitat in Alberta (and likely the other provinces) is cattle grazing. With the reduction in the number of prairie wetlands this conflict will likely only increase. Even major *R. pipiens* populations in the Cypress Hills are threatened by the expansion of cattle grazing. Cattle trample emergent edge vegetation and increase the turbidity of the water. Fencing cattle away from ponds has been successful at Prince's Spring (E. Hofman, pers. comm.).

The most prevalent cause of mortality is "red leg". It is accompanied by renal failure and associated with infection by the bacterium, *Aeromonas hydrophila*. High mortality of *R. pipiens* in Alberta in 1976 was attributed to red leg (Roberts, 1992), however, populations were not eliminated. Red leg was also common in dead frogs found in Wisconsin (Hine *et al.*, 1981). The bacterium is ubiquitous in nature but it causes disease and death only under stress such as in the laboratory or possibly during hibernation (Hunsaker and Potter, 1960). Thus it is likely that red leg is secondary to the true cause of declines. Red leg symptoms are linked to other bacteria as well as simple wounds, making epidemiology confusing (Gibbs, 1973, in Hayes and Jennings, 1986).

A pathogenic fungus, *Saprolegnia ferax*, is largely responsible for the decline of *Bufo boreas* (Western Toad) in Oregon through embryo mortality (Blaustein *et al.*, 1994b). The genus *Saprolegnia* is global in its distribution and is a major pathogen of fish and their eggs. The introduction of fish into many prairie waterbodies may increase the spread of this pathogen. Its effect on other species of amphibians is poorly understood; however, it has resulted in mortality of *Rana temporaria* (Common Frog) embryos (Beattie *et al.*, 1991 in Blaustein *et al.*, 1994b).

A high incidence of winter mortality in *R. pipiens* has been noted by many observers (Hine *et al.*, 1981), primarily due to anoxia (Merrell, 1977). Other possible causes include freezing, disease and toxic exposures. Winterkill could be exacerbated by drought conditions as shallower ponds may be more prone to freeze completely to the bottom. *R. pipiens* may be more vulnerable because it is the only Canadian prairie anuran that overwinters under water. Eddy (1976) noted large numbers of dead tadpoles, possibly the result of anoxic waters from algal blooms. Fertilizer run-off into ponds could make this phenomenon more widespread and have deleterious effects on recruitment.

Amphibians are sensitive to a variety of heavy metals. The distribution of *R. pipiens* near Sudbury, Ontario is negatively correlated with levels of zinc in the water (Glooschenko *et al.*, 1992). This is not the case for other amphibian species, although aluminum and nickel influence the presence of *R. clamitans* and *Bufo americanus*, respectively. Heavy metal contamination is unlikely a major problem on the prairies, although smelting occurs in Manitoba.

There is a large body of literature on the effects of pesticides on amphibians (see Bishop, 1992). Reduced growth rates, paralysis and mortality have been documented in tadpoles. Pesticides also can reduce food levels by killing off invertebrates and algae. On the prairies, pesticide use became more widespread from 1970 to 1985 (Biodiversity Science Assessment Team, 1994). At the beginning of that period pesticides were used on approximately 20% of the land in crop or summer fallow. By 1985 they were used on roughly 55% of that land. The amount of land under cultivation on the prairies also has increased during this time period, from roughly 21 million to 25 million ha. There is continued pressure to cultivate remaining areas such as wetlands and riparian zones, critical habitat for *R. pipiens* and other amphibians. From 1985-1990, the amount of land sprayed with pesticides had stabilized or even declined slightly (Biodiversity Science

Assessment Team, 1994). This does not necessarily mean that pesticide use has stabilized or decreased. For some crops, more applications occur and assessing the effects of different pesticides remains problematic.

Parasites are common in *R. pipiens* (Diamond, 1965; Woo, 1969; Werner and Walewski, 1976; all in Woo, 1983). Three species of trypanosomes are known: *Trypanosoma pipienitis*, *T. ranarum* and *T. rotatorium* (Woo, 1983). A total of 27 and 33% of *R. pipiens* examined from Michigan and Wisconsin, respectively, contained trypanosomes and 34% of tadpoles were infected (Diamond, 1965, in Woo, 1983).. Parasite loads are not likely a population-level problem unless other stressors are affecting health. At the breeding site in Bow City, Alberta, all 46 young of the year found in July 1992 displayed evidence of a parasitic infection (C. Seburn, 1993). The parasite was tentatively identified as a digenean fluke.

Embryo mortality has been attributed to ultraviolet radiation in the genus *Rana* (Blaustein *et al.*, 1994a). Because *R. pipiens* egg masses are often laid close to the water surface they may be susceptible to UV radiation. Further research should be conducted on this subject.

LIMITING FACTORS

Habitat modification

Rana pipiens requires a minimum of three kinds of distinct habitats: temporary ponds for spring breeding, terrestrial summer foraging habitat, and overwintering ponds that do not freeze solid or become anoxic. The removal of any of these habitats can eliminate a given population. Isolating any of the habitats from the other two — for example, through road development — can also eliminate a population. Calling intensity at breeding ponds is inversely related to proximity to paved roads, in Ontario (Pope, 1996).

Habitat studies indicate that proximity of summer forage areas to breeding sites is the strongest factor in explaining variation in chorus intensity in the Ottawa area (Pope, 1996). Possibly mortality rises dramatically if adults must wander large distances from the breeding ponds. Alternatively, breeding ponds with nearby summer ranges may simply be optimum habitat and therefore have higher densities of individuals.

It has been suggested that the modification and linking of wetlands for game fish introduction can be detrimental to *R. pipiens* (Orchard, 1992). In addition, some fish, such as *Cyprinus carpio* (Common Carp), can displace *R. pipiens* by habitat modification. Carp feeding can destroy emergent vegetation, increase turbidity and eliminate or greatly reduce algal and invertebrate populations (Leonard and McAllister, 1996). Alien plant invasions (e.g. *Lythrum salicaria*, or Purple Loosestrife,) may also alter the structure of wetland environments (Ibid.).

Habitat modification could influence the thermal characteristics of the breeding pond. Hayes and Jennings (1986) speculated that warming of breeding ponds during critical periods could eliminate some ranid species. Many ranids are most vulnerable to temperature during the embryo stage. *Rana pipiens* embryos at breeding ponds in southern Alberta generally experience maximum temperatures of less than 20°C (C Seburn, pers. obs.), well below the thermal maximum of approximately 28°C (Moore, 1939).

Increased irrigation because of drought in some areas of the prairies may result in disturbances to the groundwater and lowering of the water table (Seburn, 1992c). This in turn may accelerate the drying of breeding habitats or degrade overwintering sites. In Alberta, the remaining known breeding sites are all spring-fed ponds and most are in areas that are not irrigated.

Predation

Rana catesbeiana (Bullfrog) introductions in Colorado and Washington have been implicated in *R. pipiens* declines (Hammerson, 1982; Leonard and McAllister, 1996), but an evaluation of *R. catesbeiana* responsibility for ranid declines in western North America failed to find unequivocal evidence (Hayes and Jennings, 1986). Although *R. catesbeiana* is a predator of *R. pipiens* tadpoles, juveniles and possibly even adults, it does not naturally occur west of Ontario. It has been introduced into British Columbia and its range is expanding, but it does not overlap with *R. pipiens*. It is not involved in the decline of *R. pipiens* in western Canada.

Fish introductions are more suspect because of predation on unprotected embryos (Hayes and Jennings, 1986). Fish may be responsible for declines in species of western ranids that have evolved in relatively fish-free environments. *Rana catesbeiana* embryos and larvae are adapted to coping with fish, hence their expansion may even be facilitated by fish removing other ranids. The effect of fish is complicated, because they also eat major tadpole predators such as odonate larvae (P. Gregory, pers. comm.). However, *R. pipiens* normally breed in fishless ponds (Merrell, 1968).

Collecting

Rana pipiens has been commercially harvested in Manitoba since at least 1920 (R. Larche, pers. comm.). Harvest records represent a minimum amount as sales go unrecorded annually. Records from dealers indicate that up to 49 907 kg of *R. pipiens* were collected annually during the early 1970s (Koonz, 1992). Given 20-26 *R. pipiens* per kg then the annual harvest removed over one million frogs per year. By 1974, the harvest had declined to 5 900 kg despite no apparent change in the market. There was no commercial harvesting in 1993 or 1994, but in 1995 5,800 kg of *R. pipiens* were collected (R. Larche, pers. comm.). *Rana pipiens* is not commercially exploited in Saskatchewan (Seburn, 1992a) Alberta (Seburn, 1992c) or in British Columbia (L. Friis, pers. comm.). However, juvenile *R. pipiens* are used as bait by anglers in Manitoba (R. Larche, pers. comm.), Saskatchewan (K. Roney, pers. comm.) and Alberta (Roberts, 1991).

Eggs and tadpoles are commonly collected in all parts of Canada by children and adults who keep them to watch the tadpoles transform. Although surviving young are usually released to the wild, they may not be taken back to their place of origin and the effect of this activity is unclear.

Other factors

The prevalence of renal carcinomas in *R. pipiens* from Minnesota was as high as 10.5% during the 1960s (Hunter *et al.*, 1989). During the late 1970s, no renal carcinomas were found in an examination of 2151 frogs. From 1986-88 renal carcinomas were found in 4 *R. pipiens*; however they were from a commercial dealer and it is unclear if they were raised in captivity or were wild-caught.

High levels of hind-limb deformities in *R. pipiens* as well as *R. clamitans*, *R. catesbeiana* and *Bufo americanus* have been reported from areas in the St. Lawrence Valley, Quebec which are exposed to high levels of pesticide runoff (Ouellet *et al.*, 1997). A wide variety of factors including parasites, disease and toxins can cause deformities and the cause of the deformities in this case has not been determined. High levels of deformities have not been reported from western Canada and therefore are unlikely to be a significant factor in the decline.

SPECIAL SIGNIFICANCE OF THE SPECIES

Rana pipiens is one of the most widespread amphibians in Canada (Cook, 1984). Historically, up to one million *R. pipiens* were commercially harvested for biological supply houses from Manitoba each year (Koonz, 1992). *Rana pipiens* may not be a high profile species, but the public does respond to it. A poster campaign in Alberta to solicit information about remaining populations was highly successful with over 200 submissions (D. Seburn, 1993). Some people even took the effort to send along photos they had taken to document their observations. Clearly the general public can respond to frogs as a benign or even beneficial species of wildlife. *Rana pipiens* is used in education and research. It is among the most commonly used frog species in high school dissections and is used to demonstrate principles of metamorphosis, both in schools and homes.

EVALUATION AND PROPOSED STATUS

Decline of *R. pipiens* populations in western Canada began approximately 20 years ago and it may no longer be possible to reconstruct the causal conditions. Potential causes include wetland drainage, drought, habitat modification, game fish introductions, pesticide use, disease, wetland eutrophication and/or ultraviolet radiation. As much as 70% of prairie wetlands have been lost during this century (Biodiversity Science Assessment Team, 1994). Not only does wetland drainage eliminate populations, it increases isolation of remaining populations and may weaken metapopulation structures. Reduced water tables can cause the reduction and

elimination of many temporary ponds (Corn and Fogleman, 1984). Drawdown can result in more ponds freezing solid over the winter, increasing mortality. Waterways have been modified in a number of ways. Linkages of ponds have occurred in British Columbia (Orchard, 1992) altering hydrology and often opening up ponds to fish. Channelization of streams in Alberta may reduce ability of young of the year frogs to disperse along riparian corridors (Seburn *et al.*, 1997). The introduction of predatory fish into many modified wetlands has occurred in British Columbia (Orchard, 1992), Alberta (Seburn, 1992c) and Saskatchewan (Didiuk, 1997). No information is available on Manitoba but fish introductions likely have occurred. In the U.S., fish introductions have been implicated in anuran declines in Nevada (Drost and Fellers, 1996) and Washington (Leonard and McAllister, 1996). Chemical pesticides have a number of direct and indirect effects on amphibians (Bishop, 1992). Reduction of food, behavioural effects and mortality of tadpoles have all been observed. The most common disease of *R. pipiens* is red leg, caused by a bacterium, *Aeromonas hydrophila*. The bacterium is naturally widespread but generally is not lethal unless individuals are already under stress. Eddy (1976) witnessed tadpole die-offs when algal blooms occurred in her study site in Manitoba. High levels of algal production resulted in anoxic water. Fertilizer run-offs from agricultural fields could make this phenomenon widespread. Finally, ambient levels of UV radiation have caused embryo mortality of *Rana cascadae* (Cascades Frog) in Oregon (Blaustein *et al.*, 1994). It is unclear if *R. pipiens* is susceptible to current levels of UV.

Regardless of the cause or causes of its decline, the magnitude and rate at which *R. pipiens* collapsed in both Manitoba and Alberta dispell any doubt that it is vulnerable to catastrophic declines. As the cause or causes of these declines remain elusive, it is unwarranted to assume that populations cannot collapse again. The reduced distribution may make *R. pipiens* more susceptible to future regional collapses. A complete evaluation of the current status of *R. pipiens* is hampered by a lack of data for Saskatchewan, Manitoba, or the N.W.T. Neither the extent of the decline nor the degree of recovery can be described by any more than anecdotal information. To put the matter into context, "no detailed natural history studies or focused research projects have addressed any species of amphibian in Saskatchewan" (Didiuk, 1997). In Manitoba, despite the highly visible and dramatic collapse of this commercially harvested species, no detailed research projects have been conducted in the more than 20 years since the decline. In British Columbia and Alberta, where post-decline research has been conducted, both jurisdictions have found significant range and population reductions.

It is logical to consider separately the status of *R. pipiens* in two regions. In western Canada east of the Rocky Mountains (Alberta, Saskatchewan, Manitoba, and N.W.T.), the climate, ecosystems, and manner of human disturbance differ substantially from conditions west of the Rocky Mountains (British Columbia). The distribution of *R. pipiens* is continuous across the prairies and into the N.W.T. but populations in British Columbia are distinct both geographically and ecologically, existing in very different habitats.

A designation of **Special Concern** for populations on the prairies is recommended. *Rana pipiens* underwent a dramatic range contraction in both the eastern and western

prairies, the cause of which is still unknown. There is no sign of recolonization in western areas and little evidence from the east. Overall, *R. pipiens* seems limited to major drainage systems and high quality habitat. These isolated populations are more vulnerable to extirpation in view of a proven lack of recolonization.

For *R. pipiens* in British Columbia, a status of **Endangered** is recommended. There is strong evidence that only one population remains and breeding was not confirmed there in 1996. It is isolated from other Canadian populations, precluding recolonization from Alberta. Immigration from Idaho, directly to the south of the remaining population, is possible but cannot be evaluated. If immediate action is not taken to ensure the survival of the British Columbia population, in all likelihood it will soon be extirpated.

ACKNOWLEDGEMENTS

In the current era of government cutbacks, it has been difficult and in fact sometimes impossible to obtain the information required for this status report. We are therefore especially grateful to those individuals who took time from their extremely busy schedules to provide us with the information we requested of them. Yukon Territory: Pat Milligan, Dept of Fisheries and Oceans. Northwest Territories: Mike Fournier, Canadian Wildlife Service. British Columbia: Laura Friis, Ministry of the Environment; Penny Ohanjanian, ecological consultant; Kelly Sendall, Royal British Columbia Museum; Stan Orchard, Task Force on Declining Amphibian Populations in Canada (DAPCAN). Alberta: Larry Powell, University of Calgary; Ed Hofman, Fish and Wildlife. Saskatchewan: Andrew Didiuk, Canadian Wildlife Service; Keith Roney, Royal Saskatchewan Museum. Manitoba: Ron Larche, Wildlife Branch; Bill Preston, Museum of Man and Nature. Ontario: Francis Cook, Canadian Museum of Nature; Michael Oldham, Natural Heritage Information Centre; Frederick Schueler, ecological consultant; Shealagh Pope, graduate student at Carleton University. U.S.A.: Jim Reichel, Montana Natural Heritage Program; Edward Koch, Idaho U.S. Fish and Wildlife. This status report has benefitted from review by a number of individuals. We thank Joël Bonin, Ron Brooks, David Galbraith, David Green, Pat Gregory and Tom Herman for their valuable comments. Funding provided by the Canadian Wildlife Service, Environment Canada

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Appendix II. Management Recommendations

Management recommendations are on file with the jurisdictions and COSEWIC.

Appendix III. Locality Data

Locality data is on file with the jurisdictions and COSEWIC.