COSEWIC
Assessment and Status Report

on the

Great Plains Toad
Bufo cognatus

in Canada

SPECIAL CONCERN
2002

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE IN
CANADA

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COMITÉ SUR LA SITUATION DES
ESPÈCES EN PÉRIL
AU CANADA

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COSEWIC
Assessment Summary

Assessment Summary – May 2002

Common name
Great Plains toad

Scientific name
Bufo cognatus

Status
Special Concern

Reason for designation
This species is widespread but occurs as scattered populations that fluctuate widely in size. This species of toad is adversely affected by fragmentation of habitats, limited dispersal and conversion of its habitat to agriculture.

Occurrence
Alberta, Saskatchewan and Manitoba

Status history
Designated Special Concern in April 1999. Status re-examined and confirmed Special Concern in May 2002. Last assessment based on an existing status report.

COSEWIC
Executive Summary

Great Plains Toad

Bufo cognatus

The Great Plains toad, *Bufo cognatus*, is a widely-distributed species in western North America. In Canada, it is restricted to south-eastern Alberta, southern Saskatchewan, and extreme south-western Manitoba where it is associated with mixed-grass prairie.

Bufo cognatus is a grassland anuran adapted to survive and breed under xeric conditions. Fossorial habits and relatively long life allow it to disperse widely and survive extended periods of drought and the freezing temperatures of winter. When suitable breeding wetland conditions become available enormous numbers of young toads may be produced, but limited information suggests high overwinter mortality of juveniles is probably common.

In Alberta past concerns about declining populations may have been due to lack of investigation during years of higher water when the species can be detected more readily. Recent surveys suggest large numbers of *B. cognatus* occur at Suffield National Wildlife Area, Alberta. No information is available to assess the size or trend of populations in Saskatchewan or Manitoba.

Grassland habitat may be widely available for *B. cognatus* within its range, but many areas of grassland may not include depressions suitable for breeding when high spring runoff or heavy rains stimulate breeding. Progressive conversion of grasslands to cropland, and local impacts by grazing, may be slowly reducing quantity and quality of habitat.

Currently no federal or provincial protective legislation applies specifically to *B. cognatus*. No information is available to indicate the relative effectiveness of current wildlife protection legislation in terms of protecting the Great Plains toad and its habitat.

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.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Great Plains Toad
Bufo cognatus

in Canada

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1999

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INTRODUCTION

The Great Plains toad (Fig. 1) is a widely distributed and, in some areas, common species throughout its extensive range in the United States and northern Mexico. It has been the subject of numerous studies addressing its natural history, phylogeny, morphology, development, physiology, general behaviour, ecology, and evolutionary relationships within the genus *Bufo* (Krupa 1990). The range of this species in western Canada is limited to the southern extremes of the prairie region where very little is known regarding its distribution, abundance and ecology.

Figure 1. *Bufo cognatus*.

The early Canadian literature regarding this species focused upon reports of its presence and apparent rarity (Logier 1931; Moore 1953; Logier and Toner 1955; Lewin 1963; Cook 1960; Logier and Toner 1961; Secoy and Vincent 1976; Preston 1986; Secoy 1987). Perceptions of restricted distribution, small populations and potential risks associated with expanding agriculture within its Alberta range (Cottonwood Consultants 1986; Butler and Roberts 1987) were followed by an overview of the status of the Great Plains toad in 1991 (Smith and Wershler 1991). Distribution and reproduction have recently been investigated at Suffield National Wildlife Area (NWA) in Alberta in 1994-96 (A. Didiuk, unpubl. data).

Naturalists in prairie Canada have been, and continue to be, few in number compared to numbers present in areas of higher human populations elsewhere in North America. Interest in reptiles and amphibians by naturalists has tended to be far less than interest in flora and avifauna. Consequently distribution and life history notes on prairie reptiles and amphibians are very limited. This lack of basic information contributes to perceptions of rarity for some species which may be relatively common but are sedentary, have cryptic behaviour, or in some other manner are difficult to detect.

There have been no detailed biological investigations of the Great Plains toad in Canada. Most of the descriptions of its ecology in this report are drawn from the extensive studies of A. N. Bragg and J. L. Krupa in Oklahoma, and by B. K. Sullivan in Arizona. Some of the conclusions may not be representative of Canadian populations of the Great Plains toad.

Taxonomy

The following history of the taxonomy of the Great Plains toad is reproduced from Krupa (1990). No subspecies are now recognized.

Bufo cognatus Say in James, 1823: 190. Type-locality, "The alluvial fans of the [Arkansas] River," in Prower County, Colorado. Holotype, originally deposited in the original Philadelphia Museum; according to Baird and Girard (1853), it apparently was destroyed by fire.

Bufo musicus: Le Conte, 1855:430.

Incilius cognatus: Cope, 1863:50.

Bufo frontosus Cope, 1866:301. Type-locality, "The valley of the Colorado [River] from Fort Mojave to Fort Yuma." No information was provided on the deposition of the type-specimen. The description resembles both this species and *B. woodhousii*.

Bufo lentiginosus frontosus: Cope, 1875:29. Ellis and Henderson (1915) included this name as a synonym of *B. cognatus*.

Bufo lentiginosus cognatus: Cope, 1875:29

Bufo deptirnus Cope, 1879:437. Type-locality, "On the plains... of northern Montana...north of the Missouri river east of Fort Benton." This specimen was a juvenile *Bufo cognatus* that lacked the distinctive cranial crests. Type specimen not known to exist (Kellogg, 1932).

Bufo terrestis: Brocchi, 1882:77. Identification in question.

Bufo lentiginosus woodhousii: Stejneger, 1893:221

Bufo cognatus cognatus: Camp, 1915:331

The Great Plains toad is considered to be associated with the *Bufo cognatus* species group (Tihen 1962; Blair 1963). The most recent review of scientific and common names for North American amphibians and reptiles (Collins 1996) maintains Great Plains toad as the common name, and *Bufo cognatus* as the scientific name.

Description

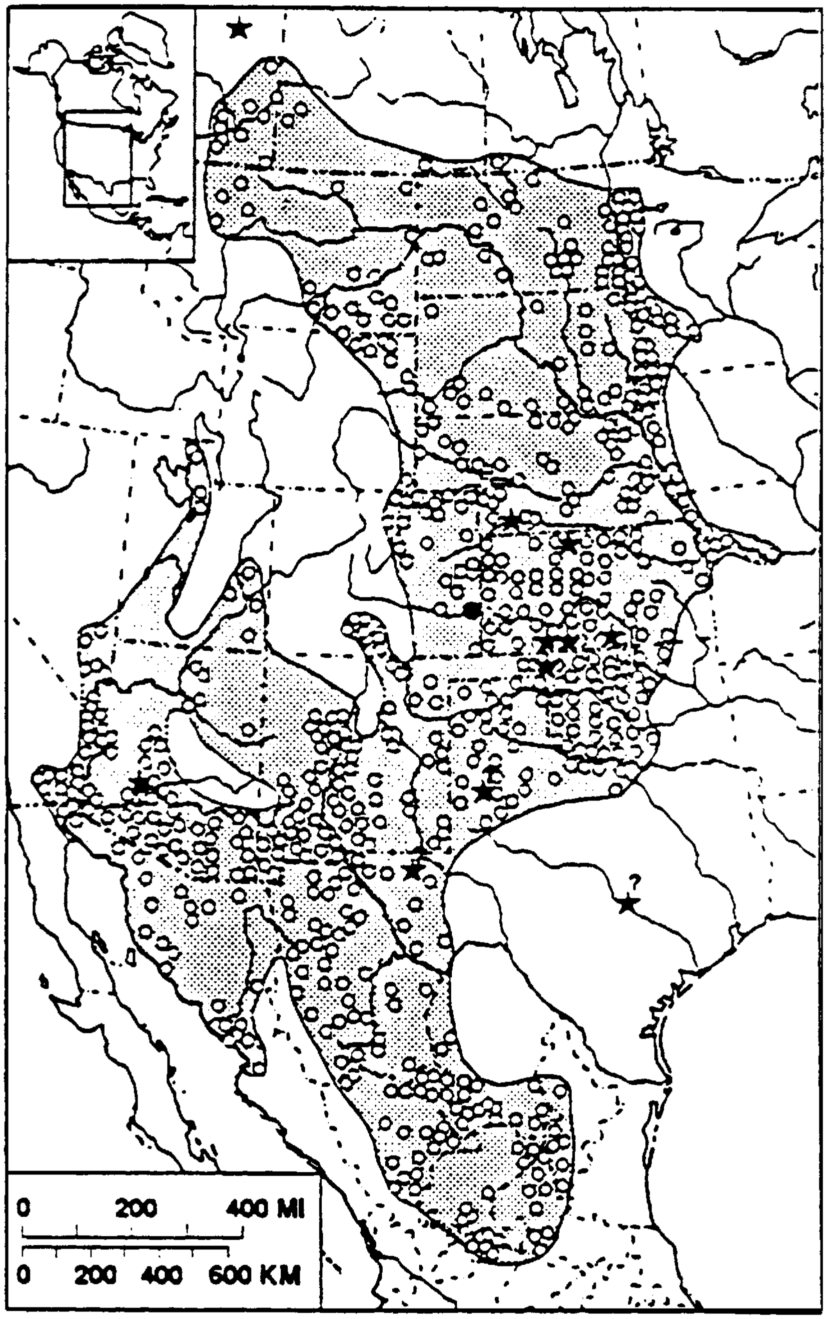
The body of an adult Great Plains toad (Fig. 1) is large and broad with a snout-vent length of 45 to 103 mm for males, and 49 to 114 mm for females. The dorsum is covered by numerous tubercles or "warts", most of which are less than one mm in diameter. The ground colour of the dorsum can vary from greenish to brown, brown-yellow or gray. There are conspicuous dorsal blotches which are rounded or irregular in shape, usually paired, and dark brown to olive in colour. These blotches have well-defined narrow borders of dark brown or black, which in turn are narrowly bordered with cream or white. The venter is granular, almost always of a uniform white or cream colour, and rarely spotted. Breeding males have a black vocal sac which, when extended, is sausage-shaped and extends above and beyond the snout. Cranial crests are distinct and diverge posteriorly from a large, bony boss in the prefrontal region between and behind the nostrils. These crests have two, strongly developed "L-shaped" structures between and behind the orbits which extend to the tympana. The parotid glands are prominent and elongate and ovoid in shape.

The breeding call of a Great Plains toad is a loud, "metallic-sounding" trill which has been compared to the sound of a metal rivetting machine. Harsh, grating, mechanical, throbbing, pulsating and clattering are other terms used to describe this breeding call. Full choruses can be extremely loud and can be detected up to two km from the breeding ponds. Some individual calls can last up to 50 seconds.

Eggs are released from females in two strings, each string with a single row of eggs, and constrictions in the strings may produce a "scalloped" effect. Eggs are small, averaging about one mm in diameter. Newly hatched larvae range from one to four mm in length and colour appears to be a uniform black. Within three days of hatching, when the larvae are between four and six mm in length, there is a distinct lightening of the ventral portion of the body. As the larvae develop there is an increase in the contrast between the dark dorsum and the iridescent venter. Metamorphs have a dark coloured dorsum with small dorsal blotches and numerous small, red tubercles.

DISTRIBUTION

The Great Plains toad occurs throughout an extensive range in western North America and the northern half of Mexico. Krupa (1990a) provides an excellent map of this distribution based on a detailed examination of literature and museum records (Fig. 2). It has been recorded from the southern prairie provinces of Canada southwards to the San Luis Potosi and Aguascalientes regions of central Mexico, eastward to Missouri, Iowa and Minnesota, and westward to southeastern California and Nevada. Bragg and Smith (1943) report on the distribution of the Great Plains toad in the mixed-grass and short-grass prairies of Oklahoma and the factors which may limit expansion of its range.



Map. Distribution of *Bufo cognatus*. Solid circle indicates the type-locality, open circles represent localities from literature and museum records. Stars represent fossils; those with question marks indicate fossils that could be of *B. cognatus*, *B. speciosus*, or a recent ancestor.

Figure 2. Distribution of *Bufo cognatus* in North America and Mexico (from Krupa 1990).

Records of the Great Plains toad in Alberta are restricted to the southeastern grasslands (Fig. 3). Smith and Wershler (1991) provide a summary of the locations of reports and museum specimens in Alberta. This species has been recorded from an area bounded by Empress and Bindloss in the northeast, an apparent western limit in the Vauxhall, Taber and Lake Newell region, and the Milk River drainage in the extreme southeastern portion of the province. Recent surveys within the Suffield military base (A. Didiuk, unpubl. data) have revealed widespread and abundant populations (Fig. 3). The Great Plains toad is likely widely distributed throughout the area bounded by the Saskatchewan border to the east, the Trans-Canada Highway and Alberta Provincial Highway No. 3 to the south, the Taber-Vauxhall-Lake Newell area to the west, and the Red Deer River to the north. Occurrence south of this area to the Montana border is unknown given the lack of reports except for the immediate vicinity of the Milk River drainage. However, it may also be widely distributed within this region and its apparent absence may represent lack of investigation at suitable times. This was the case with the Suffield military reserve until surveys in 1994 -1996.

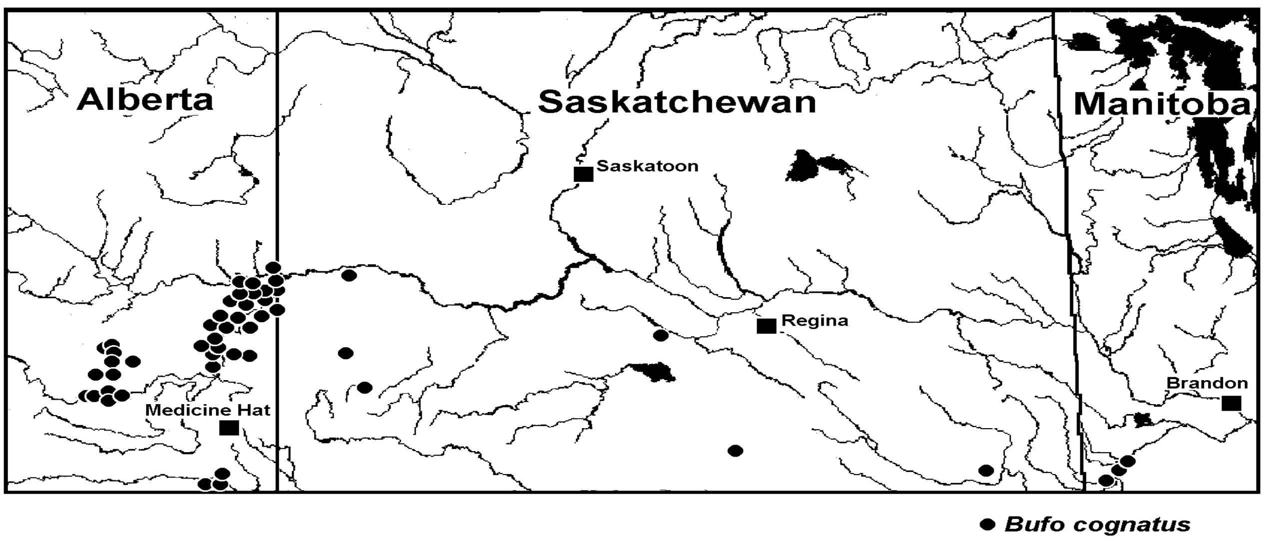


Figure 3. Distribution of *Bufo cognatus* in Canada.

The distribution of the Great Plains toad in Saskatchewan is poorly known. There are few records (Fig. 3) and most are near the Alberta border west and south of the Great Sand Hills of Saskatchewan (Piapot, Big Stick Lake, Sceptre). A few observations along the eastern edge of the Missouri Coteau (Mortlach, Big Muddy Valley) suggest an approximate edge of the species range associated with the edge of the Missouri Coteau. Recent observations near the Souris River valley in extreme southeastern Saskatchewan (J. Pollock, unpubl. data) suggest this species may occur near the North Dakota border in this region, and this report may represent a connection between records to the west and recent reports in extreme southwestern Manitoba (Preston 1986). The Great Plains toad was first recorded in Manitoba in 1983 at Lyleton in the extreme southwestern portion of the province (Preston 1986). Since this first report additional specimens have been observed at Lyleton and in the Melita and Coulter areas of southwestern Manitoba (Fig. 3).

Although it has not been reported in the northern tier of counties in North Dakota adjacent to southwestern Manitoba (Wheeler and Wheeler 1966) the range may be contiguous. The distribution of this species in Montana is not well known but it appears to be more common in the eastern portion of the state south of Saskatchewan (Black 1951; Reichel and Flath 1995). However, it has been reported in Toole and Chouteau counties south of the Milk River drainage in Alberta, suggesting the species distributions may be continous.

PROTECTION

There is no federal legislation providing specific protection to the Great Plains toad (R. Forsythe, pers. comm.). In Alberta the Great Plains toad is afforded complete "protection" as a non-game animal. It cannot be killed for any reason, cannot be bought or sold, and a permit is required for holding for education or scientific purposes. New legislation is being prepared which may alter this current level of protection (Steve Brechtel, pers. comm.). In Saskatchewan, outside of game preserves, wildlife refuges, regional parks, provincial parks, protected areas, road corridor game reserves or recreation sites any person may collect, study, hunt and hold in captivity, without a license, any frog, toad or salamander. However, the director of wildlife may issue a captive wildlife license for any person wanting to hold a frog, toad or salamander in captivity, or grant a license to secure wildlife for scientific purposes, subject to any terms and conditions considered appropriate. At this time it would appear that the current legislation does not afford any specific protection for the Great Plains toad, and discretion on the part of the director of wildlife may be important. In Manitoba the Great Plains toad is designated as an amphibian and wild animal under a ministerial amendment to the Manitoba Wildlife Act. It is designated as a protected species as are some other reptiles and amphibians. There is no information available to indicate how effective each provincial wildlife protection legislation is.

POPULATION SIZE AND TREND

During a drought period in southern Alberta it was reported that "a number of observers" had noticed a decline in Great Plains toad numbers from "known breeding sites" (Cottonwood Consultants 1986). The observed lack of breeding in native grassland areas in the Bindloss-Middle Sand Hills-Lost River areas was the basis for this assessment but it is not clear if other data were available, nor who the observers were. These authors recommended that the Great Plains toad be classified as endangered under Alberta legislation based on the above observations, and from recommendations of participants at the First Workshop on Rare and Endangered

Species of the Prairie Provinces in January 1986. The lack of recent breeding in non-irrigated areas of its range, and few known breeding locations at that time, presumably resulted in a perception of low and declining numbers.

Butler and Roberts (1987) stated the Great Plains toad was found in a "limited, scattered distribution within southeast Alberta, often confined to specific habitat requirements". They also suggested this species was "uncommon enough to be recognized as potentially threatened with extirpation in the foreseeable future" and was "deserving of special management consideration or, at the very minimum, immediately warrant some form of population monitoring". It is presumed that this assessment is based on the same information summarized by Cottonwood Consultants (1986) and their conclusion that provincial populations were low, locally distributed and declining in response to prolonged drought and human impacts. Wallis and Wershler (1988) recommended this species be designated as an endangered species based on the information provided by Cottonwood Consultants (1986).

Based on the concerns of the above authors a status report was commissioned for this species in Alberta by World Wildlife Fund (Smith and Wershler 1991). This included a summary of all previous information and records, limited field surveys in the spring of 1990, and a review of pertinent literature. From historical and new reports they concluded there were six "general populations" based on historical location data (Empress - Bindloss, South Saskatchewan River - Hilda, Medicine Hat, Lost River - Milk River, Lake Newell - Little Rolling Hills, and Hays - Purple Springs). The distribution of records (Figure 2) illustrates these "general populations" and, since it was based upon reports available at that time and limited search efforts during a drought period, it probably does not represent the actual distribution of the species. At that time there had been no dedicated survey of wetlands within the non-irrigated region throughout most of its range in Alberta when higher spring runoff fills the temporary and seasonal wetland basins and breeding congregations are easy to detect.

In the Suffield Military Base, Alberta, in 1994 and particularly in 1996, there was widespread breeding of this species in many seasonal wetlands (A. Didiuk, unpub. data). A total of 77 wetland basins with calling males was confirmed in and near the Suffield NWA which comprises the eastern 20% of the military base. Wetland conditions throughout the remainder of the base suggested breeding conditions were adequate in this large area as well, and breeding congregations were likely distributed throughout the entire military base. Reconnaissance surveys of the western portion of the base revealed other active breeding sites of the Great Plains toad and widespread breeding habitat in 1996 (L. Powell, pers. comm.).

This suggests it is likely there are many 100s, if not 1000s, of breeding localities within the range of this species in southeastern Alberta which would not be detected without surveys in years of higher water. The widespread breeding of this species in 1996, with many ponds with large breeding congregations, suggest populations can persist and are widespread even after a period of prolonged drought.

The ability of this species to survive many years, its adaptations to xeric conditions, its fecundity when breeding ponds become available, and its moderate capability of dispersal all contribute to resiliency of local populations. Given the number of breeding ponds detected at Suffield NWA, and the likelihood that many more are present in regions to the west of the NWA, and possibly to the south, the species is not restricted to a few locations and the status designation of endangered based on restricted distribution is not appropriate.

Wallis and Wershler (1988) estimated the total Alberta population to be about 1000. Smith and Wershler (1991) estimated the potential total population in Alberta to be up to 2000 using the following calculations and assumptions. For irrigated areas — calling males at 18 sites from 1987 and 1990 surveys, assume sex ratio of 1:1, total of 650 at these sites, assume "small" percentage of non-breeding males that call after the main calling period, there are undoubtedly "more" sites in the irrigated region that have not been recorded, "average maximum" of 40 individuals per site in the irrigated range, for total of 18 known sites in irrigated region there may be 800? individuals. For non-irrigated areas — only 5 calling males, 2+ individuals recorded since 1979, most in Bindloss area, use average of "average maximum" of 40 individuals from irrigated range, known 20 sites, estimated "potential" of non-irrigated areas is 800 individuals. Combining areas — combined estimated numbers at known sites in irrigated and non-irrigated areas, addition of a "few" areas of undocumented historic and recent habitats in the non-irrigated range, “could make the total estimated potential population in Alberta as high as 2000".

It is not clear from these reports how the numbers of calling males were counted or estimated (shoreline counts of calling males, or samples, or estimates from listening to calling males). The confounding effect of satellite males in the survey procedures and how these were considered in counts or estimates is also not clear.

Wallis and Wershler (1991) arrived at their estimate of perhaps 2000 individuals (presumably breeding adults) of the Great Plains toad in Alberta given the information they had available. Although new infomation from Suffield NWA suggests there may be many more breeding sites in high water years, and that there may be many other sites in areas of similar habitat adjacent to Suffield NWA, it is still difficult to generate an estimate of total numbers for the province of Alberta.

For example, in the Suffield NWA and areas immediately to the west of the NWA, there were 77 wetlands with breeding congregations of Great Plains toads. Using an average of 20 individuals per wetland results in 1500 individuals for this area alone which is a small proportion of its total range. It can be expected that the actual number of Great Plains toads within its entire Alberta range may be many 10s of thousands.

In order to arrive at an estimate of total numbers for Alberta more information is needed regarding presence within the overall range in southeast Alberta, the number of seasonal wetlands which may be utilized by breeding congregations in a year of higher water levels, the proportion of these basins which are used, and the range of numbers of calling males, as a function of wetland size, which participate in breeding congregations.

The above review indicates that past attempts to estimate populations, the new evidence to suggest wetlands used for breeding may be more common and widespread than believed, and the difficulties in obtaining realistic provincial estimates make any assessment of trends impossible at present. Smith and Wershler (1991) suggest the paucity of breeding locations in the late 1980s and 1990, in part of the irrigated portion of the range of the species, suggests these populations may have suffered declines. They also suggest lack of breeding records within the non-irrigated portion of its range suggest populations may no longer exist or be greatly reduced.

Presumably these conclusions led to their statement "Since the mid to late 1970's the provincial population of Great Plains toads may have declined as much as 50% because of widespread and extended drought". These areas have not been visited since 1990 during years of higher water levels. Until these areas are visited again, and surveyed under suitable conditions, this conclusion cannot be supported given the evidence of widespread breeding sites with abundant calling males at Suffield NWA and adjacent areas in 1994 and 1996.

There are no data to determine population size and trend in Saskatchewan. Surveys to confirm the range of the species in the province are required before there can be any attempts to estimate population size and to design population monitoring programs. Given the large expanses of native grasslands in Saskatchewan near the Alberta border, and farther east in the Missouri Coteau region, significant populations may be detected if surveys are conducted in years of higher water.

This species has only recently been confirmed to exist in south-western Manitoba. Surveys to confirm the extent of the breeding range are required before there can be any attempts to estimate population size and to design population monitoring programs. Given the known very restricted range in the province, population numbers are probably low.

The number of potential breeding sites and population size of the Great Plains toad in Alberta have probably been underestimated and are likely much greater than formerly believed. Potential habitat within the poorly known range of this species in Saskatchewan suggests there may be significant numbers of this species here as well. The very restricted known range in Manitoba suggests numbers of breeding sites and populations of the Great Plains toad are probably very low. Reasonable estimates of population size will require reconnaisance surveys in years of higher water levels to confirm extent of the range of each species in each province and to allow subsequent design of stratified surveys to determine population size.

HABITAT

Habitat Requirements

Reports from more southern locales suggest the Great Plains toad mainly breeds in temporary wetlands which fill with water following heavy rains in late spring and early summer. Bragg and Smith (1942) concluded the Great Plains toad in Oklahoma was one of the species "characteristically breeding only in clear, shallow, temporary pools." Typical situations were "flooded shallow fields and shallow ditches of clear water, usually with considerable vegetation protruding through them" and "buffalo wallows of clear water or similar shallow clear-water pools."

Bragg (1950e) provided a similar description of breeding habitat in Oklahoma - "very common in buffalo wallows, flooded fields, ditches if not deep or muddy; unknown in streams; very rare in sloughs on flood plains." In Oklahoma (Krupa 1994) breeding occurred in temporary, rain-filled ponds found on lowland pastures, river flood plains, cotton fields, mowed playing fields, road-side ditches and vacant lots in both business and residential areas. Bragg (1940a) reported use of deeper, more permanent pools or large yet temporary pools, but only along the more shallow portions.

Bragg (1940a) in Oklahoma reported the calling of male Great Plains toads in fields planted to rye or wheat but "only in the shallower portions of the pool." Bragg (1958) in New Mexico reported a small chorus of Great Plains toads in a large, shallow flooded grain field "with 1 to about 12 inches of water. The water was considerably contaminated with sewage." Near Suffield NWA in south-eastern Alberta Great Plains toads formed small breeding congregations and larvae reached metamorphosis successfully in large numbers in some wetlands in seeded pastures (A. Didiuk, unpubl. data).

Bragg and Smith (1942) reported a shallow pond where runoff had produced muddy water in one end grading to clear at the other end. A large chorus of Great Plains toads was located in the clear end and a small chorus of *Bufo woodhousii* in the muddy end. They do not indicate whether the site selection of this great plain chorus may have resulted from the chance arrival of the first males at the clear water area and their subsequent calling attracting other males, and females, to this area.

Bragg (1940a) reported use of a variety of wetlands in Oklahoma provided "the water is not muddy" and it stated it "rarely lays its eggs in muddy waters although I have occasionally found the tadpoles in roily pools in wheat fields." He also stated that "Often, conditions within a pool are kept somewhat in flux by cattle and horses; sometimes a pool which is beautifully clear when the toads breed becomes and remains quite roiled by the stomping of the larger animals. In such cases the tadpoles seem to get along well, for I have followed hundreds of them through all stages in such pools and have seen them metamorphose". Smith and Wershler (1991) in Alberta did not detect any Great Plains toad breeding congregations at pools in cultivated fields in irrigation areas.

Bragg (1940a) in Oklahoma found very little evidence of breeding in more permanent water sources, known as "tanks" in pastures even when these had many smaller, more shallow pools in proximity where breeding congregations had developed. At Suffield NWA no breeding choruses were detected at the relatively permanent water of dugouts with steep sides. Some dugouts with flooded, shallow ends connected to shallow water of adjacent flooded depressions did have small numbers of calling males. Stockponds, formed by berms along drainage channels, did attract large numbers of calling males where the shoreline gradient was low with extensive shallow water (A. Didiuk, unpubl. data).

In contrast, Brown and Pierce (1967) in Arizona reported use of more permanent water bodies (marshes and "tanks"). They suggested the rainfall in central and south-eastern Arizon is more "sparse" in the April to July period, compared to that in Oklahoma, such that breeding occurred in more permanent water sources and irrigation areas in Arizona. Bragg (1940a) in Oklahoma noted that calling males did utilize ditches with deeper water, even if muddy, but no eggs or tadpoles were ever found in these situations. He suspected the depth of water was too great for breeding to occur.

Smith and Wershler (1961), following and during a period of extended drought, noted breeding habitat in irrigated areas appeared to provide most, if not all, of the potential breeding areas in some regions of southern Alberta. They believed a rise in local water tables, or downslope seepage, in these irrigated areas allowed shallow wetlands to persist and provide breeding habitat. Increased persistence of water in "managed" wetlands, such as Ducks Unlimited (Canada) projects may provide habitat depending upon water depth and amount and distribution of emergent growth.

At Suffield NWA in 1994 and 1996 all breeding sites of Great Plains toads were associated with large, shallow seasonal wetlands with limited residual growth and some new emergent grass along the margins when breeding was initiated. Single or two males were observed calling briefly at dugouts, presumably en route to nearby breeding congregations (A. Didiuk, unpubl.data).

Bragg (1950e) noted that selection of a given pool by calling males for breeding might solely be due to the chance when male Great Plains toads may be attracted to the calls of males which first happen to arrive at the pool. However, they believed selection of pools in Oklahoma was a factor of several influences, including water depth (shallow water highly preferred), water temperature (warmer subject to depth and season), turbidity (clear highly preferred), shade (open areas preferred), water movements (standing water greatly preferred), extent (larger preferred, but shallow), permanence (seasonal), type of bottom, and abundance of food. Bragg (1950e) noted that these factors, and others, were interrelated (e.g. depth and size and permanence). He concluded breeding sites for the Great Plains toad in the mixed-grass prairie, and lower "reaches" of the short-grass prairie, in Oklahoma were characterized as shallow (<.5 m) to intemediate (1.5 - 1.0 m) depths, semi-clear (visibility to at least 0.3 m depth with noticable "haze") to clear (practically no turbidity), temporary (water present not more than a "few months"), persisting usually only a "few weeks", dry at least once a year on average, and intermediate temperature (11 - 20°C.). He also noted that tadpoles occasionally could be found in water which was "roiled".

Bragg (1950e) concluded that male Great Plains toads could call from any temporary water they might encounter but females "pay little attention to them unless the water is six inches to one foot in depth.

Bragg (1940a) concluded females will ignore calling males calling in "unsuitable" situations (water too deep, water too shallow, water too turbid) and continue moving towards other breeding pools. A calling male in these "unacceptable" ponds may intercept a female who may be able to escape from amplexus, may actually carry the male with her to another adjacent pond, or uncommonly accept the male and lay eggs (Bragg 1940a). He believed the occasional occurrence of single clutches in small pools was due to the inability of the female to leave when intercepted.

When males about shallow pools fail to find females they migrate to larger pools where others are calling. Thus, during the first night a huge chorus consisting of most of the adult male population on an area of some acres becomes congregated in one or a few pools." This type of situation, and those described below, affect determination of whether a given wetland is suitable for breeding purposes:

A given pool may have formed under unsuitable weather conditions (e.g. low temperatures in early season). By chance males may have arrived and developed breeding congregations at other pools adjacent to the one examined. Females may be attracted to adjacent pools where the number of calling males is greater, or wetland more suitable, such that no egg-laying may have occurred at the one examined. Breeding may have occurred but tadpoles may have been eliminated by tadpole predators prior to inspection. After breeding adult male and female Great Plains toads disperse from the breeding ponds. There is no information available regarding distances dispersed, "home range", site selection, activity budgets (daily and seasonal) for this species.

Great plains toads, similar to other bufonids, burrow into the soil to hibernate. There is no information regarding site selection and chronology of ingress/egress from hibernation sites for this species

Habitat Trends

Agricultural impacts upon wetland basins in southern prairie Canada involve drainage and "wetland incorporation" with cultivation of wetland depressions, reduction in grassland margins of wetlands in cultivated areas, and a variety of transitory impacts (haying, burning, grazing) and permanent impacts (clearing of shrubs, filling with stones and debris) upon basins and margins of wetlands. These impacts eliminate natural vegetation within the wetland basins, reduce their water-holding capacity, and eliminate the amount of grassland cover and biomass associated with wetland margins.

Between 1951 and 1981 Alberta accounted for 69% of the observed increase (129%) in total area of improved pasture lands in the prairie provinces, reflecting the large cattle industry in the province (Statistics Canada 1983). In Alberta 66% of the wetland basins, and 93% of the wetland margins, have been impacted by one or more agricultural practices (Turner et al. 1987). In the southern areas of Alberta these impacts are generally reduction of wetland margins for those wetlands remaining within cultivated areas, and grazing of margins in pasture areas. In Saskatchewan 59% of the wetland basins, and 78% of the wetland margins have been impacted by one or more agricultural practices (Turner et al. 1987). In Manitoba 48% of the wetland basins, and 64% of the wetland margins, have been impacted by one or more agricultural practices (Turner et al. 1987).

Natural grassland continues to be cultivated for cereal crop production or "improved pastures" in much of the southern portions of the prairie provinces, and within the range of the Great Plains toad. Large continuous blocks of natural grassland continue to exist, associated with PFRA pastures, provincial community pastures, provincial cooperative pastures, provincial and federal parks, leased crown lands, and federal military lands. There are many other smaller private holdings, in some areas forming contiguous blocks of natural grassland, in southern prairie Canada.

However, significant portions of these grasslands may not support numerous breeding sites for Great Plains toads. Some areas have very few wetland basins reflecting relief and surficial materials. Impacts upon basins and adjacent grassland habitat vary widely depending upon land ownership and associated stocking rates of livestock.

Estimates of the status of Great Plains toad habitat will require determining the range of the Great Plains toad, mapping of grassland habitat and cultivated habitat within this range, determination of abundance of wetland basins within this habitat, estimation of use of these basins, and assessment of habitat degradation. Until these assessments are conducted, only the above general statements can be provided.

Habitat Protection

Large areas of the known range in Alberta are protected from cultivation since they are within protected areas (e.g. Suffield military base, Remount Community Pasture). Grasslands to the south and west of Suffield are subject to increasing cultivation and irrigation development. Continued cultivation of leased crown lands in south-western Saskatchewan is resulting in gradual loss of natural grasslands. The Wildlife Habitat Protection Act prevents cultivation of large areas of crown land within the potential range of the Great Plains toad. No information for Manitoba is available. An assessment of the protection of habitat for the Great Plains toad will require a synthesis of land cover data and land tenure data for prairie Canada. These databases are nearing completion for each of the provinces and a "gap analysis" of estimated habitat and habitat protected should be a priority activity for this species.

GENERAL BIOLOGY

Reproduction

Many aspects of the reproductive biology of the Great Plains toad are of importance in the design of survey and monitoring programs, and are discussed in some detail where necessary.

Studies in Oklahoma (Bragg 1942b, 1950b; Bragg and Weese 1950; Krupa 1994) have reported a high correlation between precipitation and breeding, have concluded breeding does not occur in the absence of rain (Krupa 1994), and the amount of precipitation which stimulates breeding activity can vary considerably (0.4-12.3 cm, mean 4.4 cm). Initiation of breeding in response to heavy spring and summer rains appears to be typical in other southern areas such as Arizona and New Mexico (Sullivan 1982, 1983b).

Bragg (1950b) in Oklahoma reported that every recorded breeding event for the Great Plains toad had occurred after rain at air temperatures of 12°C or above. He also concluded, from some limited data regarding delayed breeding following rain, that the stimulus for breeding arose from rain at low temperatures but the actual breeding can be delayed until the temperature increased. Bragg and Weese (1950) in Oklahoma concluded that Great Plains toads will breed only after rains, typically of 2 cm or more, over a prolonged breeding season, but breeding activity was inhibited by air temperatures below 12°C. Spring rains were commonly accompanied by falling temperatures and often by temperatures too low to stimulate breeding.

Brown and Pierce (1967) observed breeding of the Great Plains toad along irrigation ditches in Arizona in the absence of precipitation. Krupa (1994) reported no effects upon breeding by irrigation activity in Oklahoma, which presumably indicates breeding did not occur in wetlands made available from irrigation activities without the stimulus of heavy rains.

Smith and Wershler (1991) stated that a prerequisite of rainfall for breeding had not been well documented for Alberta. However, in 1987, breeding in the irrigated portion of the species range in Alberta appeared to begin after at least two days of showers and light, steady rainfall. At Suffield NWA, Alberta, in 1994 and 1996, breeding of the Great Plains toad did not appear to be dependent upon heavy spring rains (A. Didiuk, unpubl. data). In these years wetlands were filled due to high spring runoff and breeding began with the first warm day in early May. During the breeding periods there were occasional days of light rain but breeding choruses were almost continual and rain, or lack of it, did not affect calling of males. In 1995, a dry year when wetland basins were dry by late April, there were no rains heavy enough to fill basins and stimulate breeding. It is unknown if breeding would have occurred if sufficient rain had filled basins in late spring and early summer.

Bragg (1946) considered the Great Plains toad to be a prairie-limited species in Oklahoma with a xeric pattern of breeding. Breeding only occurred after rain, in temporary water, at any time from early spring to early fall without any well-defined breeding season. Successful transformation of larvae was uncommon due to drying of breeding pools. Immediate breeding activity in response to heavy rains provided some chance for larvae to survive to transformation. Rapid development aided by increasing water temperature as the pool warmed and water volume disappeared through evaporation was typical.

Bragg and Weese (1950) in Oklahoma reported most breeding events occurred in the spring (April and May) although breeding could occur any time between March and September. They reported breeding in August and September during years of very dry spring conditions whereas no breeding occurred in late summer if the spring conditions were wet. They concluded that Great Plains toads wait to breed until the first rains even if they do not occur until late summer. For those areas where breeding congregations appear to be limited to periods immediately after heavy rain, a combination of precipitation, saturation of the soil, and a particular range of air temperatures may stimulate breeding and this combination may be more prevalent in spring than in summer (Krupa 1994). The number of nights of breeding in Oklahoma (Krupa 1994) varied greatly from year to year (3 to 39 nights), was significantly correlated with total spring precipitation, and was negatively correlated with the calendar date when breeding started. In this study Great Plains toads bred for 14 consecutive nights after rain in the early breeding season (March), for a mean of 4.4 nights in the mid-season (April and May), and for a mean of 1.9 nights in the late season (June). However, in the late season consecutive days of heavy rains increased the number of breeding nights.

Bragg (1950e) in Oklahoma reported a prolonged period of breeding (large choruses almost every night for a month) when rains were frequent and heavy in May and June. Subsequently he detected recently metamorphosed toads of at least three different ages which suggested several egg-laying periods. He also concluded those females that continued to feed along roads, and were not attracted to calling of nearby males, may not have been ready to lay eggs and were not receptive to males. Reports of gravid females along roads on rainy nights in late September in Oklahoma (Krupa 1994) suggest some females may refrain from breeding under some conditions even though one or more breeding events had occurred in the preceding spring and summer.

At Suffield NWA, Alberta, the first calling males of Great Plains toads were recorded on 2 May in 1994, and some were still calling at the end of May. In 1996, the first calling males were recorded on May 12, and calling at some wetlands was recorded on 14 June. Calling at most sites continued throughout this period (A. Didiuk, unpubl. data).

Detection of the first calling males at a particular pond is the most likely cue for orientation of males to the pond. It is not clear whether it is random chance that the first male happens to encounter a pond in close proximity to where it emerges, or whether other non-auditory cues are involved. Movements of anurans towards a breeding site have been observed at distances far greater than the presumed audible range of the breeding chorus (Duellman and Trueb 1986).

Several cues may be used, some simultaneously, for movements towards breeding ponds. Long-distance movements may involve celestial (e.g. Ferguson 1967) or olfactory cures (e.g. Martof 1962) until within auditory range of a breeding chorus. Celestial cues may be of limited use when migrations commonly occur on rainy and overcast nights although initial orientation before sunset may influence direction of movement (Duellman and Trueb 1986). Response to hygrotactic (humidity) gradients may be of limited value for longer movements and under rainy conditions, and geotactic (slope) gradients may be of limited value in rolling terrain (Duellman and Trueb 1986).

Most males arrived at breeding pools in Oklahoma the first night of the breeding period and most had left these pools by the third night of calling (Krupa 1994). In southern Arizona and southwestern New Mexico no more than 21% of males present mated on a night and males varied in the number of nights they spent in a chorus (Sullivan 1983b) with over 90% of males present in a chorus for only one or two nights.

In one instance six males participated in two choruses about 50 days apart (23-27 July and 12-13 August).

In Oklahoma groups of calling males tended to move from pool to pool when in "close proximity" such that pools that lacked calling males on one night often had them on following nights (Krupa 1994). It is not clear what "close proximity" means in terms of inter-pond distance. If inter-pond movement of calling males occurs in southern Canadian breeding areas this must be considered when designing surveys to confirm breeding presence and numbers.

Bragg (1937, 1942a, 1950e) reported in Oklahoma that females were attracted to the vicinity of ponds on the first night when choruses of calling males developed, but few joined calling males, selected males, and produced eggs at this time. He believed that most eggs were laid during the second night of calling by males and during the third or fourth night few males, which have not succeeded in attracting females, may call. In contrast Krupa (1994) in Oklahoma reported a great reduction in calling males and females by the third night of breeding and believed most breeding activity appeared to occur on the first night of calling. Over 90 percent of females arrived at breeding sites during the first three hours of calling by males (Krupa 1994). In southern Arizona, and southwestern New Mexico, Sullivan (1983b) reported females were usually observed only on the evening they laid eggs although "some" remained at an aggregation for approximately 24 hours following egg-laying. It is not clearly stated if these females were active within the breeding ponds or nearby, and on what days of the chorus that eggs were laid.

Males began calling approximately 30 minutes after sunset in Oklahoma (Krupa 1994). Breeding activity (based on apparent loudness of chorus) appeared to be most intense during the first three hours after sunset, with calling sporadically from 0100 until sunrise. At Suffield NWA, Alberta, calling of males did not begin until about 45 minutes after sunset (A. Didiuk, unpubl. data). A single occasion of calling before sunset was recorded at a wetland on the first day of the breeding season.

Bragg and Smith (1942) reported most breeding congresses are "built up" at night and when they occur in the daytime they usually foretell a much larger congress in the evening and through the night of the same day. On rare occasions in Oklahoma (Krupa 1994) heavy rainstorms in the early afternoon followed by overcast skies and mist promoted afternoon calling by males and amplexus with females, completion of egg-laying by sunset, followed by arrival of new females after sunset. Bragg (1950e) reported the approach of daylight to stop calling although he observed several daylight choruses. At Suffield NWA, Alberta, calling continued through the night and gradually tapered off as dawn approached (A. Didiuk, unpubl. data).

Bragg (1950e) reported that after the first night of a breeding chorus toads of both sexes remain in the vicinity of the pool during the day and sometimes in the pool itself, burrowing into wet soil or resting in shallow burrows (Bragg 1937). As twilight approached, and if conditions (i.e. temperature) were suitable, a rapid development of a full chorus within one half hour or less on the second night was possible.

Although temperatures of about 12°C., and preceding heavy spring and summer rains, were considered to be necessary to initiate breeding choruses in Oklahoma, the calling of males and breeding can continue even when the air temperature drops. Bragg (1940a) indicated this can occur if the breeding congress is already underway since, although air temperatures may drop to 8°C., the water temperatures in the early evening may still be around 12°C or more. Calling of males may be lower in pitch and frequency but some amplexus and egg-laying may still occur. Bragg (1940a) concluded that a small chorus would more likely be stopped at a higher temperature than a large chorus in this situation.

Calling males usually support their body with their front legs upon some vegetation projecting from the water surface material. At Suffield NWA, Alberta, calling males of the Great Plains toad were concentrated along the fringes of shallow wetlands where residual growth from the previous year (grass stems, annual weeds) and new emergent grasses and sedges projected from the water, and more central open water areas were rarely used (A. Didiuk, unpubl. data). Creusere and Whitford (1976) also reported a preference for "grass clump habitats" in a playa used for breeding in New Mexico. Smith and Wershler (1991) reported clumps of algae to be common and used as calling perches for males, and similar behaviour was observed at Suffield NWA, Alberta (A. Didiuk, unpubl. data).

In Oklahoma (Krupa (1989), in 22 of 26 pools monitored, short vegetation covered 100% of the shoreline and groups of calling males occurred on different portions of the shoreline on different nights. The shoreline of the other four pools appeared to be unused because of steep banks or tall, dense vegetation.

Krupa (1989), during monitoring of 51 breeding congregations in Oklahoma, reported calling males were dispersed over the surface of the pools in 10 of these choruses, and calling males confined to shorelines in the other 41 choruses. In seven of these 41 choruses every unmated male called and these choruses had low male densities (< 0.43 males/m shoreline). Of the 41 choruses with shoreline calling the males were evenly distributed around the shore of 16 of the choruses but were aggregated in one or two "call groups" (groups of toads separated from other such groups by 15 m or more) in the other 25 choruses. For those 25 choruses with call groups only 48% of the shoreline was occupied by the calling males (range 13-93%).

In Arizona Brown and Pierce (1967) grouped breeding choruses into three classes of calling intensity: 1) high intensity chorus of 200-500 calling males spaced randomly in the water and calling almost continuously, with little moving around; 2) intermediate intensity chorus of 20-75 calling males clustered and surrounded by non-calling males, with only some males calling continuously, and with a great amount of moving around and interaction among calling and non-calling males; and 3) low intensity chorus of less than 15 calling males spaced rather evenly along banks or in water, with males calling continuously or intermittently with long pauses between calls, and with no movement or interaction among males. High intensity choruses were associated with temporary water, intermediate choruses with the deeper and more permanent water such as tanks, and low intensity choruses with temporary water.

Krupa (1989) in Oklahoma observed calling males were never within 1 m of each other whereas the distance between calling males and satellites was less than 1 m. Stationary and silent males (i.e. potential satellite males) were never observed more than 1 m from calling males.

In high density choruses in Arizona with large numbers, and low density choruses with low numbers, calling males appeared to be spaced regularly or randomly (Brown and Pierce 1967). Intermediate intensity choruses were characterized by some calling males and many non-calling males which surround the calling males. These non-calling males exhibited a large amount of movement and interaction among themselves in response to the initiation and cessation of calling by individuals in the chorus.

Sullivan (1982) in southern Arizona and southwestern New Mexico also reported the presence of non-calling "satellite" males in breeding congregations. In low density congregations (< 0.01 toad per m shoreline) all males remained stationary along the shoreline and called repeatedly and were usually separated by at least one m. In high density congregations some males adopted non-calling, satellite positions within 0.5 m of calling males and up to 95% of calling males were "parasitized" by 1 to 5 satellite males. There was a significant correlation between density and proportion of calling males. Experimental continued removal of calling males resulted in calling of some of the satellite males until all of the males were calling. This interaction of calling and satellite males complicates assessment of the number of calling males at given breeding sites. At Suffield NWA some limited observations suggest this type of behaviour occurs at intermediate density choruses (A. Didiuk, unpubl. data).

Sullivan (1983b) reported that the mean SVL of males observed in amplexus (79 mm) was not significantly greater than the mean SVL of unmated males (77 mm), and he concluded females did not preferentially select larger males as mates. However, he also reported a significant positive correlation between SVL and percent of time calling, and the mean percentage of time calling for males who were subsequently observed in amplexus (77%) was significantly greater than the mean percentage of calling for unmated males (64%). He found no correlation between SVL and either dominant frequency or pulse rate of calling males, indicating females and satellite males likely did not differentiate male size using these call parameters.

Krupa (1989) in Oklahoma noted that high density of calling males may cause those males with less intense calls to lose relative vocal conspicuousness and they may switch to satellite behaviour which does not require calling to possibly attain a successful mating. The large number of males which switch between calling and satellite behaviour may represent males seeking temporary relief from the energetic costs associated with calling. A resting male may improve mating opportunity by associating with an "attractive" calling male rather than associating with an "unattractive caller" or remaining by itself. Attactive males may be those with long calls that may be more likely to attract a female.

Sullivan (1983b) in southern Arizona and south-western New Mexico concluded the Great Plains toad has a lek-like mating system where males do not defend resources utilized by females or their offspring, nor do males offer parental care. Females are able to move freely within aggregations to select mates from displaying males and can reject a male who attempts to amplexus them. Satellite male behaviour is similar to the satellite behaviour of other species with lek mating systems and operational sex ratios are highly skewed towards males.

Males clasp females in axillary and pectoral amplexus. Sullivan (1983b) observed unclasped females to either move towards calling males, or remain in one position but oriented towards calling males. When they approached a calling male they usually swam underwater, surfacing every 1 to 2 m, oriented towards the nearest calling male, and then continued underwater. Occasionally a female remained on the shore and approached a calling male by hopping along the shoreline towards him rather than swimming. The males continue to call as they crawled onto the females' backs, and calling ceased when pectoral amplexus was attained.

Sullivan (1983b) observed pairs to move together to areas of the pond distant from chorus activity where the females began laying eggs. This differs from observations in by Krupa (1994) who believed egg-laying occurred in the subsequent morning. He observed newly formed pairs to hide in the most densely vegetated areas of pools where they remained until morning. He reported egg-laying to occur in early morning (about 0600 in May and June) when pairs swam to locations free of emergent vegetation, and egg-laying was completed between 0900 and 1200.

Bragg (1936), and Ridley (1983) based upon Bragg's data, concluded amplexus in Oklahoma, from first clasping to completion of egg-laying, was approximately 24 hours. Krupa (1994) in Oklahoma reported a mean duration of amplexus, from pair formation the previous evening to completion of egg-laying in the morning, of about 13.5 hours with almost all completed within 15 hours. One pair completed egg-laying at 1500 for a total amplexus period of 18 hours.

Krupa (1994) found 88 percent of pairs to lay eggs in close proximity to one another at specific locations in breeding pools in Oklahoma. Usually one or two groups were formed in each pool when pairs moved for egg-laying in the early morning, and if two groups formed they were usually within 3 m of one another. The locations were predictable from rain to rain and year to year, and pairs would return to the site if artificially, gently dispersed around a pool. Eggs were deposited within a 1-4 square metre area as pairs slowly moved about during egg-laying such that a loose mass of intertwined egg strings was deposited within and adjacent to submerged stems of vegetation.

The advantages of those sites selected for this communal egg-laying were not clear at all. These areas were typically shallow, gently sloping areas with dense growths of submerged grass, but sites such as these did not appear to be limited as they were typical of the shorelines of the breeding sites. In fact, these sites were often exposed with rapid declines in water level with dessication of some eggs the first day after laying. It is not known if there are some other advantages of these sites (e.g. predator avoidance, thermal regulation, sperm competition, or female behaviour) which might affect fertilization efficiency and mixed-paternity to offset the effects of dessication at these sites (Krupa 1994).

In Oklahoma Krupa (1988) noted the postures of the male and female are adjusted during egg-laying. The male places his ankles medially to the female's hind legs, laterally to her cloaca, forming a triangular space between the male's legs and the legs and body of the female. This is the "basket" described by Miller (1909). The male uses his legs or feet to gather the eggs as they are extruded into this basket where they are held and presumably fertilized for approximately 3 minutes before being released. Krupa (1989) observed the formation of this basket for every pair (n=35) with a male to female SVL ratio of 0.75 to 1.18, and believed this basket behaviour may be the most important factor to ensure a high fertilization rate. Krupa (1988) noted an unpublished preliminary study indicated removal of eggs from the basket shortly after deposition resulted in a lower fertilization rate.

Bragg (1937a) reported a clutch size of about 20,000 eggs based on a count of one clutch from an average-sized female. This clutch has been widely used as representative in a variety of sources since that time (e.g. Wright and Wright 1949).

In Oklahoma Krupa (1994) reported a minimum clutch of 1,342 eggs (laid by a female with an SVL of 78 mm) and a maximum clutch of 45,054 eggs (laid by a female with an SVL of 115, the largest female recorded). The smallest female recorded (SVL of 60 mm) laid a clutch of 3,681 eggs. There was a significant correlation between female SVL and clutch size with an average-sized female (SVL 80 mm) laying a clutch of about 9,400 eggs. Krupa (1994) concluded that larger females with SVL > 80 mm were capable of laying clutches which varied greatly, from about 5,400 to 45,000 eggs, whereas smaller females with SVL < 80 mm laid clutches less than 10,000 eggs. This relationship between fecundity and size is common among amphibians.

In Oklahoma multiple clutches (23 April and 6 June) were reported for two individual females (Krupa 1986a). He also observed three females laying eggs on June 7 after they had been observed in amplexus on April 22. He also captured gravid females on roads during cool evenings in July and August after 95% of the breeding activity had occurred in the area. Clark and Bragg (1950) in Oklahoma reported that some females still carry oviductal and ovarian eggs in August and September after most of the breeding had already occurred. The eggs in these females were 24% of the body volume compared to 28% for female at the "peak" of the breeding season. These observations indicated some females of the Great Plains toad can either produce multiple small clutches or a single large clutch over the breeding season, and some may not breed at all. Krupa (1986a) noted harsh breeding conditions resulted in a low probability of offspring survival from any one reproductive event and multiple clutch production may increase the chances of a given female laying eggs in a pool which may remain filled with water long enough to allow successful metamorphosis of the larvae.
Fertilization and hatching success

Krupa (1988) in Oklahoma reported a 96% fertilization efficiency of 27 clutches (mean number of eggs 10,924; range 1,342 to 45,054) which were allowed to develop for 12 hours after amplexing pairs were removed from natural ponds and allowed to lay and fertilize eggs in shallow artificial ponds. Eggs were considered fertile at this time if division or elongation, indicative of the gastrula stage (Gosner 1960), was evident. Infertile eggs were those swollen, discoloured or decomposed. This mean fertilization rate was not significantly different from the 89% rate for 7 clutches (mean number of eggs 3,503; range 1,599 to 9,431).

It has been proposed that mates of similar SVL could attain a higher degree of fertilization of eggs because the closely aligned cloacae should permit efficient transfer of sperm to egg (Licht 1976) but this association does not appear to apply to all anurans. Krupa (1988) in Oklahoma found there was no apparent influence of size ratio of mates upon fertilization efficiency for 35 clutches from the mated pairs examined.

Bragg (1940a) in Oklahoma reported the percentage of hatching of eggs to be high under "favorable conditions in the field". Of more than fifty clutches observed only one was found in which most of the eggs did not hatch, provided the pool was not "obviously contaminated." Fertilization of eggs from masses arising from group egg-laying sites in Oklahoma (Krupa 1994) was high (98 to almost 100% of eggs) and was higher, but not significantly, than for single clutches (89%).

Ballinger and McKinney (1996), using eggs from Great Plains toads in the laboratory in Arizona, investigated temperature tolerance of eggs. They found that eggs placed at temperatures of 10.0°C. or lower did not develop beyond initial stages. At temperatures of 11.1 to 13.6°C. development stopped at stages from heart beat or opercular fold. Normal development occurred in 6 to 13 days at temperatures from 15.9 to 20.8°C., and hatching was accelerated to 4 to 5 days at temperatures from 21.6 to 25.7°C. No development occurred at 39.1°C. and the minimum lethal temperature was estimated to be near 14.0°C. and the upper maximum lethal temperature to be above 34.5°C. but below 39.1°C.

However, these trials were under-conducted with temperatures held constant. This situation does not address the potential for accelerated development allowing tolerance of higher temperatures (Zwiefel 1968, 1977). It is not known if eggs of the Great Plains toad in southern prairie Canada are subject to the same minimum lethal temperature but some observations at Suffield NWA, Alberta (A. Didiuk, unpubl. data) indicated overnight water temperatures during the egg-laying period are often less than 14°C. yet successful hatching occurred.

Developing embryos become externally ciliated by the time the neural tube closes, and they may rotate in the jelly due to a strong ciliary beat directed backwards. In the laboratory embryos have emerged from the jelly in 53 hours. The gelatinous capsules become softer, a cavity forms and surrounds the developing larva, and the larvae emerge using ciliary action when a small exit hole is formed in the capsules. The embryos are oriented with their lateral surfaces upwards, use ciliary action to move away from the capusle, and soon attach to a substrate using an adhesive organ. Bragg (1941a) provides a detailed description of the hatching of eggs.

Development

The larval period of the Great Plains toad has been estimated to be about 45 days (e.g. Wright and Wright 1949) based on a several early studies in Oklahoma (Bragg 1937b, 1940, 1950b). Other studies in Oklahoma have suggested a similar range of time for the larval period from 18 to 35 days (Bragg 1939d, Gates 1957, Hahn 1968) with a possible minimum period of 14 days (Strecker 1940). Bragg (1940a) in Oklahoma reported the length of larval life to be close to one and one-half months. In Oklahoma (Krupa 1994) the period of time from the day of egg-laying to the first observation of metamorphs on shore was extremely variable with the longest larval period (49 days) recorded in early to mid-season breeding seasons (March - April) and the shortest larval period (18 days) in late breeding seasons (June).

This variability in larval development arises from variation in temperature, larval density, food availability and competition for same (e.g. Werner 1986). Larval survival appeared to be consistently low throughout the breeding season in Oklahoma (Krupa 1994). Although pools retained water longer in the early season (April) the lower temperatures and higher larval density associated with large breeding congregations at this time resulted in slower development of larvae such that even a 45-day development period was insufficient to avoid desiccation. Warmer temperatures and lower larval densities in the later season (June) resulted in accelerated rates of development but pools of water also dried more quickly, and again tadpoles rarely developed quickly enough to reach metamorphosis.

Zweifel (1968) reported the range of tolerance during embryonic development of the Great Plains toad to be 16.0 to 33.5° C. The number of hours to reach gill circulation decreased with increasing temperature (21° C. - 86 hours; 26° C. - 43 hours; 32° C - 25.5 hours). The maximum temperatures tolerated by Great Plains toad larvae was 40.5° C. for exposures up to 6 hours (Zweifel 1977), reflecting adaptation to high water temperatures which can occur in the shallow breeding ponds. The larvae can also rapidly increase their tolerance to increasing water temperatures as they accelerate their development in response to increasing temperature which is another facet of their adaptation to high water temperatures in breeding pools (Zweifel 1968, 1977).

Bragg (1940a) in Oklahoma reported that variation in size at metamorphosis was not marked. Head-body lengths ranged from about eleven to about thirteen millimetres, and the tail was somewhat longer than this. Seldom did a tadpole reach a total of greater than thirty millimetres before transformation began.

Metamorphosis

Bragg (1940a) provides a detailed chronology and description of the changes in size, morphology and colouration of larvae during metamorphosis. Krupa (1994) reported metamorphosis to be highly synchronous. At Suffield NWA, Alberta in 1996 newly emerged metamorphs were abundant in the immediate vicinity of two breeding ponds, and no larvae were visible in the pool, suggesting metamorphosis was highly synchronous.

Bragg (1940a) described the metamorphosis of larvae at a single pond with a 12-day period between the first and last emergence of metamorphs. It is not clear from his description if this was the result of variable growth of larvae from a single breeding event, or the result of two or more breeding events resulting in larvae of different ages. Smith and Wershler (1991) in Alberta reported that "small young-of-the-year" have been observed on June 28 and July 18. At Suffield NWA, Alberta, newly emerged toads were observed on July 15 (A. Didiuk, unpubl. data).

Bragg and Weese (1950) considered successful metamorphosis to be uncommon particularly in a dry spring when breeding might be delayed until later in the season. Large numbers of eggs were often produced in these situations but larvae had to develop at the beginning of a period of high temperatures and hot, dry winds such that most tadpoles were killed by evaporation of water from ponds.

In Oklahoma Krupa (1994) reported the successful metamorphosis of larvae was infrequent due to drying of breeding pools (emergence of metamorphs on 9 occasions from 26 pools after 18 rain events). He concluded successful metamorphosis was a relatively rare event at any time in the overall breeding season and pools with the lowest densities of larvae appeared to be more successful.

Bragg (1940a) in Oklahoma reported that tadpoles avoided deep water and at metamorphosis thousands of young emerged from the water only along those shorelines with shallow water. At Suffield NWA, Alberta, specific portions of shorelines had concentrations of newly emerged young toads whereas other sections of the ponds had very few or no young toads present. Presumably this reflected the concentrations of tadpoles prior to metamorphosis but water depth appeared to be similar along the entire shorelines (A. Didiuk, unpubl. data).

Bragg (1940a) describes several stages of metamorphosis. The time from start of metamorphosis to emergence is two days. During the first two days after emergence the metamorphs remain very close to the edge of the water under cover. Within the next three days some of the larger metamorphs may move up to 20 m from the breeding pond, and they no longer seek water for protection. Within the next week many are found more than 40 m from the breeding pond.

In contrast, Bragg and Weese (1950) in Oklahoma reported young toads, upon emergence at metamorphosis, to remain near the pool as long as the pond contains water, up to several weeks. Eventually they moved away, and did not scatter widely but sought areas of soft soil in which to burrow. Their movements were stimulated by showers but most individuals continued to feed each night through the summer and well into September whether it rained or not. Young toads were collected on nights between days of maximum temperatures of over 100°F. and when no precipitation had occurred for over a month. Similarly Bragg (1950e) in Oklahoma reported young Great Plains toads to remain about the pond for some time after metamorphosis and disperse from it only when water evaporated or when the toads reached an age of approximately two to three months.

Creusere and Whitford (1976) in New Mexico monitored the behaviour and survival of a mixed species assemblage of juvenile bufonid and pelobatids, including the Great Plains toad, in the vicinity of a drying playa used for breeding. All age classes were active at night but on rare occasions dense overcast conditions resulted in diurnal activity. Activity was initiated with rain with peak activity occurring within a few hours of a rainfall event. Moisture declined as the soil dried, and when the upper 20 cm of soil were dry activity ceased and juvenile toads remained inactive until the next rainfall.

Creusere and Whitford (1976) observed young toads to begin to retreat under surface objects (e.g. cow dung, wood, clumps of dead vegetation) or into fissures in the soil at daybreak. They emerged from these retreats about one hour before sunset. They reported significant mortality of young toads which used surface cover during the day but all toads found within fissures were found alive.

It is not certain when recently emerged toads become more nocturnal in their movements. Bragg and Weese (1950) in Oklahoma found they could find metamorphosed toads when they remained diurnal in their activity near the breeding pond, but after they became nocturnal they were forced to make collections at night at what seemed to be favorable times. This statement does not clearly indicate whether young toads were active and/or visible during the day, or whether they were clumped and not fully under cover near the water's edge. Presumably as they move away from the pond they begin to burrow and remain below the surface during most of the day.

Growth, Sexual Maturity and Survivorship

Bragg (1940a) in Oklahoma reported an average snout-vent length of 12 mm, and an average weight of 0.15 grams, for newly emerged metamorphs. Within a week after the young toads have departed from the vicinity of the pool some individuals had increased their weight over 200 percent but many others did not exhibit this gain in weight, and all were still very small with the largest still weighing less than a gram.

Bragg (1940a) in Oklahoma reported toads to have a variable growth rate in the first four months after emergence. A mid-October sample of toads associated with one breeding area (n = 12) had an average SVL of 52 mm (range 48 - 63) and average weight of 22 grams (range 12 - 37). A second sample of young toads associated with another breeding area (n = 27) were smaller with an average SVL of 42 mm (range 36-56) and an average weight of 12 grams (range 7 - 20)

Bragg and Weese (1950) in Oklahoma reported considerable variation in growth rates of juveniles in their first summer. This applied to toads which emerged from the same pool at the same time. Some juveniles which emerged late in the summer might have an SVL of 30 mm or less at the beginning of hibernation whereas those which emerged early in summer may be as large as smaller adults of broods of the preceding breeding season. They assumed "aggressiveness", injury or the simple availability of food caused this variation in growth rate.

Bragg and Weese (1950) in Oklahoma monitored the sequence of events for the sexual development of male Great Plains toads. At about 15 weeks, near the end of the first active season after metamorphosis, males began to issue a juvenile "peep" protest call when handled and the dark-coloured gular patch started to develop in some. At about 20 weeks, prior to hibernation, most males issued the protesting note when handled, and most had a dark smudge on the throat indicating the beginning of the pouch. This development appeared to be independent of SVL of individuals.

Upon emergence from hibernation the next spring (about 10-12 months after metamorphosis) all males issued the protest call when handled and all showed development of the gular pouch. There was no evidence of any breeding by males of this age. Late in the summer (about 13-15 months after metamorphosis) some males showed complete development of the gular pouch.

Upon emergence from hibernation the following spring (about 22-24 months after metamorphosis) practically all males showed complete development of the gular pouch, and the protest note when they were handled was now the adult quack rather than the juvenile peep. In breeding pools the sizes of the smallest males at this time compared favorably with the sizes of those taken in adjacent roadways. They concluded that young males attain sexual maturity at this time.

Bragg and Weese (1950) were unable to collect information to determine the likely age of sexual maturity for females. However, they noted that the SVL's of mated females in the breeding ponds were larger than those female toads in adjacent roadways which were be believed to be have emerged 22-24 months previously. They postulated that females may not attain sexual maturity until about 34-36 months after metamorphosis. In Oklahoma Krupa (1994) found females at breeding pools to be significantly larger (snout-vent length (SVL) 60 - 115 mm) than males (SVL 56 – 98 mm with only 10 of 758 females with an SVL of less than 60 mm). He found a significant correlation between SVL and mass for both males and females.

The mean SVL of samples of breeding adults not individually marked increased significantly in Oklahoma in one year (about 10 mm for males, 13 mm for female) but not in another (Krupa 1994). A small sample of marked adults (9 males, 4 females) measured within and among breeding seasons revealed a great variation in increase of SVL for both sexes (males mean 6.6 mm/yr, range 2.5 - 14 mm); females mean 12.3/yr, range 7.0 - 20mm).

There is no information available for survival rates among years and age cohorts for the Great Plains toad. Overall survival rates for young pleobatids and bufonids of various species in a playa environment in New Mexico, over each of two winters, was about 10% (Creusere and Whitford 1976), and this may have reflected their inability to accumulate fat stores during the harsh, arid conditions in the summer after emergence. They also noted that juvenile toads on the fringe of a drying playa used for breeding were only active for a day or two after a rain event whereas juveniles which remained on the playa bottom itself were active for up to 55 consecutive days. They concluded those toads using the drying playa bottom would grow more rapidly since the more moist conditions would allow activity, and more of these would survive under arid conditions.

Aestivation and Hibernation

Great plains toads burrow to avoid dry conditions, including high air temperatures and low air humidity, and their retreat beneath the surface may be for extended periods of time. This species has a variety of adaptations, common to other fossorial anurans which live in arid regions, to permit extended periods of aestivation.

Highly fossorial species tend to have greater tolerance to desication and can lose a great portion of body water before death (greater osmoconcentration tolerance) compared to more aquatic species (Schmid 1965). Their integument is more permeable to water compared to aquatic anurans, and their burrowing into cool, moist soils allows retention of body water.

The ability of anurans to absorb water from soils when they have burrowed may be an important factor in determining their distribution. Walker and Whitford (1970) reported the Great Plains toad had an absorption threshold between 2.5 and 2.7 atmospheres and lost water to the soil at 2.75 atmospheres. It was able to fully rehydrate using soil moisture at a tension of 1.2 atmospheres. Mean hydration time in soil saturated with water at 0.8 atmospheres was 12 hours, but this was considerably more than the 8.5 hours required for rehydration in free water. Note that distilled water has a water potential of 0 atmospheres.

Hillyard (1976) describes the relationship between soil moisture, osmolarity of body fluids, and net water flux across the skin of the Great Plains toad. He noted that contact between the skin and the soil may be an important factor in the absorption of soil moisture. Yokota and Hillman (1984) describe the role of the amphibian antidiuretic hormone arginine vasotocin (AVT) which mediates cutaneous water uptake in dehydrated anurans.

Urinary bladder fluid is an important reserve of water in dry conditions (Ruibal 1962; Shoemaker 1964). The Great Plains toad can store up to 30% of its body weight as water in the urinary bladder and those devoid of urinary water had no substantial water reserve (Schmid 1962). This water initially has a concentration of less than 1% and under conditions of dehydration the bladder water is resorbed which permits a degree of homeostatic control of the concentration of blood and lymph. As dehydration progresses the concentration of the urine rises and presumably when the urine is isotonic to the lymph or blood the concentration of the lymph starts to rise. Schmid (1969) found the relative capacity of the urinary bladder (adjusted for body weight and percentage body water) was higher (37%) in the Great Plains toad compared to *B. americanus* (28%) and *B. hemiophrys* (24%) and he considered the bladder to be an important storage organ for water. The use of bladder urine as a water reserve allows survival over long periods of drought and allows hunting for food far from water sources (Schmid 1962).

Whitford (1969) reported the heart rate of the Great Plains toad to decrease from 65 beats per minute to 31 beats per minute within 24 hours after burrowing although several individual toads maintained a relatively high heart rate (30-50 beats per minute) for two weeks after burrowing. This decrease in heart rate appeared to be independent of ambient temperature when in burrows since a four- to sixfold decrease in heart rate was observed at the same ambient temperatures at which "normal" rates were obtained from toads which had not burrowed. This brachycardia in aestivating toads was considered to reflect the reduction in metabolism associating with burrowing.

However, Armentrout and Rose (1971) suggested this brachycardia may be associated with oxygen stress and not a reduction of metabolism. They noted liver glycogen depletion, blood glucose increases, and accumulation of lactic acid in the blood during anoxia which suggested anaerobic glycogenolysis. This shift to anaerobic metabolism, accompanied by cardiovascular adjustments to maintain most of the blood in the area of the heart and brain, are adaptations for oxygen stress during burrowing.

The skin, lungs and buccal cavity may all participate as respiratory surfaces in adult anurans and the relationship between body size and surface area to gas exchange may be an important factor affecting ecological distribution. Hutchinson et al. (1968) reported pulmonary oxygen uptake of the Great Plains toad increased linearly between 5° and 25° C and cutaneous oxygen uptake increased between 5° and 15° C but did not increase significantly between 15° and 25° C. Hillman and Withers (1979) describe the role of respiratory surface as a limit to activity metabolism in anurans, including the Great Plains toad, and Withers and Hillman (1983) describe the effects of hypoxia on pulmonary function and oxygen consumption in the Great Plains toad.

McClanahan (1964) reported that muscles of Great Plains toads from Arizona exhibited a higher tolerance to hypertonic urea solutions compared to muscles of *Rana pipiens* and suggested this may be an adaptive trait to burrowing when urea from protein metabolism is stored in body fluids.

Great plains toads, similar to other bufonids, burrow into the soil to hibernate. They have been reported to be intolerant of freezing, regardless of crystallization temperature (Swanson et al. 1996). There is little information regarding site selection and chronology of ingress/egress from hibernation sites for this species. Smith and Wershler (1991) reviewed reports of the Great Plains toad in Alberta, noted the latest documented record was August 19, and concluded that by late summer all ages have burrowed underground where they remained until the following spring. Whether they do so at or near breeding sites, or in a more dispersed fashion, was not known. Whitford and Meltzer (1976) reported juvenile Great Plains toads did not attempt to burrow in soil containers and did not survive whereas other species did burrow. They concluded juvenile Great Plains toads may not excavate their own burrows and may require other excavations such as ant nests in which to overwinter.

When dormant the Great Plains toad is subject to a negative energy balance and must rely only on energy reserves, in the form of stored lipids, to meet metabolic maintenance requirements. Reproduction activities, including calling and vitellogenesis, will require lipid stores in the spring. Fat stored in gonadal fat bodies are the main storage site for lipids in many anurans (Fitzpatrick 1976) and presumably for the Great Plains toad. Wygoda et al. (1987) reported the Great Plains toad lacked cutaneous adipocytes, another potential lipid storage area, whereas many other species did possess these fat storing deposits in the dermis. They did possess subcutaneous adipocytes. These, and other lipid storage sites associated with other organs, may supplement gonadal fat bodies for lipid storage.

Movement and Migration

The Great Plains toad is primarily nocturnal (Bragg 1940a) although Strecker (1910) and Bragg (1937) reported this species to be occasionally active during daylight, particularly during moist weather and during the height of the breeding season, presumably males and females en route, near, or departing from breeding pools.

Strecker (1910) in Kansas reported that during wet seasons these toads were found in low places on the plains in enormous numbers, that hundreds were killed by wagons in ruts in the road, and that it was more diurnal in habits than most toads. He also noted that the Great Plains toad might be active on cloudy days as late as eleven o'clock in the morning and as early as three in the afternoon, and at the springs at all hours of the day. Usually, however, they came out of their burrows about an hour before dusk. In Oklahoma Bragg (1940a) reported no activity even at night during periods of drought, especially when air temperatures are high, but light rain showers would often bring them out in numbers.

Breckenridge (1938) in southwestern Minnesota reported heavy rains during 1937 brought out great numbers of Great Plains toads. The average SVL of these toads suggested they were too big to be juveniles but too small to be adults (average 41 mm in July and early August, and 53 mm in late August and September). After reviewing weather records he concluded a moist season in 1935 resulted in a good hatch and successful metamorphosis but the animals would have been too small to attract any general attention that year. In 1936 extreme drought may have kept them dormant most of the time and little growth took place. The next year the heavy rains brought out the small two-year old toads which may have thrived on abundant insect life and became very conspicuous.

The Great Plains toad in Minnesota was judged to be capable of extensive movement across uplands (Breckenridge and Tester, 1961). In Minnesota Tester et al. (1965) demonstrated that *B. cognatus* demonstrated the least thermoregulation compared to *B. hemiophrys* and *B. americanus*. They concluded the Great Plains toad did not possess as much thermoregulatory capability compared to the other two species, or it was better able to tolerate higher air temperatures. At air temperatures above approximately 38°C. the Great Plains toad usually burrowed. When the air temperature dropped below 30°C. the Great Plains toad became very active. These observations suggested the Great Plains toad could exist at higher environmental temperatures than the other two species.

When not actively foraging Great Plains toads burrow below the surface using an effective backward digging and burrowing motion. Strecker (1910) in Kansas reported these burrows were located in sandy soil at the roots of bushes and weed clumps. Bragg (1940a) in Oklahoma found these almost impossible to detect even though they may have been shallow, yet they provided protection from excessive heat and moisture. On occasion, if moist conditions prevail, they only partially penetrated the soil surface such that the burrows were mere depressions just fitting the body of the toads.

It is not known if Great Plains toads exhibit a high degree of homing to breeding ponds. Unusual mass migrations, or eruptive movements, of juvenile Great Plains toads in late summer were reported for a large area of eastern North Dakota and western Minnesota (Bragg and Brooks 1958). These movements involved many millions of toads, were concentrated in an area of 125 miles north and south by 55 miles east and west, involved no adults, and all juveniles were heading in a northerly direction. They also noted the greater tendency of this species to aggregate in localized areas in Oklahoma, but without a definite migration, compared to other local species of Bufo. They postulated these juvenile toads were reacting to each other's presence by sometimes migrating extensively or locally with a strong directional trend.

Brattstrom (1963) reported the temperature of three active Great Plains toads to be 21.8° C but this limited sample does little to indicate the relationship between body temperature and activity. Schmid (1965) in the laboratory, using toads from western Minnesota, determined that the upper lethal temperature of *B. cognatus* was about 2.3° C higher than for *B. hemiophrys*. Survival of *B. cognatus* was about 1.5 minutes at 43.5° C, 2.5 minutes at 42 degrees, 5 minutes at 40° and 30 minutes at 38 degrees. At the latter temperature 10 specimens of *B. cognatus* appeared unaffected after 3 hours whereas 10 specimens of *B. hemiophrys* survived for an average of only 40 minutes. It is not clear how this laboratory information can be used to assess lethal temperatures in toads not immersed in water, but it does suggest *B. cognatus* may be more tolerant of higher temperatures within its more western and southern range.

Brattstrom (1968) investigated temperature tolerance of Great Plains toads obtained from Sonora, Mexico. He reported critical thermal maxima of 37.4°C with acclimation at 5° C, 39.7° C with acclimation at 23° C, and 41.3° C with acclimation at 30°C. He reported a critical thermal minimum of -4.0°C. Paulson and Hutchinson (1987) reported a critical thermal maximum of 38.2°C with acclimation at 15°C for toads obtained in Oklahoma. They noted that acute heat stress appeared to have no lasting effects upon *B. cognatus*. Paulson and Hutchinson (1987) describe muscle response at temperatures at and near the critical thermal maximum for the Great Plains toad.

Food Habits

Bragg (1940a) reported larvae to feed upon algae, the remains of insects and any other animal or vegetable matter which becomes sufficiently softened by the action of water or bacteria, and he considered them to be partially scavengers. Hartman (1906) reported snout beetles and dung-beetles were consumed by adult Great Plains toads. Tanner (1931) reported predation primarily upon ants, with occasional feeding upon beetles and beetle larvae. Bragg (1950e) in Oklahoma concluded that food (arthropods) for adults was so abundant in moist habitats during the warmer seasons that little in the way of special adaptations had evolved in these animals. The average individual diet depended upon availability and relative size of the food objects. He also suggested that adults of all species of *Bufo* do more feeding in the spring and early summer than later in the season.

Bragg (1940a) reported newly emerged metamorphs to begin feeding immediately upon a variety of animals small enough to swallow. From examination of fecal masses he detected the presence of mites, various small beetles including small ground beetles (Carabidae), young snails (Physa) and a variety of unidentified small insects. Captives accepted gnats, spiders, leaf-hoppers and small beetles two days after metamophosis and did not accept insects as large or larger than house-flies. An interesting observation was the presence of a live mite in a fecal mass which he believed had passed through the digestive tract apparently unharmed. Bragg postulated feeding sometimes starts before the digestive system is "fully prepared".

Bragg and Smith (1949) provide a detailed analysis of the stomach contents of juvenile and adult Great Plains toads in Oklahoma and compare their results to samples from other species of *Bufo* in the area. Many of their samples were obtained from roadways but many were captured on the "prairie" as well. They recorded 71 prey items in the spring and 65 in the summer for the Great Plains toad. In the spring adult toads fed almost entirely (99%) upon arthropods with annelids the balance. Insects were the dominant item (92%) with the balance primarily mites and terrestrial Crustacea. About half of the insects were Coleoptera with carabid and scarabid beetles most frequent in insect samples. In summer samples from adults indicated the diet was entirely arthropods, almost entirely insects (98%).

In the spring juvenile toads, with SVL of 10-15 mm, fed entirely upon arthropods with mites the most important type of prey (60%) and insects providing the balance (Hymenoptera 25%, small carabid and scarabid beetles 13%). When these juvenile toads attained an SVL of 21-40 mm arthropods remained the entire diet but almost no mites were taken and insects were the prey taken, with many more Hymenoptera (75%) and carabid beetles (13%) but few scarabid beetles. Bragg and Smith (1949) considered a meal of 200 mound-building ants or 30 June beetles (Phyllophaga) to constitue large meals for an adult female Great Plains toad. Males ate less, possibly reflecting their smaller body size.

LIMITING FACTORS

Habitat Loss and Fragmentation

Most of the range of the Great Plains toads in southern prairie Canada is not subject to urban encroachment given the concentration of homes and industry of towns and cities in defined areas. Some impact has occurred in areas adjacent to these communities as outward development occurs (e.g. Great Plains toads in golf course at edge of Medicine Hat, Alberta) (Bleakney and Cook, 1957, National Museum of Canada collections). The oil and gas industry in southeastern Alberta and southern Saskatchewan is involved in the construction of well sites, pipelines and compressor stations. The cumulative area of habitat loss and alteration associated with these structures is minimal.

In recent decades conversion of natural grasslands to cereal cropland has likely resulted in the loss of many potential breeding areas for amphibians, and reduction in the quality of foraging habitat adjacent to those ponds which remain (Butler and Roberts 1971). Repeated cultivation of the bottoms of wetland depressions in dry years can reduce the water-holding capacity of these wetlands.

Smith and Wershler (1991) concluded drought periods increased the frequency of construction of dugouts for livestock watering within natural wetland depressions. In many cases these dugouts provide limited breeding habitat with bare, steep shorelines and often eroding spoil piles, deeper water, and disturbance by livestock. In years without exceptional spring runoff they expressed the concern that local surface and subsurface water would collect in the deeper dugout and reduce the persistence of surface water in the adjacent wetland depression. This process will depend upon local conditions, and in some cases low-gradient shorelines at the ends of some dugouts can provide growths of emergent sedges and shallow water which may be used by some Great Plains toads (A. Didiuk, unpubl. data).

Land Use

The ability of shallow wetlands within cropland to persist and provide adequate breeding habitat for the Great Plains toad, and impacts of cereal crop habitat upon dispersal, foraging and successful hibernation, are unknown. Application of herbicides and pesticides may affect all age classes in both wetland and upland areas.

Mortality of burrowing toads, at all seasons, by tillage is unknown. Hibernation depths are likely deeper than conventional tillage but emerging adults may be at risk if emergence coincides with late April and early May cultivation of fields for seeding. The practise of summerfallow tillage, although decreasing in frequency, may affect mortality of the Great Plains toad in the summer and during early hibernation in late summer and early fall when they burrow to shallow depths. Mortality from actual harvesting may be minimal since harvesting generally occurs during low humidity conditions. However, toads may use swaths as cover and be subject to mortality during harvesting.

Impacts upon water quality by grazing activities have not been quantified. Potential impacts are the grazing and trampling of shoreline vegetation by livestock. In southern prairie Canada breeding of the Great Plains toad, which occurs from early May to mid-June, may not result in great impacts by this mechanical damage since cattle are usually released onto pastures in late May or early June after most egg-laying and hatching has occurred. Larvae are able to develop in more disturbed, turbid water conditions.

However, concentrations of livestock at wetlands can result in greatly increased nutrient loading of water due to defecation of cattle and can lead to massive mortality of larvae. At Suffield NWA, Alberta, complete mortality of larvae of tiger salamanders was observed in these situations (A. Didiuk, unpubl. data). Concentrations of cattle can be reduced by ensuring salt blocks are located away from wetlands used for watering.

Large numbers of Great Plains toads may be killed upon paved and unpaved roads (Bragg 1940a; Bragg and Brooks 1958), especially if these roads are near breeding wetlands and if they have high traffic. Breckenridge (1938) reported heavy rains in southwestern Minnesota "brought out great numbers of toads [great plains], and thousands of them were killed on the gravelled and paved highways in this section."

Many small mammals, birds, reptiles and amphibian can become entrapped in artificial structures, particularly depressions or well-like structures. At Suffield NWA, Alberta, Great Plains toads have been observed on several occasions to have fallen into natural gas well caissons where they cannot escape (A. Didiuk, unpubl. data). During the summer there are abundant beetles and flying insects available at the bottom of these caissons, and humidity can remain high. The toads can burrow into sand at the bottom of these caissons or hide under objects which may be present. It is unknown if they can survive the winter by burying into the sand but it may be quite possible. Even if they do survive they are effectively eliminated from the natural population.

During construction of pipelines the open trench for laying of pipe may entrap Great Plains toads during their foraging, particularly if toads are moving towards a breeding pond near a pipeline trench. Recent mitigation procedures involving inspection of trenches during the brief time they are open, primarily to remove snakes, may assist in removal of Great Plains toads as well (R. Lauzon, pers. comm.). However, Great Plains toads may burrow into the soil at the bottom of trenches and not be detected.

Climate

The Great Plains toad has adaptations for living in a xeric environment. It is able to exploit ephemeral wetland breeding habitat when it becomes available in years of high surface runoff, or after periods of heavy rain in spring and early summer. During these breeding events enormous numbers of young toads may be produced. During periods of drought the fossorial behaviour of the Great Plains toad allows it to survive although breeding is not possible. Even though heavy rains may not occur frequently, high humidity on occasion, or light showers and dew conditions, may promote emergence to feed.

Dry periods of several years, without reproduction, are common in other regions and significant numbers of young survive, grow and enter the breeding population with other adults. However, the impact of many years of drought without successful reproduction, or decreasing frequency of years of successful reproduction over the long-term, is unknown.

There is no information to confirm whether significant mortality may occur over the winter period. Greater mortality of young toads in their first winter likely applies to the Great Plains toad which may reflect selection of wintering location and reserves. Bragg (1940a) postulated if winter-killing were common one would expect the numbers of toads to be visibly depleted after three winters had passed without breeding. A long-term study (e.g. Green 1992) would be required to assess the potential effects of winter mortality upon different age cohorts.

However, Bragg (1960) reported the apparent disappearance of an entire first-year cohort of Great Plains toad although he did not actually state that mortality during the winter was the cause. He did note large numbers were killed the preceding season by vehicles and farm machinery but considered these sources of mortality to be insignificant in relation to the vast numbers of toads produced. He also did not believe migration or mass directional movements (Braggs and Brooks 1958) were the cause.

Competition

No information is available to assess whether other endemic anurans can effectively suppress or displace populations of Great Plains toads. Competition for food resources between larvae of the Great Plains toad and the boreal chorus frog (*Pseudacris maculata*), the most common and abundant anuran which breeds in the same wetlands, may occur. At Suffield NWA, Alberta, breeding congregations in May and early June were dominated by Great Plains toads and only a few plains spadefoot toads (A. Didiuk, unpubl. data). Following dry springs, heavy rainstorms in early summer may stimulate large breeding choruses of plains spadefoot toads and if Great Plains toads also initiate breeding there may be competition among larvae. In these situations the more rapid growth of spadefoot larvae and potential for predation may limit recruitment of Great Plains toads. In the Canadian range of the Great Plains toad there are no known introduced species of amphibians of concern.

Predation

Bragg (1940a) reported in Oklahoma that "the spadefoot toad (*Scaphiopus bombifrons)* often breeds in buffalo wallows and its tadpoles are much larger, more active and develop at a faster rate than those of *Bufo cognatus*, and they are carnivorous." Trowbridge and Trowbridge (1937) also believed the larvae of spadefoot toads preyed upon the larvae of the Great Plains toad. Bragg (1950e) reported a pond where "thousands of tadpoles of *Bufo cognatus* in a buffalo wallow disappeared progressively as tadpoles of a known predator (*Scaphiopus bombifrons*) increased in dominance and individual size."

Bragg (1940a) reported predation by predaceous diving beetles (*Hydrophilus triangularis*) whose larvae can occur in large numbers in the buffalo wallows. At Suffield NWA, Alberta, larvae of dytiscid beetles and dragonflies were abundant in ponds and these species are likley important predators of all anuran larvae in the prairies.

The plains hognose snake (*Heterodon nasicus*) is considered to frequently prey upon Great Plains toads and spadefoot toads and given its use of similar mixed-grass prairie habitat it may be an important predator (Platt 1969). It has a venom which may be effective in immobilizing anuran prey and its posterior teeth may assist in deflating seized toads which have inflated themselves as a protective measure. In Alberta the plains hognose snake has been reported to prey upon Great Plains toads (J. Picotte, pers. comm. in Smith and Wershler 1991). Other species of snakes, the western plains garter snake (*Thamnophis radix haydeni*) and the wandering garter snake (*Thamnophis elegans vagrans*), also prey upon grassland anurans. The bull snake (*Pituophis melanoleucus sayi*), which mainly preys upon small mammals and birds and their eggs or young, may on occasion prey upon toads (Bragg 1940a). Creusere and Whitford (1976) observed predation upon bufonid and pleobatid juveniles by the plains hognose snake and the bull snake.

A variety of species of birds can be expected to prey upon the Great Plains toad. All ages and sizes can be vulnerable to larger birds such as crows (*Corvus brachyrhynchos*) and black-billed magpies (*Pica pica*) (Bragg 1940a). Adult ducks and ducklings (Anatidae) may opportunistically prey upon larvae in shallow breeding pools. Congregations of newly emerged toads near the shoreline of breeding ponds may be particularly vulnerable to avian predators. The great blue heron (*Ardea herodias*) and black-crowned night heron (*Nycticorax nycticorax*) may breed or forage in Great Plains toad habitat, but are probably infrequent predators.

Diurnal raptors such as the Swainson's hawk (e.g. *Buteo swansonii*) may also occasionally prey upon toads (Bragg 1940a). Predation by these species is likely opportunistic during conditions when the toads are accessible during the day (moist conditions which promote some day activity, or concentrations of newly emerged toads near breeding ponds). Burrowing owls (*Athene cunicularia*), which forage at night for small mammals, are known to prey upon a variety of grassland anurans (Haug 1985).

There is no information available to determine if any species of grassland mammals frequently prey upon the Great Plains toads. The American badger (*Taxidea taxus*) and the coyote (*Canis latrans*) are carnivorous species which may be predators but toad skin and parotid gland secretions may be effective deterrents. The recent northward range expansion of the racoon (*Procyon lotor*), an efficient predator of amphibians, is of concern for some species of amphibians associated with riparian habitat. The grassland habitat of the Great Plains toad suggests the racoon may not be an important predator.

The temporary nature of the breeding ponds greatly limits the possibility of fish, many other amphibians and aquatic reptiles (i.e. turtles) as major predators. The larvae of tiger salamanders (*Ambystoma tigrinum*) were present in all breeding ponds used by the Great Plains toad at Suffield NWA, Alberta, but the impact of predation upon its tadpoles by the salamander larvae, if any, is unknown (A. Didiuk, unpubl. data).

Disease and Parasites

Trowbridge and Hefley (1934) reported a single Great Plains toad to harbor a "heavy infestation of intestinal Protozoa (*Opalina* sp.) and a cestode referred to *Ophiotaenia magna* was also found. No trematodes, nematodes or arthropods were seen."

Heavy infestations of intestinal Protozoa were noted in several individual Great Plains toads (J. T. Self in Bragg 1940a) as well a a cestode (*Nematotaenia americana* Jewell, *Distoichometra bufonis* Dickey, or a closely related form) which commonly occurs in the intestine.

Ulmer (1970) reported on the trematodes of amphibians in Iowa and found none in the two Great Plains toads he examined. Ulmer and James (1976) investigated infection of amphibians by cestodes in Iowa and found no adult or larval cestodes in the four Great Plains toads they examined. Brooks (1976) investigated the incidence of platyhelminths in the amphibia of Nebraska and found no platyhelminth parasites in the 58 specimens of the Great Plains toad he examined.

The general low incidence of parasites in the Great Plains toad and other fossorial species of anurans may reflect the reduced exposure to aquatic habitats given the generally brief breeding period and fossorial behaviour of this species. Brandt (1936) suggested there was a positive correlation between the degree of aquatic habitat selection and the degree of metazoan parasitism in anurans. Those species which are highly fossorial in behaviour and are only briefly associated with breeding ponds are characterized by low parasitism.

Environmental Contamination

There is no information available regarding the extent, or effects, of toxic substances upon the Great Plains toad throughout its range in prairie Canada.

Populations of Great Plains toad which breed and forage in natural grasslands are unlikely to encounter pesticides and herbicides except in areas immediately adjacent to cultivated areas where these substances are applied. Airborne transmission of toxic chemicals to "pristine" environments is well-known, but the degree to which this occurs in the range of the Great Plains toad and the effects, if any, are unknown.

The oil and gas industry is widespread throughout the range of the Great Plains toads and there may be occasions when individual toads may encounter small area of spillage of various chemicals during the exploration and construction stage of these developments. Occurrence and impact are likely to be minimal.

SPECIAL SIGNIFICANCE OF THE SPECIES

The public is generally unaware of this specific species, reflecting the general lack of understanding and knowledge of reptiles and amphibians. It probably is not subject to the same degree of persecution directed towards snakes. There is no commercial harvest of the species in Canada and current legislation and philosophies suggest harvest of this species is unlikely to occur in the near future. There is no current medical research using this species in Canada. Investigations of antibiotic properties of the dermis of other bufonids (e.g. Houston toad) are being conducted in the United States.

The range of the species is very extensive throughout North America and although habitat and populations of this species and many other anurans have likely been reduced to some degree, it appears to remain widespread and abundant throughout most of its range. The species may be contiguous with populations south of the Canadian prairies. Canadian populations may have developed adaptive traits to ensure survival and reproduction at the extreme northern edge of the species range.

EVALUATION AND PROPOSED STATUS

Evaluation

The range of the Great Plains toad in prairie Canada, based on potential habitat and recent surveys under appropriate conditions, has likely not contracted and is probably much greater than formerly believed. Past reports of dramatic declines in populations are probably a reflection of the intermittent breeding of this species. The Great Plains toad is adapted to surviving and breeding in xeric grasslands and is capable of enormous reproductive output under suitable conditions. There are extensive areas of natural grassland habitat within the range of the Great Plains toad. Large areas of grassland habitat are associated with federal and provincial pastures, parks and military reserves, and these are protected from conversion to cropland. However, grassland habitat on private or leased crown lands continues to be gradually converted to cereal crop production or improved pasture, and these upland conditions are unlikely to be as suitable for foraging, aestivation and hibernation of the Great Plains toad. Grazing impacts upon grassland habitat on private and public lands vary in their degree of effect upon grass biomass and wetland water quality on a seasonal basis. Wetlands throughout the range of the Great Plains toad are subject to degradation via drainage, filling and cultivation in areas where grassland is converted to cropland. In grassland areas concentrations of livestock near and within wetlands can affect water quality, and reduce or eliminate recruitment of amphibians.

Proposed Status

Populations of the Great Plains toad are expected to persist throughout a range which may be larger than formerly believed. Previous concerns about dramatic population declines may reflect intermittent breeding rather than actual declines, and the designation of threatened or endangered, as proposed for Alberta populations in a previous report, is not considered to be appropriate. Considering the gradual attrition of grassland habitat in prairie Canada, which affects all grassland flora and fauna, the need to maintain proper stewardship of remaining grasslands, and the uncertainty of distribution and population size (particularly in Saskatchewan), the Great Plains toad should be designated as **Special Concern**.

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