ECOLOGY AND BIOGEOGRAPHY OF AMPHIBIANS

(SOUTHWESTERN YUKON/NORTHWESTERN B.C.)

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CONTEXT:

The diversity of herpetofauna decreases dramatically through equatorial, temperate and arctic ecosystems. Amphibians in particular, being ectothermic,(dependant on the external temperature) and dependent on water at some point in their development are constrained by a number of intersecting and excluding climatic factors. They require a length of season adequate to allow metamorphosis from egg to adult, a stable body of water and a hibernation site to survive winter. They have a limited range of tolerance to cold and generally do not generate stable body temperature metabolically. Very little is known about Northern herpetofauna; which species are present or the ranges. Their ecology and habitat associations are largely unresearched. Amphibians play an important role in wetland dynamics. As large consumers of invertebrates; annelida, crustacea, insecta, and arachnida they constitute a primary predator in the pond food chain. Their springtime calling has an evocative haunting quality which gives impulse to the poetic in the human psyche. They have an almost magical ability to call up childhood within us and have called many small children into an appreciation of the natural world. They have recently come into the public focus because of a widespread concern that they are declining globally. Scientists around the world have noted this phenomenon. Research aimed at identifying the causes has been initiated through the I.U.C.N. (The International Union for the Conservation of Nature) Because this decline has been noted in "wild" areas not immediately impacted by habitat destruction some have postulated that a subtle environmental factor such as Ozone depletion is responsible and that frogs are an early warning symptom of serious environmental degradation.

The Yukon has potentially about 6-7 species of amphibians and one reptile. Three amphibian species have been documented; Rana Sylvatica - Wood frog, Rana Pretiosa - Spotted frog, and Bufo Boreas - Boreal Toad. Wood frog has an extensive distribution across North America reaching far into the North, found even above treeline, easily the most hardy and adaptable amphibian. Its extremely fast development rate even in low temperatures and its ability to withstand being frozen solid during hibernation allow it to penetrate arctic ecosystems. The Boreal toad and the Spotted frog are both apparently at the limit of their range within the continental Yukon. Although the Boreal toad is found in coastal regions to Prince William sound, and is common locally in the extreme Southwestern portions of the Southern Lakes (Atlin Lake, Fantail river, and Lindeman Lake) there is only one sighting in the Yukon from Whitehorse in 1948. The Spotted frog was sighted in 1949 at Bennett B.C. and more recently in the Tutshi river subalpine uplands, and in the Yukon, West Arm of Bennett Lake area. Both Spotted frog and the Boreal toad inhabit areas both wetter and

with higher snowfall. This suggests some constraint present in their tolerance of freezing during hibernation. There may be a number of other environmental parameters required by them to survive in particular ecosystems. Its discovery catalyzed this project and opened the possibility of other species being present within certain micro-climatic niches throughout the north. The Northern Chorus frog may penetrate into the Liard basin, the Long toed Salamander known as far north as the Taku river, may have remnant populations in wetter, higher snow fall areas, The Garter snake also found as far north as the Taku may have colonies in the Yukon. The Rough Skinned Newt predominately a coastal species conceivably could survive in subalpine ponds on the eastern side of the coast range. The fact that the Yukon is quite untouched, having populations which should be healthy and unimpacted by human encroachment(relatively natural population dynamics) as well as being at the Northern limit of a number of populations makes it a logical place to focus some longer term studies concerning the global decline question. The lack of Northern research on Amphibians and reptiles makes it an abundant and fertile field. The most elementary knowledge is lacking on the general ecology of these species in the Northern environment. Some very interesting results may come from a survey of widely scattered hot springs. If scattered remnants exist a comparison of their morphology and ecology could give clues to the past climatic regimes, and how separated populations change when separated, presuming a once continuous distribution now isolated due to climatic change. The North therefore offers a unique opportunity at this time. The present global concern, our relatively untouched ecosystems, the dearth of knowledge of Herpetofauna in the region makes for an abundance of exciting possibilities in research.

RATIONALE

This project was stimulated by the discovery of Rana Pretiosa, Spotted frog in the vicinity of Log Cabin B.C. This area is a subalpine highland, forming the headwaters of the Tutshi river. This drainage is interesting because it begins on the divide between the coastal and Yukon watersheds on the spine of the Coast range. The climate is quite influenced by the proximity of the ocean. The subalpine ecosystem has a blend of coastal and interior botanical elements. To the west over the pass is a completely coastal ecoregion containing Sitka spruce, Hemlock and second growth birch as well as the highly specific understory species of coast forest. In the subalpine is the abrupt transition between the coast biotic area and the continental boreal forest. The unique wetlands of the Tutshi uplands share in both biota. Mountain Hemlock, an integrade Lupine species between Articus and Nootkatensis, isolated Salmonberrry, a variety of Fern species, two Sundew species, Marsh Marigold, False Hellabore and others make it an eclectic ecosystem. As well the higher rainfall and snow fall have created different vegetative processes. There are large areas

of sedge meadows with interconnected sunken pools apparently formed as the sedges progressively colonized wet depressions. They lay down a peat substrate which gradually fills in a depression. This creates a level carpet punctuated with deeply sunken pools that are entirely enclosed within the peat. The rim of these ponds is the leading edge of this dynamic process creating undercut and very deep pools. The bottoms are covered with a deep layer of vegetative matter. This area has a number of unique attributes which may precisely account for the presence of Rana Pretiosa and may harbour other herpetofauna. On the basis of this biogeographical view I chose other study areas with similar climatic and geographical features primarily within this narrow belt of wetter more coastal influence along the interior aspect of the Coast range. Possibly a range of other species have survived in this and other variant microclimatic niches. As each specific ecosystem comprised of a particular assemblage of species and process expresses the response of biota to the topographical and climatic location very precisely, a description of the flora of each study area was documented. The project was primarily aimed at simply presence/absence of herpetofauna in the study areas. Nonetheless a wide range of other data and observations were included to begin establishing patterns, connections and possible pathways of research.

Note * Upon beginning this project I was contacted by Pat Milligan, a federal fisheries biologist who was contacting persons doing research on Amphibians. He had been approached by David Green, National Coordinator DAPCAN (Declining Amphibian Populations -Canada) to become the Yukon Coordinator. Pat wanted to know if I was interested in being involved. The result was we have formed a Dapcan Yukon which has met to decide further research and possible eduction initatives. We attended The DAPCAN III Conference in Victoria in October 1993 where a number of Herpetologists presented current research papers relevant to Amphibian declines. There were representatives from across Canada, the Western United States and one participant from Germany. Bob Johnston the President of the IUCN gave the opening and closing remarks.

I was personally amazed at the interest this project generated. I was interviewed by the Newspaper, and CBC Radio, did a lunch hour talk for the Science Institute, and was collared by drunks who explained were frogs could be found.

ABSTRACT

HERPETOFAUNA SURVEY

In response to finding a population of Rana Pretiosa in the Tutshi uplands, an inventory of selected wetlands was undertaken. The first objective was to survey these wetlands for all herpetofauna, to establish the extent of their ranges, and to identify possible biogeographical factors which determine them. The second objective was to note all observations pertinent to comparative life history, morphology, and ecology of the species present. Thirdly the objective, given the above observations, was

to identify possible factors explaining the reputed global decline.

The Field Research included;

1. BREEDING POND SURVEY - In early spring while active calling was occuring, breeding ponds were surveyed. First, a number of accessible ponds throughout the interior; Carcross, Tagish, Atlin and Whitehorse region were explored and then secondly the area adjacent Log Cabin was checked. These were most typically late evening trips, focused on the active mating period.

2. EXPLORATORY SURVEYS OF SELECTED SITES This was a series of longer field trips (4 - 6 days) focused on presence/absence of species, biogeographical data, and observations on ecology of species. These areas were selected on the hypothesis that, as the Spotted frogs were found in a unusual coastal influenced niche at their apparent Northern limit other marginal amphibians (those at the limit or beyond of their normal range) may also share similar parameters.

The areas chosen were

1. Tutshi uplands, Chilkoot trail; Deep Lake/Lindeman Lake, and Bennett area
2. Mush and Bates Lake Area/Kluane,
3. Taku Arm, Fantail River, Bighorn creek area
4. Sloko Inlet, South end Atlin Lake
5. West Arm, Bennett Lake including Partridge lake, and Munro lake
6. Chilkoot Trail; Bareloon lake, Dan Johnson lake

METHODOLOGY

The early season breeding pond survey was generally an evening field trip. As frogs were audible, singing, the focus was a quiet approach, a silent waiting stance and a final attempt to observe closely with the minimum disturbance. Sometimes capture was attempted but my primary interest was to watch, and listen and note the most natural condition of the mating possible. The extreme sensitivity of Wood frogs made this nearly impossible. After the inevitable silencing of the pond upon approach I would wait until croaking resumed. This could take 1/2 an hour. I would attempt to focus in on their active location moving as close as possible. Attendant on this was noting, and keeping a record of the habitat associations, description of species, evidence of vegetation process, particulars of that day/time (ie. plant budding, flowering etc.) I would take water temperature, air temperature, pH, and general weather conditions. If I captured a specimen I would note its species, size and location found.

Dependant on the particular objective and circumstances, I would either focus in on one location or move slowly around the pond or ponds. I would wade the margin slowly, with a long handled dip net pausing to listen.

After evening field trips I did a series of longer camp field trips. These were very similar except not focused on the mating activity (which was over) but on general ecology and habitat

associations. Each day I would pick an objective, (some group of ponds or wetlands) and hike or paddle to the area. I followed the same general philosophy as above. I was far more interested in observing the species undisturbed than in simply counting them. Nonetheless where simple presence or absence was not verified, I would slowly wade the margin where any frogs would dive into the pond. There they could usually be netted, and noted.

Edge of pond searches were by far the simpliest most effective way of capturing Spotted frogs. As I did not begin with a knowledge of where I was going to find amphibians I also searched other types of habitat usually nearby ponds. I explored wet seepage areas, meadows, stream edges, decayed logs, moist woodlands especially areas with lush understory, willow thickets, muskeg, lakeshores, forest edges adjacent ponds, backwaters of rivers, and warm springs.

I devoted one longer field trip (around Bareloon lake) for the use of modified minnow traps to check for Salamanders and Newts. These were baited with dew worms and set in a variety of small lakes, ponds and creeks for an extended period (hours) I ran a small trapline of them, checking twice a day and moving them from place to place throughout this area.

At the end of the season I went to Headwaters meadow to find if they were still active into mid Septemember as a wrap up activity. I followed a typical seach pattern

RANGE DATA

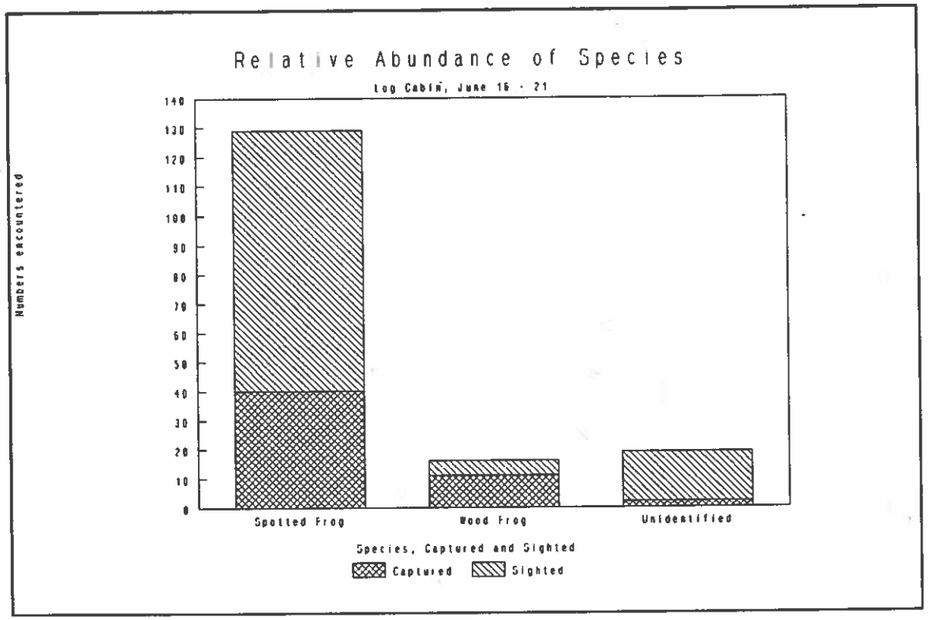
First as far as range parameters I noticed to some extent Rana pretiosa where I expected them to be; the West arm of Bennett lake, a much expanded area in the Bennett, Chilkoot Pass, Tutshi uplands, and South end of Atlin lake. These all are areas just inside the Coast range, and have much higher precipitation evident from climatic data and from the representative botanical communities. The real oddity here was the area around the Fantail River, which theoretically should have populations of Rana Pretiosa. This area is the obvious place where a connection to a Southern population should exist. Nonetheless no Spotted frogs were sighted here which suggests a possible remnant isolated population in the Tutshi uplands. Possibly I never ran into suitable habitat, although I surveyed a broad spectrum of types; an extensive backwater slough including wide shallow reedy basins and deeper pools with distinct edges, lakeshore, meadows, and very old vegetated beaver ponds. These were seemingly adequate, and appropriate habitat. Interestingly I found a healthy population of Wood frogs along this backwater slough. This was in direct opposition to the normal trend where Wood frogs were often sporadic while Spotted frogs if present were abundant and easily found. This bears more investigation because it supports the idea of an isolated population within the Tutshi uplands.

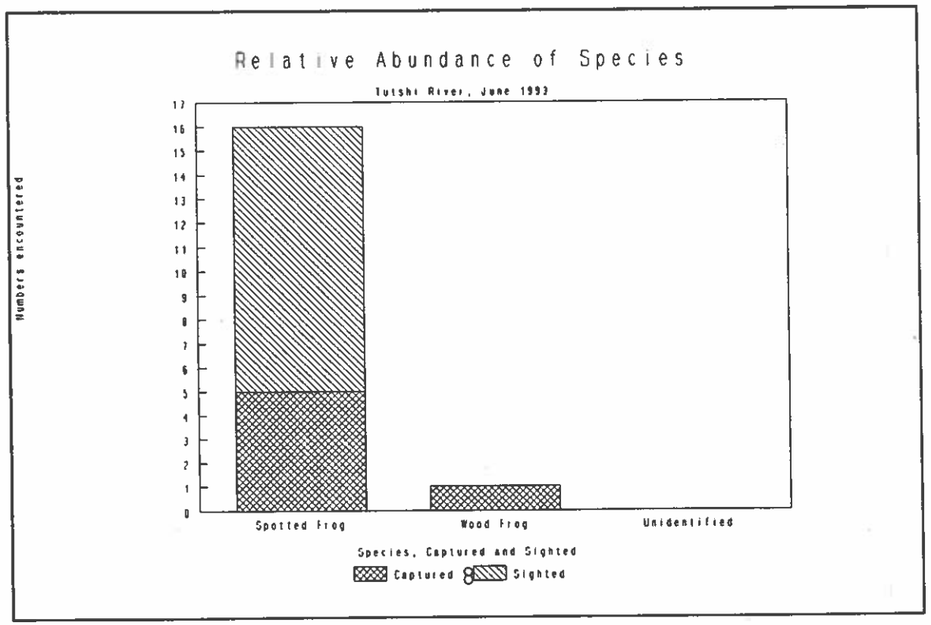
Wood frogs were found at almost every location although in much lower numbers and more irregular distribution. The Mush and Bates lakes trip turned up only one specimen, a Wood frog. Extensive

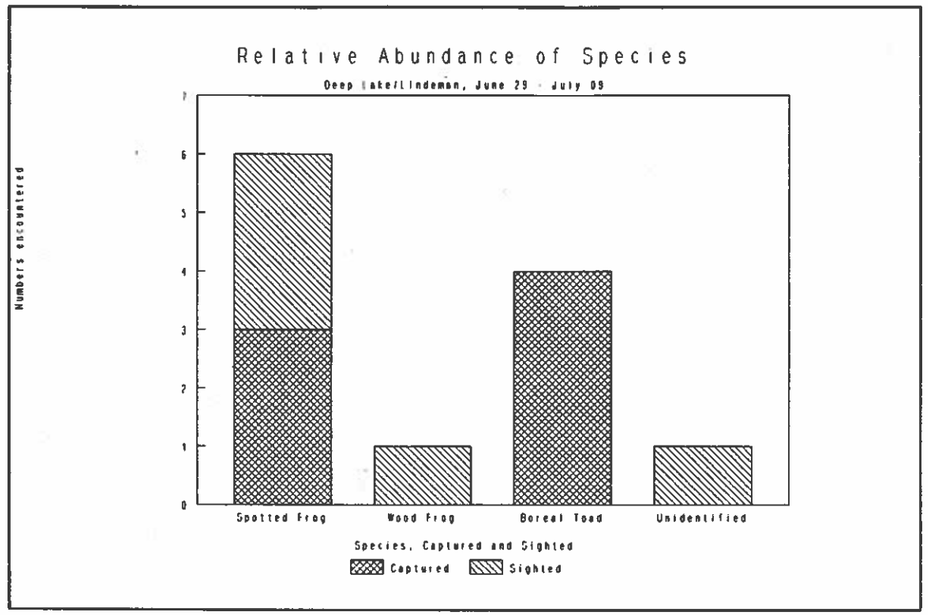
searching in the breeding season throughout the interior Southern lakes revealed only Wood frogs. All other field trips revealed two or more species and always Wood frogs. The one exception was the Partridge valley area which had only one found location of frogs, those being Spotted frogs. This also was unusual in that this whole area was extremely impoverished in frog habitat. The steep rocky valley with Glacial stream and fjord like lake had little wetland at all. The one location was a beaver dam on a tiny feeder stream high up above the valley bottom. * a most unusual and notable location.

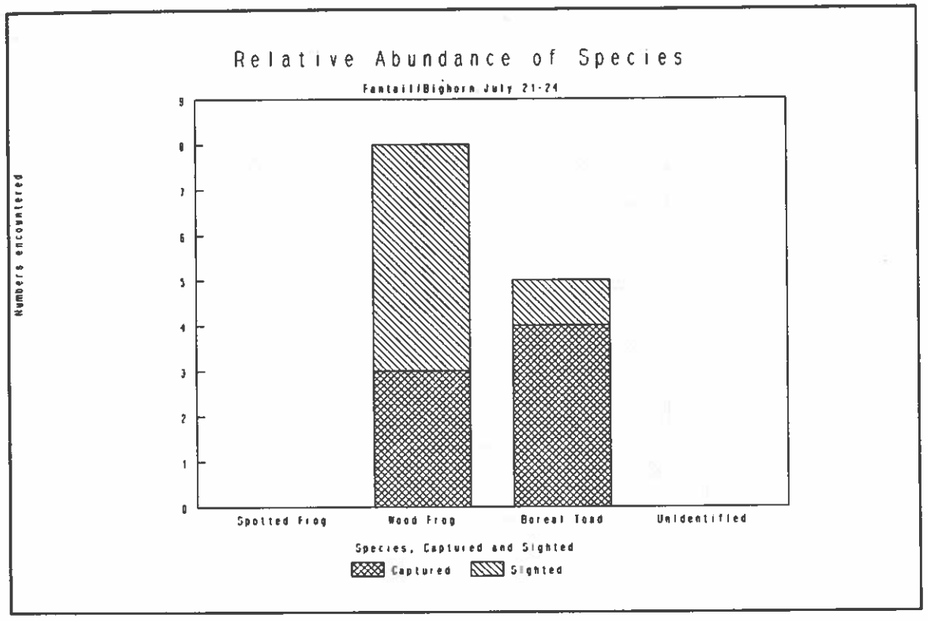
Boreal toads were found abundantly in three locations; the mouth of the Mountain river/Lindeman lake; the Fantail Slough and surrounding forest/meadow; and the south end of Atlin lake and surrounding ponds. Unusually in the Sloko inlet area I found them in small deep beaver ponds in rugged terrain 350 feet above Atlin lake. This suggests a very limited specific type of habitat niche. When found they were relatively abundant especially considering the fact that they were dispersed in terrestrial locations and not concentrated along pond edges.

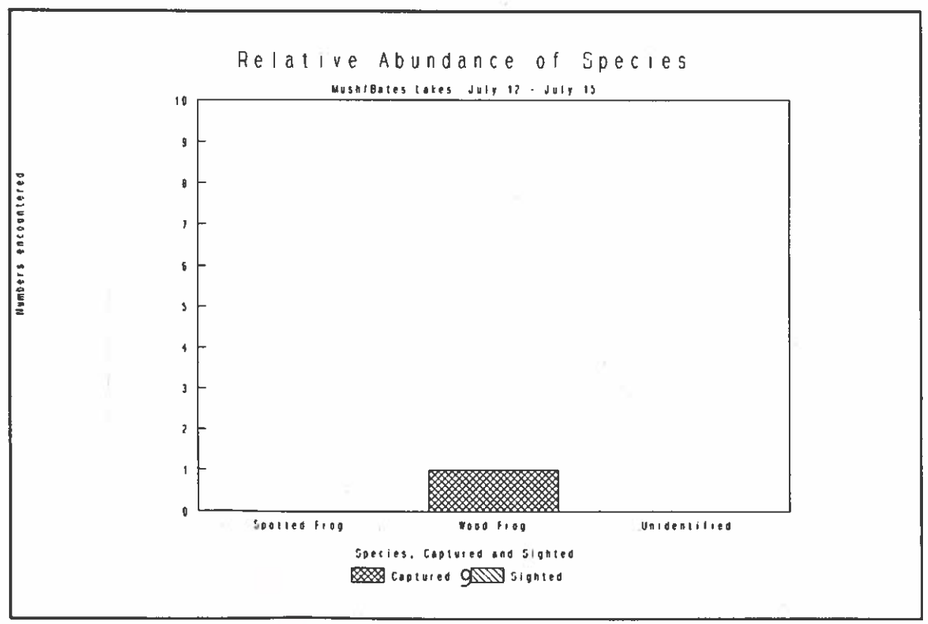
TABLE OF OCCURANCE, CLIMATIC DATA AND RANGE MAP

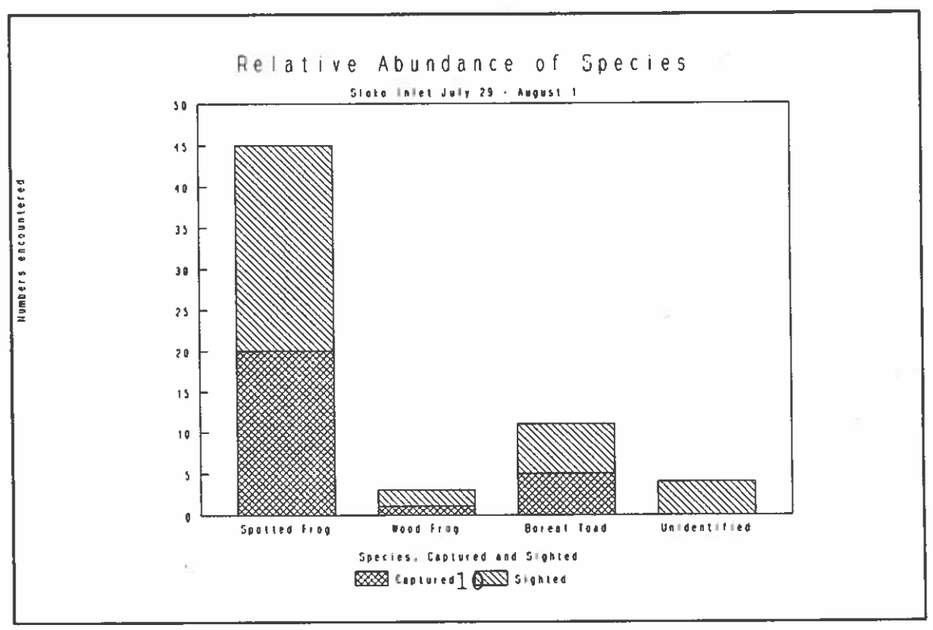


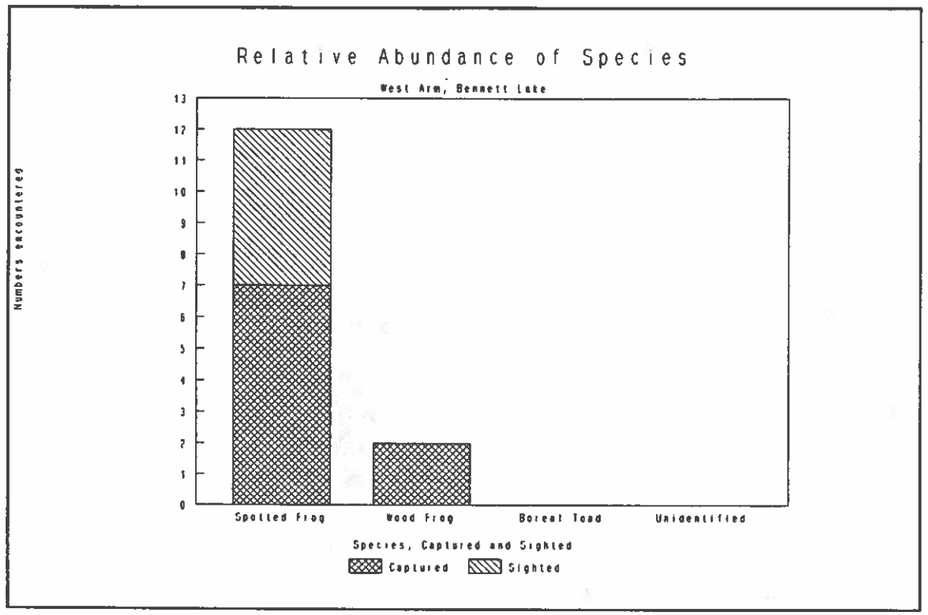


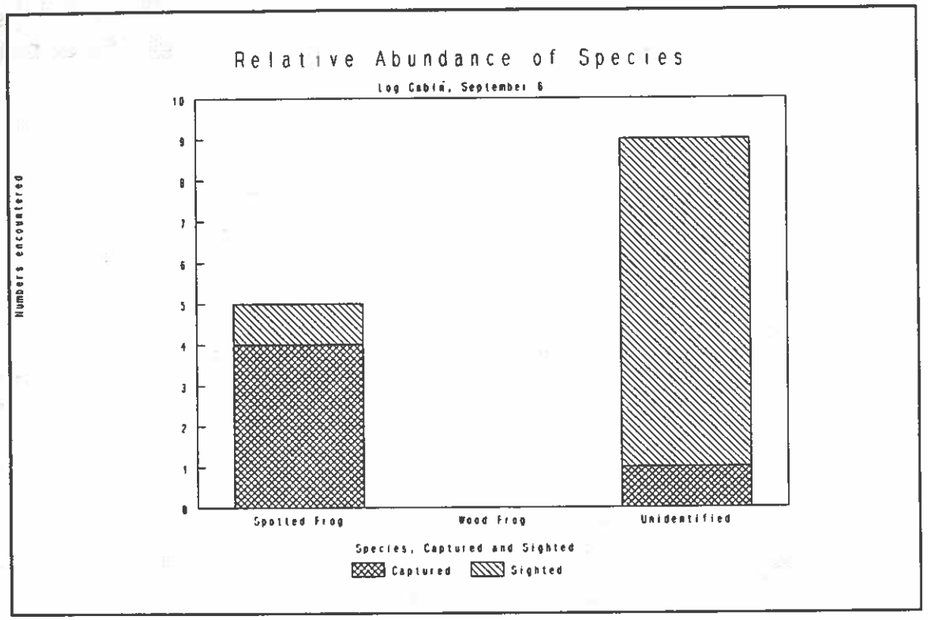


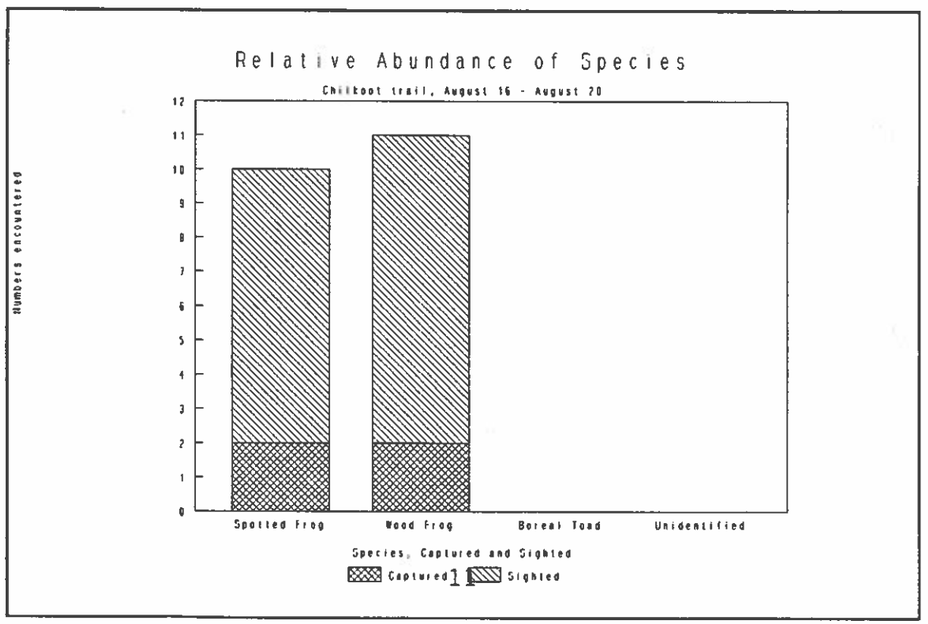


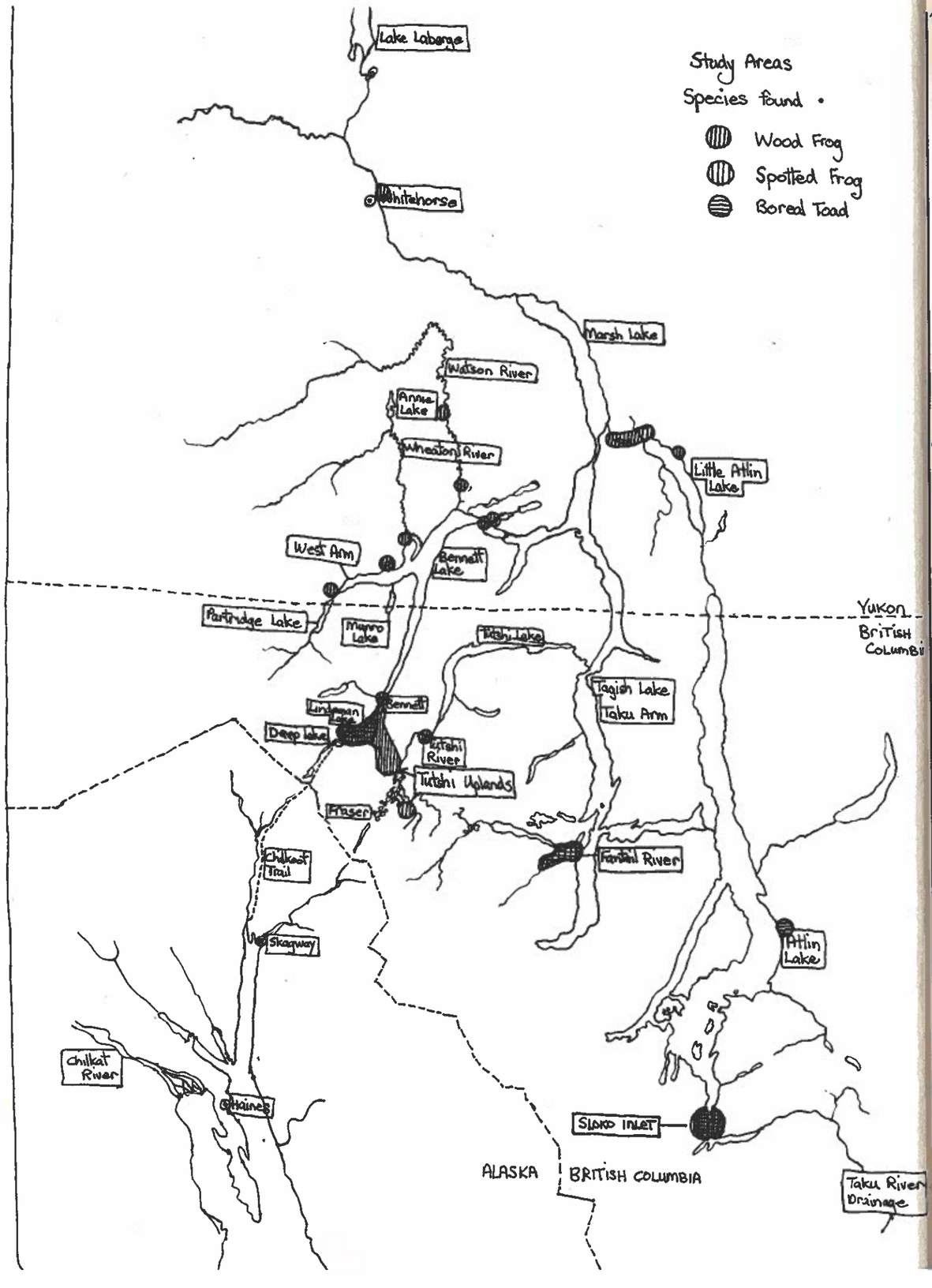





Relative Abundance of Species
West Arm, Bennett Lake
Numbers encountered
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Spotted Frog
Wood Frog
Boreal Toad
Unidentified
Species, Captured and Sighted
Captured
Sighted


Relative Abundance of Species
Log Cabin, September 6
Numbers encountered
0
1
2
3
4
5
6
7
8
9
10
Spotted Frog
Wood Frog
Unidentified
Species, Captured and Sighted
Captured
Sighted


Relative Abundance of Species
Chilkoot trail, August 16 - August 20
Numbers encountered
0
1
2
3
4
5
6
7
8
9
10
11
12
Spotted Frog
Wood Frog
Boreal Toad
Unidentified
Species, Captured and Sighted
Captured
Sighted



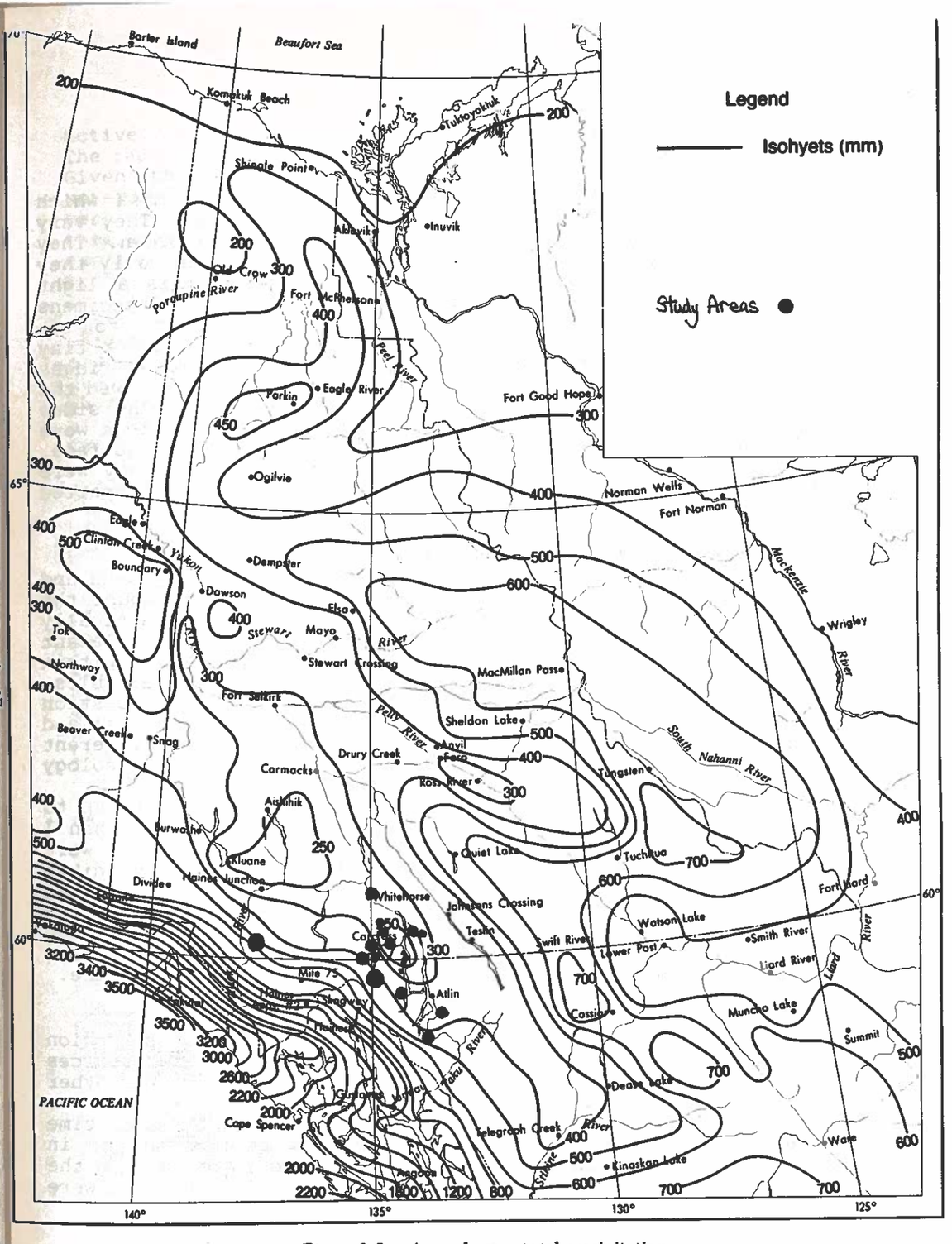


Figure 9.5 Annual mean total precipitation

WOOD FROG - RANA SYLVATICA

DESCRIPTION

A small (2-5cm long) frog distinguished by a black mask which covers the tympanum (eardrum) and a white upper lip. They vary widely in overall tone from light brown,grey to darker brown. They often have spots or mottled blotches on the back. Generally they are light white or grey. Another striking feature is a light dorsal stripe although this is not always present. The specimens I found often had a copper pink or reddish undertone to the dominant greyish coloration. This would be evident as a tiny flecking. The prominent dorsal lateral folds which run in ridges down either side of the backs were often ligher and also showed the undertone. Inky black irregular spots were present on the sides and sometimes to a lesser degree on the back. The back legs were often ribbed or banded and had a lighter line on the top surface. Undersides were white to grey and had some mottling. They were much lighter, smaller and more delicate in appearance than Spotted frogs.

COMPARATIVE ECOLOGY - OVERVIEW

The Wood frog is known to range throughout the study area and to locations above the Artic circle. It is without a doubt the most Northerly adapted amphibian. Its wide range geographically West to East and South to North would suggest that it is tolerant of a wide range of habitats, and is able to secure a niche within a wide range of climatic, geographic and biotic variables. Throughout this particular study area it was not in question whether Rana Sylvatica would occur. The difference between it and the other species, the types of areas exploited during different phases of life cycle - some knowledge of its comparative ecology was the hoped for result.

During the survey a number of interesting patterns began to emerge. Wood frogs were far more numerous and widespread than I could have believed. During the short mating season they were noticable in every marshy lakeshore, pond, slow stream and ditch with their calling. Later in the season they had all but vanished relative to their apparent number. They seemed to have very specific mating/calling and egg laying areas defined by vegetation development. In areas with another species present they were noticably segragated by the intra-pond zones they choose to use.

LIFE CYCLE

Wood frogs began calling in the Southern Lakes region somewhere near the end of April. I had reports from two sources indicating frogs croaking, one from Little Atlin lake and the other a pond in the spring low marsh of Nares lake, days before April 30. I began evening exploration April 30 at Nares Pond. At this time the larger lakes are still frozen, and snow patches linger in sheltered places. Signs of this years growth could be seen in the ponds, new sedge shoots and mosses. Snails and water boatmen were

active. Around the pond willows are in bloom and birds abundant. The raucous calling of Wood frogs sounds much like ducks muttering. Given that mating roughly conincides with the migration of waterfowl suggests some adaptive value. Although abundant they were very sensitive to approach. I never approached without disturbing them no matter how cautious. I always went to listen in the late evening twilight assuming they only sang then, nonetheless on one occasion I found them active and croaking on a bright sunny day. As I approached on this occasion I could see the movement in the water. I went directly to the site, and after an exhaustive search (broad daylight) could not locate a single frog. Egg masses were clumped in exactly that location. This was typical of many late evening searches. The blatant announcement of their presence in every marsh was misleading. Their ability to fade into the pattern of sedge and pond was miraculous. No movement of escape was noticable. They had vanished.

On occasion I managed to sight Wood frogs during this mating season. They would be calling from an aquatic positon, floating near the surface, legs splayed, with only their nostrils above water. Croaking would rise and fall in intensity sometimes becoming repetitive or rythmic. At those times splashing and underwater movement would be evident.

They displayed very quick development. The earliest sighting of any egg mass was May 2 in a pond outside Whitehorse. (This was also the one case were I found frogs croaking in broad daylight). I found egg masses in two other locations, Nares Pond and Little Atlin creek pond, on May 12 and May 8 respectively. I followed the Nares Pond quite closely taking tadpoles and watching them metamorphos in my aquarium. May 14 tadpoles were elongated and wriggling and by May 24 distinct tadpoles were 1cm. long and independant. By June 7 tadpoles were 2cm long and some showed signs of back legs. I placed them in my aquarium and by June 24 they were essentially tiny frogs. I would assume development would be somewhat slower in the actual pond.

By May 22 the croaking had stopped entirely.
Their abundance during this period as reflected by a number of croaking males is not reflected in later season surveys. They are noticably sparse through the remainder of the summer. This suggests a wide dispersal away from ponds. How far they may go, whether they return to their natal ponds again to breed, whether this dispersal allows them to colonize new areas and effect their adaptability are questions for the future.

MICRO BIO-GEOGRAPHY/HABITAT ASSOCIATIONS

They seemed to have very specific locations for breeding; calling and egg laying. This seemed to be a function of vegetation process surrounding the pond. Typically wetland areas would have varying edge relief. The Wood frogs were calling from areas where a gentle slope, in shallow water was being sparsely colonized by sedges. These areas were not widespread but represented an anomalous case within a pond. Let me be clearer on this point.

Ponds are dynamic processes whereby various species (quite often sedges) are continuously building solid ground out into the water. Sedge species are often the leading edge of this movement. A great variety of species of differing sizes and water depth tolerance are proceeding. The variables of physiography, and therefore plant species occuring creates a wide range of potential micro habitats. It appears to that Wood frogs require a particular configuraton of a certain species, (or at least species of similar size) in a particular location which spatially suits their size needs. Many ponds would have a very dense border of a large carex species. They would form an impenetrable wall of tightly growing sharp stalks which would be growing in 2 or 3 feet of water. This would constitute the outward pond edge. Upon first appearance this looked like the archetypal frog pond imbedded in every small childs imagination. Not only were they not being used by mating frogs I never actually sighted a frog a such a spot throughout the survey. Logically this makes sense. That sedge stand would be unusable space, too dense, and too deep for escape. Their would be no resting place and the sedge stalks would be too large to attach egg masses. Mating activities were occuring in areas in transition, those having a dispersed fabric of smaller sedges moving into shallow areas. These areas are open enough for frog movement. The stalks used for attaching eggs, are protecting from waves, wind and predators, the sedges creating an maze like interior. These areas were distinctive and easily identified. They represent critical habitat. This is an important factor in considering global declines which I will discuss later.

When I switched to the Tutshi uplands Wood frogs were quite evident by their rambunctious calling, and apparently much more abundant than Spotted frogs. Notable was the fact that they occupied quite different spaces within the ponds. Woods frogs were in spaces much like the sedge colonization areas in the lower interior ponds, in the while Spotted frogs were up on what seemed to be the flooded margins of level sedge lawns in very shallow water. The Wood frogs were noticably sparse during the remainder of the summer. This was clearly shown from the Mush Bates Lake trip. The Alder creek/Fraser Fen wetland is an extensive area of excellent looking habitat. I explored intensely both in and around the marsh and in the surrounding areas for 4 days, on foot, and by canoe. I explored the adjacent forested areas, both the lush deciduous Cottonwood/Aspen hillsides and the mature Spruce forest. In all this apparently excellent habitat I didn't see a single frog. At the last moment pausing on road out I stumbled upon one lone Wood frog. It spoke volumes. There was a population of Wood frogs present, but so invisible.

In direct contrast to this was the observations at the Fantail river. This area had abundant Toads and tadpoles but no Spotted frogs. The Wood frogs though were relatively abundant and occupied the same pond edge locations I had become accustomed to seeing Spotted frogs.

These last two observations reflect the "unknowns" of Wood frog ecology and perhaps the complexities of their Habitat

associations.

SPOTTED FROG - RANA PRETIOSA

DESCRIPTION

Spotted frog is a robust, large (4-7 cm long) highly aquatic frog. Apart from the size the really distinctive feature is a red/salmon orange belly which can be brilliant. Generally they are a darker brown, olivaceous color with raised spots on their back and sides. Younger specimens are quite uniformly brown with little distinguishing characteristics, little or no red undermarkings. They can easily be confused with Wood frogs at this state. Mature medium sized individuals are the "classic" They have a lighter tonality, which has a golden aspect. The spots are evident and have a distinct halo (a black halo around a light center). The underside is a rich salmon red predominately on the back legs,but spreading around the belly and up the front legs. Their is no distinct eye mask althought they often are darker around the eyes. They have a light yellow line on the upper lip. The dorsal lateral folds are lighter than the body tonality, often having hint of the reddish underside colour. The largest specimens (the oldest?) seem to loose the dark halos on the back. They are the lightest tone and have the most extensive and brilliant red underside.

COMPARATIVE ECOLOGY- OVERVIEW

As explained in the Rationale this project was stimulated by the presence of this species in the subalpine Tutshi uplands. To delineate the extent of Rana pretiosa's range by exploring other similar anomalous habitats was a major focus of this project. Secondly to describe what factors in life style and habitat requirements explain the particularity of their range.
As with the Wood Frog some definite patterns could be seen during the course of this project, reflecting the distinct species ecology and habitat associations. Some patterns, I think begin to explain the vulnerabilities of amphibians, especially the Spotted Frog. Like the Wood frog they had specific critical habitat associations. What was particularily interesting and I think relevant was the locations chosen for mating/egg laying which require very stable predictable fluctuations and conditons in the water table.

Note (A pilot research program was carried out in Alaska,(the Stikine basin) gathering baseline data on the Spotted frog and other herpetofauna. Declines and local extinctions of Spotted frog and its close relatives through large portions of its range in Washington and Oregon stimulated this project).*

During breeding they were in contrast to Wood frogs, in fact in direct opposition to their pattern. The Spotted frog was very subdued, and apparently rare during the breeding period. Nonetheless when found they were not disturbed by my presence and carried on unconcerned. After the breeding season they were abundant and visible along practically every pond margin. There was evidence of a two year developmental process which is similar

to Neoteny.

LIFE CYCLE

I began investigating ponds in the Log Cabin area in Mid May. By then the activity of Wood frog breeding in the lower elevations ponds around the more interior southern lakes was just about over. The conditions at Log cabin May 22 were similar to April 30 in the interior ponds. Extensive areas of snow still lingered in hollows, some into the ponds, which still had some ice. See description of area in Rationale. Some buds were beginning to appear but generally it presented a very wintery aspect. Wood frogs were immediately obvious, their raucous calling prevalent in all directions. Not knowing what the Spotted frog would present, I strained to here anything unusual. Hodge describes their singing as a bass drone. Near the outlet of Narrow rock pond I heard a very soft repeated duonk, duonk, duonk. I waited for a considerable time and did not heard it repeated. I was heading home around the end of the pond when I saw some rapid movements in the shallow water. Examining closer I found Spotted frog after Spotted frog and realized I was in the midst of their mating activities. They were extremely active and did not seem effected by my presence. There was a large Egg mass floating in very shallow water. It was visible because it actually bulged out of the water. It did not appear to be attached but was gently rolling about in the shallow margin. Numerous frogs were moving around apparently jostling for position. I watched them calling underwater, the same duonk, duonk, duonk I had heard earlier, very soft and muted. I never saw amplexus but watched many attempts. All the mating behaviour was occuring in very shallow water (a flooded margin). All calling, movement and attempted amplexus was done on the bottom within an arms length under my headlamp. My other evening trips to Log Cabin ponds failed to find anything like this again but only the odd muted call.

Spotted frogs were immediately evident in and around the breeding ponds after mating/calling time. This was in direct contrast to Wood frogs which I never saw in and around the interior ponds after mating. Tadpoles similar to Wood frogs remained close to the deteriorated Egg mass. They were difficult to find after this point and I only sighted them very sporadically, usually hidden in the mud and decayed grasses of the margin. Later in the year I saw very large tadpoles with only the back legs, in ponds near Bareloon lake. These possibly were Spotted frog tadpoles, indicating slow development and concurring with finding early season immature frogs still with vestiges of tail. This could indicate some two year development times.

During the Summer/Spring Spotted frogs were easily found within their range areas. They are described in the literature as a very aquatic frog and this was certainly the case. They were almost always on the immediate margin of ponds. They apparently would sit at a spot, basking or hunting, waiting for insects, within one jump of the pond. If disturbed they would launch

themselves into the pond, dive for the bottom and either bury themselves in the sediment or reverse in and under the bank. In some locations they would be abundant, positioned along the edge every few feet. I saw them right through the summer and into September, essentially maintaining the same positions along pond edges. I noted a few along creek areas and two in distinctly terrestrial locations (both moist lush forest).

Frogs being ectothermic are influenced greatly by weather. One sunny morning I was sitting by a stream near my camp. Within a few feet was a small pond; an old oxbow of the creek. After sitting quietly for a while I got up to move. Suddenly a barrage of frogs catapulted into the pool. They had noiselessly moved up on to the bank in the sun while I was sitting there. After days of cool moist weather this was the first real warmth. I watched and within minutes they had all returned. They crawled up out of the water right beside me and resumed their spots, hidden amongst the grass. I observed one catch a spider that came walking right past the motionless frog, perhaps stationed on a "game trail". The activity around the ponds that morning was remarkable. It was as if the Sun had turned up the power. Spotted frogs were everywhere. Frogs would dive in all directions as you walked by any pond. This of course is logical. From my temperature readings I noticed that on cool days or evenings the water temperature was slightly above the Air temperature. Frogs were in the water, along the edge, maximizing the warmth on those cool days and seemingly much less numerous. Now the warm banks and higher air temperature presented the most benefical situation and as a result frogs were up and about.

The literature describes them as bottom hibernating. This is in contrast to Wood frogs who hibernate in shallow terrestrial sites. Wood frogs are renowned for their capacity to be frozen solid, thaw out and resume activity. Spotted frogs are reputed to be more sensitive. This would correlate with the higher snowfall areas they inhabit, and my own observations that the ponds they were found in almost invariably had a silt, mud or vegatative bottom. They would often dive into it as a way of escape. This kind of bottom would provide a frost protected zone.

MICRO BIO-GEOGRAPHY/HABITAT ASSOCIATIONS

As with the Wood frog, they seem to use a very specific configuration of micro biogeography for Breeding and Egg laying, but have a completely different type of area and strategy. Immediately after the breeding season I returned to investigate the breeding site and some other nearby ponds. I discovered 3 other egg masses, by now deteriorated, in identical types of micro habitat in other ponds. At this time the water levels had receeded considerably leaving the remains of the egg mass settling in the grass. Under and throughout the remains of the jelly were tadpoles, now virtually on land. The level margins of the pond where the breeding and egg laying had taken place were just puddles in the grass. There remained enough water at this point

for Tadpoles to escape to the pond but continued receeding would landlock them immediately.
The areas were eggs were found and the locations I observed them mating appeared to be flooded terrestrial margins and not actually part of the pond. A short description of the habitat will give a clearer idea of this.
The pond wetlands of the Tutshi uplands have a distinct configuration. Large areas of level or slightly sloping meadow composed of a very small fine carex gives the appearance of neatly moved lawn. Within these areas are very deep sunken ponds with sharp clearly defined edges in smooth sinuous curves. Small equally succinct creeks and small water ways weaving in and around these pools give the area an impression of exquiste gardens. This very level sedge lawn is a characteristic of the Tutshi uplands. Perhaps the seasonal flooding in the spring is precisely the factor which determines the botancial species, the process and the landform of these sedge peat formed wetlands.
The pond areas therefore are very discreet, with a very defined edge. Later in the season water levels dropped till they were entirely contained witin the bowl of the pond. When I observed the mating, though, the water level had flooded out of the bowl creating shallow "rice paddies" out onto the level lawns. It was here that mating was occuring. This certainly suggests a vulnerability given variables in snow and rain. They require a very specific yearly innudation maintained for enough time that tadpoles can escape into the pond. Wood frogs, by comparison, whose egg masses were within stable ponds, albeit the shallow zones, seemed to be less at risk or to have a wider margin of security. To all appearances the Spotted frog egg masses I observed on May 29 were a potential catastrophe. This would require continued observations over a period of years correlated to Weather data to determine what effect these variables may have.

The places with the highest density of Spotted frogs were small stream outlets on ponds. Three locations in particular were exceptional. Interestingly these locations were quite different botanically than the edges of the pond. Immediately noticable is the sudden change in species composition at those locations. Tall lush grasses, graminae not carex, ferns, and composites create a rich micro niche. This exuberance seems to be a function of the stable flow of moving water. I suspect the underground hydrology of a sedge pond with a constant high water table inhibits some plants, and creates a potential permafrost condition. The outlet points have higher ground relative to the now dropping drainage yet with the constant water supply stimulate a variety of plant species more intolerant of wet feet. Perhaps the oxygenation of the water plays a part in aquatic richness but, whatever, these areas are biotically rich. One small stream outlet where I saw Spotted frogs in the bubbles and froth of the swift brook, I also noticed very high density of fresh water shrimp apparently grazing on the algae covered rocks.

As Spotted frog was the impetus for this project a more detailed analysis of the range locations will follow.

I found "Rana Pretiosa" in the Sloko inlet area at the South end of Atlin lake, not only along the edge of ponds as was typical but also along the edge of Atlin lake and in a moist forested areas. This was a particularily lush rich area resembing a coastal ecosystem. Very large Alpine fir trees with an understory of Devils club, Cow parsnip, Poison Hemlock, Ferns, High bush cranberry and tall graminae. I found both Boreal toads and Spotted frogs in locations away from water in moist draws, meadows. Aside from the one Spotted frog I discovered in the the Woods above Headwaters meadow (Tutshi uplands) this was the only terrestrial sighting of a Spotted frog. Also unusual was finding them all along the actual shore of Atlin Lake. It was quite narrow and protected in Sloko inlet where I was, nonetheless the shoreline was not like the usual spongy sedge margin of the smaller ponds. Although it was grassy, it was gravelly and glacial murky. The other ponds I found adjacent to the inlet were more typical. They were rich in aquatic vegetation, both along the shore and on the bottom. They were in fact very similar in appearance, species, and process to the Log Cabin ponds; a sedge peat building process.
The two most Northerly sightings both were in the area of Partridge lake and West Arm of Bennett Lake. They both were atypical. They also were extremely separated populations. Their habitats were small enclosed wetlands completely isolated by miles of steep mountainous terrain populations. One high above the Partridge river was a very old beaver dam. It was a completely vegetated dike through which the spout of a tiny stream poured to meander through a bog meadow and abruptly down a solid rock face several hundred feet to the valley bottom. The pond behind did not have a shore undergoing sedge peat development. It was a moderately sloping mud bank with sparse reeds blending into the water. Spotted frogs were abundant around the outfall and along the pond. The other pond north of West Arm near Milhaven bay was atypical in that it was the typical interior pond resembling Spirit or Emerald lake near Carcross. It had a short margin of quite coarse sedge and a white calcareous bottom. Black Spruce and willows were colonizing the edge. It appeared most unpromising. In fact seconds before catching the first known Spotted frog in the Yukon I commented to my companion " This doesn't look very good to me".
I didn't find them throughout the White Pass area, the Fantail river and the Mush/Bates lakes regions. I suspect that Mush/Bates lakes proximity to the bulk of the St. Elias Icefields may shorten or make erratic the season, by lowering the mean temperature locally. The area looked promising with extensive wetlands in the huge Alder creek/fen. The surrounding terrestrial ecosystem was equally promising, with large Popular and Cottonwood forests and exceedingly lush diverse understory. I found one Wood frog after days of concenctrated search.
The Fantail river area seemed perfectly possible, I can't see any factor that may have excluded the Spotted frog here. This area is quite important because the Fantail river area is the corridor which communicates directly to log cabin through a wide shallow and forested pass. I picked this area because it seemed the natural

route for any range movement from the south into the Tutshi uplands. It is in fact the only route. Thus although inconclusive the population in the Tutshi uplands and north may be an isolated remnant, enclosed in this specific habitat.
I did one day trip heading east from the Klondike highway across the rocky barrens of the Fraser area towards the wide valley which eventually comes out at the Fantail river. This was also undertaken to determine if the Spotted frog population was continuous from Log Cabin towards Fantail. The area in the valley containing Maude lake (one of the many in the Frazer area) is a unusual. Although lower in elevation than Log Cabin, and similar rock basis it is extremely barren as if you have risen in elevation a few hundred feet rather than gone down a hundred. Some suggestions here may be that previous glaciation scoured the valley bottom pushing the rubble and till up around behind the mountains. This would leave material easier for plants to colonize. The other suggestion is that small mountain glaciers in the relatively recent past have flowed from the coastal peaks down into White pass and spilled out towards Tutshi lake. Their recent departure is then evidenced by a much less vegetated, barren area full of pools and water ways but appearing like an exposed alpine ecosystem. As we explored across this area, checking any potential habitat we found no amphibians. Once across the open exposed valley and as the terrain began to rise into forested and ponded areas we again picked up Spotted frogs. This suggests a relationship to a certain degree of forest and vegetation development and the ensuing moderated habitat. Interesting the first pond we came across with a Spotted frog was very anomalous; a deep gravelly pond in what appeared to be and esker.
In summary Spotted frogs were always associated with wetter, more mature ecosystems. they required a specific type of edge, both for mating, egg laying and for their customary habit of perching on an edge to forage or bask. pH did not seem to make a pattern. All the ponds I surveyed were quite basic 6.4 to 9.5 and all with Spotted frogs. Temperature played an important part in daily location, whether in the water or on the bank.

BOREAL TOAD - BUFO BOREAS

DESCRIPTION

Boreal toads are a rotund rough skinned amphibian. The literature says they range in size from 6-11 cm and females up to 12.5 cm. The specimens I found were generally smaller than that ranging from 3.5 cm to 10 cm. I found a wide range in coloration, from dark brown, reddish brown, deep forest green, and grey. These colours are arranged in organic irregular patterns on their backs and speckled in reddish or brown warts. The undersides are light mottled with grey of black spotches. In one pond I caught two immediately beside each other one a predominately chocolate brown the other a light grey. They often have a light colored dorsal stripe. Behind their eyes is a prominent parotid gland, like a

large extended wart. They are predominately terrestrial, and found often far from water. They are quite unlike the smooth stream lined frogs described above giving an overall impression of an irregular lumpy, slow moving creature. They will walk, waddle away when disturbed. Apparently they have a poisonous secretion which their skin exudes as a protection.

LIFE CYCLE

I never located any toads during their mating. From the literature it is noted that they do not generally have any mating call. One location in Alberta has reported some calling. Whether the populations in the southern lakes do call or not has not been discovered. The areas I actually found them are remote enough to make it a formidable task to get to, especially as Tagish and Atlin lakes are near break up in the early spring. My excursion to the Atlin warm springs gave some insight into the breeding period. Although I did not see any mating activity all stages of development where represented. They lay their eggs in long strands or ribbons which are woven through aquatic plants. According to the literature male Toads search the breeding area looking for mates attempting to clasp in amplexus anything resembling a female toad. I had a neighbour who brought a pair clasped in amplexus to their aquarium, in which they remained for days.

They apparently disperse widely after mating judging from the distance I found many from any water source, and the variety of habitats I saw them in. She had also noted that she had seen toad tadpoles very late in the season unmetamorphosed which may mean that they too have a two year development cycle.

MICRO BIO-GEOGRAPHY/HABITAT ASSOCIATIONS

I found Boreal toads in four locations. At Sloko inlet they were interspersed with both Wood frogs and Spotted frogs. On the margin of Atlin Lake, in a small weedy backwater at a creek mouth was the only place I found all three together literally within a few feet of each other. They were abundant in the vicinity. I found two specimens in terrestrial locations in very moist luxuriant undergrowth. The majority here though were occupying pond edges or lake edges. One particularly unusual pond was very high up (300 feet) in a rocky rugged area of very steep relief above Sloko inlet. Here I found three large toads along the pond margin. I noted one evening after the sun had gone down a Toad climbing up from the lake edge into the willows.
At Lindeman City they were reported to be seen frequently by the wardens throughout the adjacent area. This is a large rocky alluvial area at the mouth of Moose creek covering a few hundred acres. They seemed to be associated with rocky terrain. In and around Lindeman they were often seen escaping or sitting under rocks. The area is covered in second growth pine and associated understory; soapberries, bunchberry, saxifrages, arnica, lichens and grasses. At one end there is a small wet meadow with some permanent water immediately behind the vegetated beach shingle.

The abundant tadpoles are along the outer shore from here to the mouth of the mountain river. I found a number of adult toads in protected places along the edge of this meadow against the willows. At Fantail/Bighorn creek I found a number in a large natural meadow in very similar situation to the ones at Lindeman. They were at the side of the clearing sheltered in a willow thicket. These two observations are the only concurring sightings suggesting a pattern of foraging. I had many reports of toads from people who had hiked along an old mining trail up Bighorn creek. This is a moderately moist version of a typical interior Boreal forest. There are large areas of pine benches which appear very dry. North slopes have a mossy alpine fir forest. Large areas of muskeg/black spruce on spaghnum in lower poorly drained areas.

Also at the Fantail river I also found abundant toads and a large breeding area with huge numbers of tadpoles. The breeding area was backwater to the large brawling Fantail river, with a narrow opening communicating between them. Large shallow, silty, weedy basins and a long narrow deep channel were enclosed off the river. The size and extent of this tadpole population and the very specific type of area suggest this may be THE breeding location in the Fantail area. I certainly never came upon any similar landform.

The other location I found Boreal Toads was at the Atlin warm springs. This population is unusual in that breeding takes place much earlier than the natural season would allow. I went on April, 2 and found everything from egg ribbons, through tadpoles and all levels of tadpole development to full adults. Not only is it unheard of to see all stages of metamorphosis present at one time but it is unbelievable for this to all be present in early April. Atlin Lake is still frozen and 2-3 feet of snow surrounds the small open area immediately around the springs. The air temperature in the bright sunshine is around 0 C. I found one active adult out on land on this day. This case cannot be considered anything but a striking amomaly but reveals the adaptive strength of boreal toad. Note* more in the Appendix

Toads appeared sporadically in a wide range of locations throughout the summer,I found many far from water, in mixed forest (pine, spruce and fir with equiseteum understory), and in the luxuriant moist forest of Sloko inlet. This makes an interesting comparison with Wood frogs who presumably disperse widely in the woods as well. I never encountered Wood frogs in forested areas in the entire project. Toads do not seem attempt to disguise their presence either with the tadpoles or as adults. I assume this must be accounted for by the poisonous secretions which render them very unappetizing. Chilkoot park warden reported to me that she had seen a toad repeatedly in the same location along a trail sitting in a protected place under some rocks. This would suggest some kind of territorality.

I know from the toad tadpole areas I found they have a unique life cycle, tied to specific habitat associations. The two areas I observed had extensive populations of Toad tadpoles carpeting the bottom, in a shallow muddy backwater slough, and along a lakeshore

at the mouth of a river. This in itself reveals a very different strategy than the two frog species whose tadpoles disperse in a tangle of vegetation along small protected ponds. Huge populations of Toad tadpoles were in open and exposed view. In the backwater slough they were pressing into the mud at the edges, their sides out of the water, basking in the warm sunny day. The black innumerable tadpoles presented no attempt at camouflage against the light silt bottom. The population in lake Lindeman were interspersed amongst large boulders, silt, and tall equiseteum yet plainly grazing on the sides of large rock slabs. Whether tadpoles are equipped with a noxious secretion which deters predators or their large numbers allow for some escape I don't know. I never saw any predators evident around these populations. This was in striking contrast to the frog tadpoles which were hidden and rarely seen.

The toads I found around the Fantail/Bighorn area may have used the particular backwater slough I discovered (there being no other nearer area that I discovered) for breeding. If this was the case then the toads were dispersing quite long distances (perhaps 2-3 miles)from the breeding site. This would indicate that they may be dependant on breeding locations. The breeding locations where quite different than the other two species with their attachment to small stable ponds. First they were much larger exposed bodies of water and much more active. They were along the margins of lakes which would have wave and wind motion, at the mouths of large rivers where sediment and silt would innundate, or in the backwater slough adjacent the brawling muddy river in open view. They would appear to need silty bottomed shallows with murky water. They don't appear to need protected stable ponds but seem to thrive in very challenging rough environments. The presence or absence of an appropriate area, perhaps coupled with the necessity of high snow fall cover for hibernation protection may be the limiting factors. It would explain the very particular and localized ranges in which they are found.

CONCLUSION - RELEVANCE TO AMPHIBIAN DECLINES/CENSUSING

One of the main concerns of the I.U.C.N. initiatives to decipher apparent declines is to come up with accurate means of censusing amphibian populations. One method that has been used extensively in southern Ontario by Naturalist and Conservation groups is estimation of numbers from breeding ponds by listening to the numbers of males calling. This is very time consuming and not considered particularily acccurate. Therefore other methods are being devised.

From the observations I made of various stages of the life cycles I think that each species has a particular point where the mumbers could be estimated. Bufo boreas had extensive areas of tadpoles which were concentrated in special spots. They were not hidden or difficult to observe. These critical areas if known could be photograghed year to year and quite accurate knowledge of

comparative populations could be generated. This would be the point in the Boreal Toad cycle which is most visible and easily censused. Rana Sylvatica is most evident in mating season when croaking identifies the exact locations of mating. Follow up surveys of egg masses at those sites combined with the estimated numbers croaking per pond would be the most accurate method of population censusing for Wood frogs. Rana Pretiosa really lends itself to censusing. Again if the mating sites were mapped (assuming they have site fidelity.) their communal egg laying and mating habits could be observed easily. Repeated surveys year to year will reveal if they use these sites yearly and also what happens in relationship to variations in water regime. Spotted frog also is easily found throughout the season along pond edges. This fact also allows for straight forward censusing.

The knowledge of their different ecological patterns within the environment also has signifigance for understanding possible factors for global declines. Each of the three species had very different patterns of behaviour and habitat use, which reflect their unique capacities to survive in particular environments. This also translates into their having particular vulnerabilities which limit them or put them at risk. Obviously at the northern limit of a particular species you are observing the point at which some climatic variable accumulates to the point to deny the species access to a habitat. All other factors and needs may be present. Nonetheless in some particularity of its ecology it presents a vulnerability at that point. For example; the Spotted frog is obviously at home in very artic sub-alpine environments. Its abundance, at the brink of treeline in the Tutshi uplands which has a shorter summer period than the adjacent lower elevation interior, shows this. Yet somehow it does not penetrate this seemingly more benign lower environment. It would seem that its habit of aquatic bottom hibernation and its intolerance of freezing, limit it to areas with early and deep snow fall which protect it from frost. This is one possible explanation. The point is that each species due to its unique individuation inhabits a geographic niche for very exact and prescribed reasons. Any alteration in an ecosystem pattern will potentially squeeze it out.

I noticed during this project a number of factors which may be relevant when considering the global concern questions. I collect these together into a broad heading;

STABILITY

I first began noticing that certain types of ponds which I though looked excellent and promising would show nothing. One noticable characteristic of these ponds was a wide band of very tall sedges growing in deep water. This particular species of sedge was tall, sharp and coarse. Often the actual shoreline was not evident but was lost in a tangle of growth and last years stalks. As I waded about in these areas it occured to me that there was no place for frogs to perch. (which was the most common activity I discovered them in) They would be exposed to fish (if present), could not climb out of the water and in short there was no distinct

shoreline, the sedges posing a formidable obstacle to movement. From the frogs point of view it was uninhabitable.

Once I started thinking in terms of the spatial reality from a frogs perspective a number of other considerations became evident. The amphibians I was seeing had very specific habitat requirements, permanent water areas for mating, egg laying, food, perhaps pH limitations, temperature, length of season etc but also some distinct Spatial factors (an environment where they could move around easily, sit out of water, and hide from predators)The locations they chose to use had specific characteristics.

As described fully above I noticed that all the species had particular and unique areas especially for breeding. The Spotted frog mated in the flooded margin of very distinct type ponds. The Wood frog as well seemed to have critical habitat zones within ponds. The boreal toad was identified with a specific kind of breeding area. During the summer the Spotted frog especially was associated with a distinct pond edge as a perch. These particularities of strategy for species may be relevant to Amphibian declines. As I mentioned before the Spotted frog appears to be very dependant upon a predictable water cycle. The areas it chooses to mate only exist temporarily in spring flood. This example of the Spotted frog reflects a specific vulnerability that they have. If climatic conditions changed, even simply disrupted from something like the seasonal sequencial norm, it could have catastrophic effects. A very low snow fall year may not even provide even an opportunity for flooded margins. Dry springs would landlock tadpoles. Obviously all species deal with these kind of unpredictable fluctuations all the time. Nonetheless if climate has been stable within certain limits,(if the variables have oscillated around a mean) species have found a niche within that degree of uncertainy. The precise reason they can exist is the degree of stability/certainty a habitat contains. A frog may be able to exist in very high mountain ponds above treeline on a particular hot long season. Yet if that amount of warmth is not predictable year after year no stable populations will persist. This defines the range of a species. As well if climate is destabilized, places where amphibians can now exist within those fluctuations may loose the margin of safety.

The dynamics of vegetation change are dependant to a large degree on hydrology. Some species of sedge, for example, grow tall and seem tolerant of continuous flooding. Others require and can tolerate only a certain depth. This is seen in ponds where a definite line of sedge is moving out into the pond. Each colonizing year allows for a slow build up of vegetative matter building out. They contribute to a changing edge by laying down a mat of growth which becomes land. This has the effect of constantly moving that edge outward making a way for plants which can tolerate less aquatic conditions. Frogs have to fit in to this process of vegetation change, finding zones which satisfy their requirements amidst this slow motion development. Plants are indicators of water regime. They speak such things as " I can manage an area that floods to this depth but never goes entirely

dry, or I can tolerate flooding only in short periods."

The pond edge particularily is a delicately balanced dynamic process of a number of species which is literally the indicator of hydrological norms, the place which has a very specific group of plants tolerant of those variables of conditions normally present. Over a period of time the plants which manage to cope with that degree of variation develop a stable but moving equilibrium of species. This key edge ecology may suffer more than the purely aquatic or purely terrestrial. For example in an active beaver pond the dam quickly causes an innundation into normal land environments. This kills the trees, and the grasses that are not tolerant of aquatic conditions but makes way for species which can exploit the new situation. This will have little effect on the fish in the pond except to temporarily open up new foraging areas. Likewise this will have little effect upon the squirrels and mice. They will just move back a little. But for species which require that particular configuration of aquatic and terrestrial it may be disastrous. Both Wood frogs and Spotted frogs appear to need sites which have specific qualities created by certain plants at a certain stage of density at a certain depth. These type of places take time to develop and are indicative of stable (albeit moving) conditions.

The Wood frog although abundantly evident during the mating season is noticably scarce during the summer months. Presumably they have dispersed to forage in terrestrial ecosystems. This would allow them to find and utilize new areas, and also makes them less dependant on the pond. The areas they choose to mate although site specific were places much more resilient to water fluctuations than the very ephemereal edges chosen by the Spotted frog. The Spotted frogs were typically creatures of the edge, sitting along the shoreline or just in water. This requires a specific kind of pond, one which had a distinct edge yet had cover within a leap. This possibly would limit Rana Pretiosa to certain stable ponds whereas Rana Sylvatica by dispersing on land would be able to use a wide range of habitats. These factors paint a picture of the Wood frog as a generalist that has less defined or less narrowly defined mating areas, less dependance upon stable ponds, and a capacity to migrate and colonize new areas. In contrast the Spotted frog has very narrowly defined mating areas, is dependant throughout the season upon stable ponds and does not appear to migrate or travel. As well Spotted frogs need a pond bottom to hibernate that is below the frost line and easily penetrated whereas the Wood frog needs only leaf litter and a shallow burrow. (obviously many of these need to be confirmed by further research.) A clear picture of the comparative ecology of these species will point to the peculiar vulnerablities of each one.

Rana Pretiosa in my estimation is particularily sensitive. I think that the key factor in the life cycles is a "Stable" hydrology and ecology. The vegetation process occuring in the edge zone creates the micro habitats that the frogs are dependant upon. Erratic changes in climate, or unusual fluctuations in water table

would put at risk the stable focal edge of pond plant ecology which is the critical habitat of amphibians. This would translate into the Erratic population shifts which apparently are occuring world wide in Amphibian populations. The difficulty would be in defining what are normal or natural variations and which are results of human induced environmental changes. Population studies may find that there is a correlation between population levels and water table fluctuations, nonetheless it may be more difficult to prove that those fluctuations are tied to human causes.