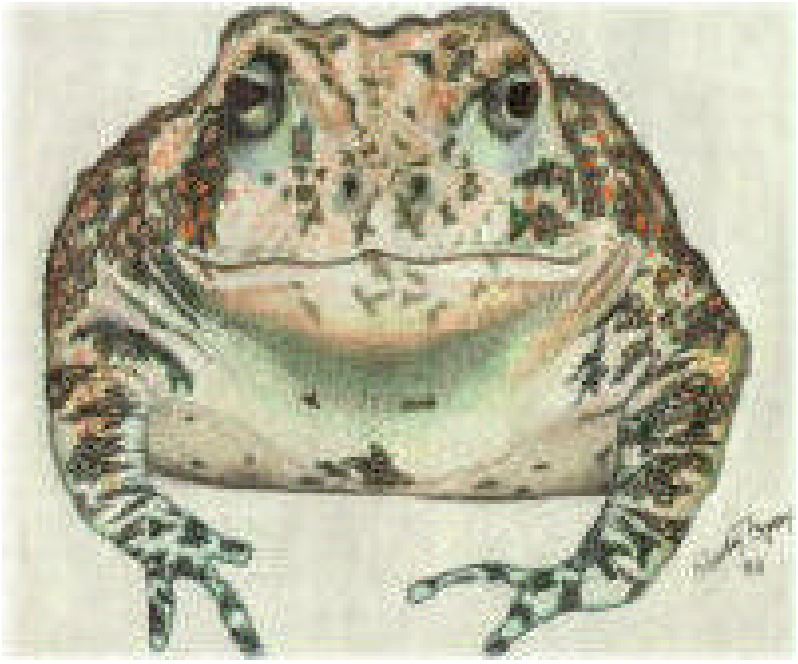
ECOLOGY AND MANAGEMENT OF THE ENDANGERED HOUSTON TOAD (*Bufo houstonensis*)



Painting by Glenda Crysup
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A Topical Index and Annotated Bibliography

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INTRODUCTION

The Houston toad was originally described in Houston, Texas, in 1953 (Sanders 1953), but has since been extirpated from the area due to the city's expansion. In 1970, it was the first species in the state of Texas to be placed on the endangered species list (35 CFR§16047, 16048). Although it once ranged throughout most of southeastern Texas, the Houston toad now resides primarily in an area of deep sandy soils in the "Lost Pines" region of Bastrop County (Campbell 1996). Currently, many factors threaten this Houston toad population. Urban expansion practices including agriculture and community development were the first major threats to Houston toad populations. Other threats include introduced species such as the imported red fire ant (*Solopectis brazilences*), logging in Houston toad habitat, and road mortalities due to increasing human populations in the County. The conversion of Bergstrom Air Force Base, near the south end of Austin, into an international airport, also is expected to intensify development in Bastrop County and negatively affect Houston toad habitat (FWS 1999).

As Bastrop County moves forward with its mission to implement a countywide Habitat Conservation Plan to protect the Houston toad, a comprehensive database of relevant literature will be needed. This bibliography includes some sources of scientific information that may be useful in the development of this plan, and is for the use of the Biological Advisory Team for the Houston Toad Conservation Project.

ACKNOWLEDGEMENTS

We would like to thank Dr. James R. Dixon and James H. Yantis for providing access to their resources and guidance on important and available information. We would also like to thank Lisa O'Donnell, Dawn Whitehead, and the U. S. Fish and Wildlife Service for allowing us access to their resources and for providing us with specific information and materials. Thanks to Lisa Johnston for formatting. Although we thank these individuals for their assistance, any errors encountered within this document are solely our own.

TOPICAL INDEX FOR THE HOUSTON TOAD

This Bibliography includes references and annotations intended to provide users with a summary of the available scientific literature on the ecology, management, and conservation of the Houston Toad. While many of the references focus specifically on the Houston Toad, other references are included to provide information on the ecology and management implications for other *Bufo* species, other non-bufo amphibians, and the Lost Pines Ecosystem – the last major expanse of Houston Toad habitat.

I. HOUSTON TOAD

A. Surveys and distribution

1. Armentrout et al. 1994
2. Brown 1975
3. Campbell 1996
4. Dixon 1983, 1990
5. HTRT 1984
6. Martin 1979
7. Sanders 1953
8. Thornton 1976
9. Yantis 1990, 1992

B. Life history, biology and evolution

1. Anonymous 1996
2. Armentrout et al. 1994
3. Bragg 1960
4. Brown 1971, 1982
5. Campbell 1996
6. Hillis 1984, 1993
7. Jacobson 1989
8. Kennedy 1962
9. Mays 1985
10. Thomas 1984, 1997

C. Threats

1. Allen et al. 1998
2. Anonymous 1996
3. Armentrout et al. 1994
4. Campbell 1996
5. Freed and Neitman 1988

D. Conservation efforts

1. Armentrout et al. 1994
2. Quinn 1980, 1984, 1987
3. Spradling et al. 1998
4. HTRT 1984

II. BUFO

A. Mating call, sound production and behavior

1. Blair 1956, 1958(a)
2. Bosman et al. 1996
3. Brown and Littlejohn 1972
4. Martin 1967
5. McAlister 1959
6. Weist 1977

B. Evolution, hybridization and reproduction

1. Blair 1959, 1963(a), 1963(b), 1972(a), 1972(b)
2. Bogart 1968
3. Brown 1967
4. Guttman 1967, 1969,
5. Licht 1967, 1976
6. Martin 1973
7. Sanders 1953
8. Sanders and Cross 1964
9. Tihen 1962

C. Growth and survival

1. Goater 1994
2. Schmidt and Anholt 1999
3. Taylor et al. 1999

D. Movement patterns

1. Grubb 1970, 1973 (a), 1973 (b)
2. Sinsch 1987
3. Van Gelder 1973

E. Recovery plans and conservation

1. Denton et al. 1997
2. USFWS 1991

F. Field guides

1. Conant 1991
2. Dixon 2000

III. NON-BUFO

A. Forest management

1. Prescribed Burning effects

a. Chambers and Samways 1998
b. Fair and Henke 1997
c. Ford 1999
d. McLeod and Gates 1998
e. Paquin and Coderre 1997
f. Reed 1997
g. Russell et al. 1999
h. Siemann 1997

2. Timber Harvesting effects

a. Bird et al. 2000
b. McLeod and Gates 1998
c. Demaynadier and Hunter 1998
d. Harpole 1999
e. Lemckert 1999
f. Paquin and Coderre 1997
g. Petranka et al 1994
h. Rudolph and Dickson 1990
i. Welsh 1990

3. General management effects

a. Bennett et al 1980
b. Hanlin et al 2000
c. Greenberg and McGrane 1996

B. Other threats

1. Roads

a. Fahrig et al. 1995
b. Findlay and Houlahan 1997
c. Gibbs 1998
d. Mader 1984
e. Reh and Seitz 1990
f. Van Gelder 1973
g. Vos and Chardon 1998
h. Yanes et al. 1995

2. Habitat degradation

a. Urbanization effects

1) Delis et al. 1996
2) Lehtinen et al. 1999
3) Minton 1968
4) Orser and Shure 1972

b. Fragmentation effects

5) Andreassen et al. 1996
6) Andren 1994
7) Bowers et al. 1996
8) Gibbs 1998
9) Knuston et al. 1999
10) Laurance and Yenson 1991
11) Lehtinen et al. 1999
12) Margules et al. 1994
13) Reh and Seitz 1990
14) Saunders et al. 1991
15) Soule et al. 1992
16) Tiebout and Anderson 1997
17) Vos and Chardon 1998
18) Wigley and Roberts 1997

3. Predation and competition

a. Allen et al. 1998
b. Hecnar and M'Closkey 1997
c. Morin and Johnson 1988
d. Peterson et al. 1992
e. Tejedo 1993
f. Werner 1999

C. Relocation

1. Fischer and Lindenmayer 2000

D. Demography, movement patterns and reproduction

1. Aars 1999
2. Baker and Halliday 1999
3. Banks and Laverick 1986
4. Berven and Grudzein 1990
5. Blair 1958 (b)
6. Denton et al. 1997
7. Dodd and Cade 1998
8. Halley et al. 1996
9. Laan and Verboom 1990
10. Pechmann 1995
11. Peterson et al. 1992
12. Semlitsch 1998
13. Turner
14. Welsh 1990

E. Amphibian decline

1. Adams 1999
2. Blaustein et al. 1994
3. Dodd and Cade 1998
4. Fisher and Shaffer 1996
5. Pechmann and Wilbur 1994

IV. LOST PINES

A. Forest management

1. Fire effects

a. Cain et al. 1998
b. Garza and Blackburn 1985
c. Lloyd-Reilley et al. 1984
d. Siemann 1997

2. Timber harvesting

a. Bird et al. 2000
b. Dalton and Messina 1995
c. Valigura and Messina 1994

3. Chemical

a. Lloyd-Reilley et al. 1984
b. Scifres 1982

B. Plant Diversity

a. Unknown 1990
b. Van Auken et al. 1979

C. Animal Diversity

a. Dixon et al. 1990
b. Weist 1977

ANNOTATED BIBLIOGRAPHY FOR THE HOUSTON TOAD

Aars, J., E. Johannesen, and R. A. Ims. 1999. Demographic consequences of movements in subdivided root vole populations. Oikos 85(2): 204–216.

We studied three types of movements: (1) movements leading to permanent transfer of individuals between habitat patches, (2) movements (excursions) into habitat corridors and (3) into a barren matrix area, and the demographic consequences in 12 enclosed populations of the root vole, *Micrototus oeconomus.* Each population was subdivided into two demes inhabiting one habitat patch each. The two patches were approximately two male home range diameters apart in a vole-hostile, devegetated matrix. While the patches were connected by a narrow (0.5 m) habitat corridor for six of the populations, the other six populations inhabited isolated patches. The experiment was initiated by introducing laboratory raised founder demes onto each patch in the beginning of July. The populations were thereafter monitored by live trapping for the next 4–5 months during the snow-free season. After the snow melted the following spring the experiment was terminated by removal trapping. The experiment was run over two years (1994 and 1995) with six population replicates each year. Movements into the corridors and permanent transfers of animals between patches were registered during ordinary live trapping at 15–d intervals. Movements into the barren matrix habitat were registered continuously during the snow-free season by activating edge traps along the fences of the enclosures every night. Except for males early in the summer, movements leading to transfer of individuals between dames were rare relative to mortality and recruitment, and transfer did not act to synchronize the dynamics between demes. Moreover, transferred animals possessed the same survival probability as those staying in their natal deme. Corridors slightly enhanced the rate of transfer in females, but not in males. Excursions into corridors and the matrix area took place much more frequently than transfer and mo st frequently in the first cohorts early in the season and more in males than in females. Movements in the hostile matrix had a considerable negative effect on survival and, thus on the demography of the populations. Predation by birds is the most likely cause of this movement related mortality which may play an important role in the dynamics of patchy vole populations during the snow-free season. Movements into the corridors did not have any independent effect on survival probability, and habitat corridors may thus act to transfer animals more safely from one patch to another. (Author's abstract)

Adams, M. J. 1999. Correlated factors in amphibian decline: exotic species and habitat change in western Washington. Journal of Wildlife Management 63(4): 1162–1171.

Amphibian declines may frequently be associated with multiple, correlated factors. In western North America, exotic species and hydrological changes are often correlated and are considered 2 of the greatest threats to freshwater systems. Bullfrog (*Rana catcsbeiana*) introductions are frequently cited as a threat to lentic-breeding anurans native to western North America and are a suspected factor in the decline of red-legged frogs (*Rana aurora*) in California. Introduced fish and habitat change are cited less frequently but are equally viable hypotheses. I examined the relation among introduced species, habitat, and the distribution and abundance of red-legged frogs in western Washington. Red-legged frog occurrence in the Puget Lowlands was more closely associated with habitat structure and the presence of exotic fish than with the presence of bullfrogs. The spread of exotics is correlated with a shift toward greater permanence in wetland habitats regionally. Conservation of more ephemeral wetland habitats may have direct benefits fat some native amphibians and may also reduce the threat of exotic fish and bullfrogs, both of which were associated with permanent wetlands. Research and conservation efforts for lowland anurans in the West should emphasize the complexities of multiple contributing factors to amphibian losses. (Author's abstract)

Allen, C. R., R. S. Lutz, and S. Demarias. 1998. Ecological effects of the invasive nonindigenous ant, *solenopsis invicta,* on native vertebrates: the wheels on the bus. Changing Resource Values in Challenging Times: Transactions of the Sixty-third North American Wildlife and Natural Resources Conference, Orlando, Florida, USA.

The effects of red imported fire ants on populations of northern bobwhites, box turtles, Houston toads, Florida redbelly turtles, loggerhead sea turtles, American alligators, Texas cooters, and Texas horned lizards are discussed. Some native species are directly affected by the ants, while others suffer indirect effects as their food supply or habitat is altered by the ants. (Authors' abstract)

Andreassen, H. P., S. Halle, and R. A. Ims. 1996. Optimal width of movement corridors for root voles: Not too narrow and not too wide. Journal of Applied Ecology 33(1): 63–70.

1. The characteristics of male root vole movements as a function of corridor width were tested in a 310 m long habitat corridor connecting two habitat patches. Detailed observations of movements were made by means of radiotelemetry and recording of footprints. 2. The highest connectivity, in terms of transference rate of individuals in the corridor system, was observed in the intermediate of three corridor widths tested (3 m, 1 m and 0.4 m). 3. The behavioral mechanism behind the lower connectivity of the narrowest corridor was a reluctance of voles to enter it, while linear progress in the widest corridor was hampered by a high frequency of cross-directional movements. 4. The relationship between corridor width and movement behavior was unaffected by the simulated presence of competitors and predators. 5. Our results challenge the 'the-wider-the-better' principle of movement corridor design, and provide elements for an understanding of the behavioral mechanisms underlying the movement ecology of individuals in linear habitats. (Authors' abstract)

Andren, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat - a review. Oikos 71(3): 355–366.

Habitat fragmentation implies a loss of habitat, reduced patch size and an increasing distance between patches, but also an increase of new habitat. Simulations of patterns and geometry of landscapes with decreasing proportion of the suitable habitat give rise to the prediction that the effect of habitat fragmentation on e.g. population size of a species would be primarily through habitat loss in landscape with a high proportion of suitable habitat. However, as the proportion of suitable habitat decreases in the landscape, area and isolation effects start influencing the population size of the species. Hence, the relative importance of pure habitat loss, patch size and isolation are expected to differ at different degrees of habitat fragmentation. This conclusion was supported by a review of studies on birds and mammals in habitat patches in landscapes with different proportions of suitable habitat: the random sample hypothesis was a good predictor of the effects of habitat fragmentation in landscapes with more than 30% of suitable habitat. In these landscapes, habitat fragmentation is primarily habitat loss. However, in landscapes with highly fragmented habitat, patch size and isolation will complement the effect of habitat loss and the loss of species or decline in population size will be greater than expected from habitat loss alone. Habitat patches are parts of the landscape mosaic and the presence of a species in a patch may be a function not only of patch size and isolation, but also of the neighbouring habitat. Habitat generalists may survive in very small patches because they can also utilize resources in the surroundings. Furthermore, the total species diversity across habitats in a given landscape may increase when new patches of habitat are created within the continuous habitat, since new species may be found in these new habitats, even if they are human-made. (Author's abstract)

Anonymous (1996). Species toad, Houston, Virginia Tech. 2000.

The Houston toad (*Bufo houstonensis*) has been designated an endangered species pursuant to the Endangered Species Act of 1973, as amended. The species has this status wherever found including the State of Texas. Critical Habitat has been designated in areas of Burleson and Bastrop Counties, Texas. This website gives an in-depth look at the Houston toad's habitat, reasons for decline, life history, and best management practices. (Summary compiled mostly from author's direct quotes)

Armentrout, D., B. Arroyo, et al. 1994. Houston toad population and habitat viability assessment. Austin, TEXAS, U.S. Fish and Wildlife Service Conservation Specialist Breeding Group: 125.

Fifty biologists, managers, government officials, professors, non-government organization representatives, interested private individuals and policy makers attended a Population Habitat Viability Assessment (PHVA) Workshop at the University of Texas, Austin, Texas on 23-25 May, 1994 to assess the current status and trends of the populations of the Houston toad. The Conservation (formerly Captive) Breeding Specialist Group, of the IUCN/Species Survival Commission was asked to conduct this PHVA workshop to assist in assessment and subsequent planning. One purpose was to review data from wild populations as a basis for developing stochastic population simulation models. Other goals included review of the current state of knowledge about habitat requirements, population sizes, role of direct threats as a factor in the decline of the species, potential role of other threats such as disease and pollution, and to discuss research needs and priorities. This is the assessment of these meetings. (Abstract composed primarily of authors' direct quotes)

Baker, J. M. R., and T. R. Halliday. 1999. Amphibian colonization of new ponds in agricultural landscape. Herpetological Journal 9:55–63.

Newly constructed ponds on farmland were surveyed for amphibians and compared with long-standing farm ponds. The frequencies of amphibian occupation of the two pond types were similar (65 and 71% respectively), but the species composition differed. *Bufo bufo* was found more frequently in new ponds than in old ponds, whereas *Triturus cristatus* and *T. vulgaris* were found less frequently in new ponds. The differences in the amphibian species assemblage between the two types of pond reflected the ponds' functions and the amphibians' dispersal abilities. New ponds were larger and tended to support fish and waterfowl more frequently than did old ponds. *Triturus cristatus* was not found in any fishponds. Principal component and discriminant analyses of variables related to ponds and the surrounding terrestrial habitat indicated that, for *T. cristatus* and *T. vulgaris*, the location of new ponds relative to existing ponds was a significant factor in pond colonization. *Triturus cristatus* and *T. vulgaris* did not colonize ponds at distances greater than 400 m from existing ponds. *Rana temporaria* and *Bufo bufo* were not so constrained by dispersal abilities and were able to colonize new ponds at distances up to 950 m from existing ponds. *Rana temporaria* was more likely to be found in new ponds containing submerged vegetation; however, multivariate analyses could not discriminate between ponds that were, and were not, colonized by *Bufo bufo*. The results of this study are discussed with regard to the construction and management of ponds for the conservation of these amphibians. (Authors' Abstract)

Banks, B., and G. Laverick. 1986. Garden Ponds as amphibian breeding sites in a conurbation in the north east of England (Sunderland, Tyne and Wear). Herpetological Journal 1: 44–50.

A survey of the distribution of amphibians was carried out in Sunderland (Tyne and Wear). Five species were present in the area, but *Triturus cristatus* and *T. helveticus* were uncommon. All the amphibian species were declining or apparently extinct in the wild ponds. Garden pools were less common than in other parts of England that have already been surveyed, and as a result of the low density of ponds many had not been colonized by amphibians. There was an encouraging number of colonies that had been started by deliberate introduction however. *Rana temporaria* and *T. vulgaris* were the only species that had colonized the ponds to any great extent. Both were found to be very susceptible to fish predation, and mechanisms for surviving in fishponds are discussed. Another danger was the destruction of garden ponds which was astonishingly common. (Authors' abstract)

Bennett, S., J. Gibbons, and J. Glanville. 1980. Terrestrial activity, abundance and diversity of amphibians in differently managed forest types. American Naturalist 103: 412–416.

This is a study of diversity indices and relative abundance for amphibians inhabiting three differently managed forest types in South Carolina. Study sites were contiguous around a small lake, and included a slash pine forest, a loblolly pine forest and a hardwood forest. The slash pine forest was planted in 1953, the loblolly forest in 1952. The mixed hardwood forest was second-growth and was used as the control. The hardwood forest yielded approximately 50% more amphibians than either pine forest during both years of the study. Authors suggest that the 24–26 years of limited disturbance within the pine plantations permitted the development of a variety of amphibian niches that would otherwise not exist. (Authors' abstract)

Berven, K. A., and T. A. Grudzien. 1990. Dispersal in the wood frog (*rana sylvatica*) — implications for genetic population structure. Evolution 44(8): 2047–2056.

Recapture of marked juvenile and adult wood frogs in five Appalachian Mountain ponds showed adults to be 100% faithful to the ponds in which they first bred, but approximately 18% of the juveniles dispersed to breed in ponds other than the one of origin. Effective population sizes were generally smaller than the population censuses and genetic neighborhoods had an average radius of 1,126 meters. Values of standardized genetic variance based on effective population size and mating success were relatively small. Genetic population structure estimated from the dispersal data suggested that ponds within about a 1,000 meter radius should show little genetic differentiation; ponds separated by a distance greater than 1,000 meters should experience little gene flow and show higher genetic differentiation. Wood frogs in these ponds do not show a meta- population structure as suggested for newts. (Authors' abstract)

Bird, S., R. N. Coulson, and D. A. Crossley. 2000. Impacts of silvicultural practices on soil and litter arthropod diversity in a Texas pine plantation. Forest Ecology and Management 131(1–3): 65–80.

In this study we used the diversity of soil and litter arthropods as a metric for evaluating the ecological effects of silvicultural practices of various intensities in a loblolly pine (*Pinus taeda L.*) forest ecosystem. The treatments included low and high intensity harvesting, soil bedding, chemical herbicide application, and nitrogen and phosphorus fertilization. Soil and litter cores were used to sample arthropods after harvesting. In the first year following removal of trees, species diversity was higher in hand-fell, hole-only harvested plots than in mechanical, whole-tree harvested plots and higher in non-bedded plots than in bedded plots. However, these differences did not persist into the second year following harvesting. The recovery of undergrowth vegetation in the second year and the development of a rudimentary litter layer may have increased diversity in the more intensively treated plots. Arthropod species richness increased following nitrogen and phosphorus fertilization, but Shannon diversity did not. This indicates that the arthropod community had responded to fertilization with a shift in community composition. The rapid recovery of arthropod diversity in the second year following tree removal suggests that the silvicultural treatments used at this site did not put long-term productivity at risk. Comparisons with other similar studies suggest that when aiming for sustainable forest management, the particular silvicultural practices that allow for ecosystem recovery may depend on local and regional conditions. (Authors' abstract)

Blair, W. F. 1956. Call difference as an isolation mechanism of southwestern toads (genus *Bufo*). Texas Journal of Science 8(1): 87–106.

Sound analyses have been used to compare the mating calls of 13 species of toads in the southern and southwestern United States. The chief variables are frequency and trill rate, which vary with body size, and duration, which is independent of it. The call of each species differs from the call of each other one in at least two of these three variables. The roles of call difference and size difference in the isolation mechanism complexes of toads in the eastern deciduous forest, central grasslands, and southwestern desert are discussed. (Author's summary)

Blair, W. F. 1958. Mating call in the speciation of anuran amphibians. American Naturalist 92(862): 27–51.

Analysis of the mating call is useful for the study of evolutionary problems in anuran amphibians because characteristics of the call are chiefly related to the functions of attracting a mate and of species identification in breeding congresses. Use of the sound spectrograph in recent years has made possible the measurement and objective comparison of calls.

Variations in call occur among individuals in local populations and between the calls of the same individual under different conditions. Frequency and repetition rate tend to increase with increased environmental temperature and to decrease with increased body size. The call may vary in relation to sexual excitement.

Natural hybridization sometimes occurs between species with well differentiated calls. All well authenticated natural hybrids among U.S. toads involve crosses between *Bufo woodhousei* with representatives of the *B. americanus* group or with *B. valliceps.* This indicates that call differences are not necessarily sufficient to prevent interspecific hybridization when other isolation mechanisms are weakened or eliminated. Hybrids are also known as Scaphiopus.

The calls of hybrids between closely related species are intermediate in character between those of the parental species. The calls of hybrids between two distantly related species (*Bufo woodhousei* and *B. valliceps*) are imperfect and tend to resemble the calls of the male (*B. valliceps*) parent. (Abstract compiled from author's direct quotes)

Blair, W. F. 1958. Distributional patterns of vertebrates on the southwestern United States in relation to past and present environments. Pages 433–468 *in* C. L. Hubbs, editor. Zoogeography. A.A.A.S. Publishers.

A large body of paleontological and zoogeographical data supports the thesis that present distributional patterns of the warmth-adapted vertebrates of the Gulf of Mexico and the southern Atlantic coastal plains reflect Pleistocene splitting of this faunal group into eastern and western populations. The agency of this splitting, as hypothesized by previous workers, is considered to be the southward shifting of climatic belts during the glacial stages of the Pleistocene and the resultant enforced withdrawal of the warmth-adapted biota into separate refuges in Florida and Mexico.

The evidence from the fossil patterns and from plant macrofossils indicates that at times in the Pleistocene northern species of trees such as spruce, hemlock, fir, larch, and arbor vitae extended onto the gulf and southern Atlantic coastal plains. Boreal mammals and a few fishes of northern affinity are known from Pleistocene deposits far south of their present

distributions and as far south as southern Nuevo Leon in Mexico. Both the plant and animal fossils are indicative, then, of major ecological changes in the Southern United States in the Pleistocene.

Evidence from various sources indicates that the southern grasslands have not acted as a continuous barrier to the exchange of forest biotas between the eastern United States and the Mexican highlands since their origins in the late Miocene and the early Pliocene. The Pleistocene mammalian fauna of Florida includes various groups of South American origin, some of them forest types, that must have crossed the area of the present grasslands barrier, as their entry into North America would necessarily have followed the emergence of the Central American land bridge in the late Pliocene. Various Pleistocene fossils from the area of the present grasslands are indicative of greater moisture and of forests at times in this area in the Pleistocene. These include such indicators of extreme departure from present ecological conditions in the area as *Neofiber* in the Texas Panhandle and *Tapirus* in trans-Pecos Texas. An impressive number of present day relicts of forest-adapted species in the grasslands also argues against past continuity of grassland in the area.

Present distributional patterns of coastal plain vertebrates indicate many east-west and very few north-south disjunctions. Some of these involve eastern, forest-adapted and western, grasslands-adapted populations, with the forest-grasslands boundary important in their present distributional relationships. Other patterns involve the Mississippi Embayment as a distributional boundary, and in this group the hiatus between eastern and western populations may include either forest or grassland, or both. Still other patterns involve eastern and western forest-adapted types, some of which have their western populations as relicts in the Mexican highlands.

The fossil evidence of ecological change in the southern United States during the Pleistocene and the evidence derived from the existing distributional patterns of vertebrates are consistent in indicating that the east-west splitting of the warm-adapted biota by the southward shift of colder climates and of the cold-adapted biotas has been the chief agency initiating speciation in this area. The urodeles of the eastern United States show very different distributional patterns from the anurans, because the conditions that fragmented the ranges of the warmth-adapted anurans promoted the southward and westward spread of the urodeles. Then, the conditions that permitted reoccupation of the coastal plain by the anurans would have forced northward and eastward the retreat of the urodeles. (Author's summary)

Blair, W. F. 1959. Genetic compatability and species group in U.S. Toads (*Bufo*). Texas Journal of Science 11: 427–453.

The results to date of crosses among U.S. species of toads (*Bufo*) are discussed, and the percent state of knowledge about genetic incompatibility as a clue to evolutionary relationship and as an isolating mechanism in this faunal group is summarized. Approximately one-third of the possible hybrid combinations in this of the 14 species and one additional subspecies discussed have been made. Twenty-one of the 22 hybrid combinations of species in the same species group, as arranged primarily on morphology and call structure, have undergone metamorphosis, and all of the six that have been tested by backcrossing have proved fertile. Twenty-eight of 51 hybrid combinations involving members of different species groups failed at stages prior to metamorphosis. Among the 23 inter group combinations in which metamorphosis occurred, two have been tested by backcrossing and found effectively sterile, and the abnormal offspring in another failed to survive to sexual maturity. The remaining 20 have not been tested.

The *americanus* group, with six species, the *boreas* group, with three species, and *punctatus* appear possibly more closely related among themselves than they are to other U.S. species. The species *debilis*, *valliceps*, and probably *marinus* appear to represent distinct evolutionary lines insofar as U.S. species are concerned. The position of the *cognatus* group, with two species, is uncertain.

Genetic incompatibility in the toads may be a post-mating isolating mechanism of great significance if other (pre-mating) mechanisms break down, as in *B. woodhousei* and *B. valliceps*. The external morphological characters of one parental species may appear to be largely color pattern and crests in crosses with members of the *cognatus* group and of the *debilis* color pattern in a cross with *terrestris* of the *americanus* group. As expected, some of the hybrids resemble one parent in some characters and the other parent in others. (Author's summary)

Blair, W. F. 1963. Evolutionary relationships of North American toads in the genus *Bufo*: A progress report. Evolution 17(1): 1–16.

The application of all available lines of evidence permits a number of generalizations about the evolutionary history of the genus *Bufo* in North America, although some lines of evidence are as yet incomplete.

The limits of most species groups, which apparently reflect the geologically most recent speciations, are well established for most of the groups. The few exceptions stem from inadequate biological data. These particularly concern the position of *B. alvarius* as a presumed member of the *boreas* group, and the speciational stages of the species included in our *punctatus-marmoreus* group.

At a higher level of relationship, the evidence points to two major evolutionary lines of *Bufo* in North America, and possibly all species in North America are derived from one or the other of these two lines. The existence of Asiatic counterparts of these two lines suggests that the separation of these two lines occurred prior to the entrance of the genus into North America, possibly in the Oligocene.

Essential restriction of one North American line and its Eurasian counterpart to temperate climates and similar restriction of the other North American line and its Asiatic counterpart to tropical and subtropical climates suggest that fixation of climatic adaptations in these respective lines dates far back in the evolutionary history of the genus.

A majority of the North American species can be definitely associated with one or the other of the two evolutionary lines when all evidence is brought to bear. In most instances, the evidence from morphology, call structure, genetic compatibility, and geographical distribution is in accord in implications as to relationship, although there are various instances of convergence and parallelism between the two lines. The *cognatus* group is the only one in which there is a strong disagreement between evidence from structure and that from compatibility tests.

For the better known species groups (*americanus*, *valliceps*, and the allies *canaliferus* and *coccifer* groups) the evolutionary history can be reconstructed with a considerable degree of confidence. Geographical speciation, with isolation under climatic shifts, differentiation, and sometimes populational interactions under subsequent sympatry, can account for the diversification of North American toads. In the best known (*americanus*) group several levels of differentiation may be detected. These are interpreted as follows: (1) separation of *B. woodhousei* from the remainder of the group appears to have been the first dichotomy, (2) subsequent speciation of the *B. woodhousei* element appears to have been interrupted by secondary interbreeding of eastern and western components, (3) the non-*woodhousei* segment of the group appears to have been separated into western (short-calling) and eastern (long-calling) segments, (4) these subsequently underwent fragmentation to produce the present allopatric species, (5) finally, there are relicts (particularly of *B. hemiophrys* and *B. microscaphus*) that are interpreted as results of the most recent (presumably late Pleistocene) fragmentations of ranges. Differentiation of the allopatric species in mating call and in genotype to the extent that viability of hybrids is reduced appears to provide the ingredients for the reinforcement of isolating mechanisms under future sympatry. (Author's summary)

Blair, W. F. 1963. Intragroup genetic compatibility in the *Bufo americanus* species group of toads. Texas Journal of Science 15: 15–34.

This paper reports in detail the outcome of interspecific crosses among the 6 members of the *Bufo americanus* species group of toads. Eighteen of the 30 possible hybrid combinations have been attempted, and metamorphosis occurred in all. Females of all species except *Bufo houstonensis* have participated in these crosses. Various of the F1 hybrids have been tested for fertility through backcrossing and through production of an F2 generation, and all of the hybrid combinations tested show at least some degree of fertility. From the purely qualitative data, the conclusion is evident that the potential for interspecific gene exchange exists among the 6 species of this group.

Quantitatively, the results suggest that there is a greater genetic incompatibility between *B. woodhousei* and any other member of the group than there is among these others, although interpretation of these results is made difficult by intrusion of problems of technique. *Bufo americanus* and *B. terrestris*, as represented in our material, show evidence for a considerable amount of genetic differentiation. Finally, the considerable amount of genetic incompatibility among the various species may explain in part the continued coexistence of *B. woodhousei* with 4 of the other species in spite of natural hybridization with them. (Author's summary)

Blair, W. F. 1972. Evidence from hybridization. Pages 196–232 *in* W. F. Blair, editor. Evolution in the Genus *Bufo*. University of Texas Press, Austin, Texas, USA.

Artificial hybridization experiments provide a powerful tool for evaluating the degree of affinity of species. The results of these experiments now provide a large body of data that contribute to knowledge of how closely species are related and hence place of origin and direction and distance of the spread of the various differentiates within the genus. Blair uses in vitro fertilization to determine the ability of different species of toads in the *Bufo* group can produce viable offspring. (Abstract composed mainly of author's direct quotes)

Blair, W. F. 1972. Characteristics of the testes. Pages 324-328 *in* W. F. Blair, editor. Evolution in the Genus *Bufo*. University of Texas Press, Austin, Texas, USA.

The sacrifice of male toads for artificial crosses allows for the testes to be examined and compared. At first, sketches were made showing the appropriate shape and proportion, and the color was recorded. Later, actual measurements as well as records of color were made.

The two main measurable attributes of the testes, color and proportions, do have phylogenetic significance and do reinforce other evolutionary evidence. All the sketches, measurements, and records of color were made in freshly killed animals. (Abstract composed mainly of author's direct quotes)

Blaustein, A. R., D. B. Wake, and W. P. Sousa. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. Conservation Biology 8(1): 60–71.

Extinctions are normal biological phenomena. Both mass extinctions in geological time and local extinctions in ecological time are well documented, but rates of extinction have increased in recent years-especially in vertebrates, including amphibians-as illustrated by recent reports of their population declines and range reductions. We suggest that long-term population data are necessary for rigorously evaluating the significance of the amphibian declines. Due to the physiological constraints, relatively low mobility, and site fidelity of amphibians, we suggest that many amphibian populations may be unable to recolonize areas after local extinction. (Authors' abstract)

Bogart, J. P. 1968. Chromosome number difference in the amphibian genus *Bufo*: the *Bufo regularis* species group. Evolution 22(1): 42–45.

Bufo houstonensis has been found to have 22 rather than 21 chromosomes. Considering this correction, the cosmopolitan genus *Bufo* has consistently been reported to have a diploid chromosome number of 22. Several species of African toads have only 20 chromosomes. It is the opinion of the author that all the African species reported which have 20 chromosomes represent a natural species grouping derived from a common ancestor possessing 22 chromosomes. (Author's summary)

Bosman, W., J. J. Van Gelder, and H. Strijbosch. 1996. Hibernation sites of the toads *Bufo bufo* and *Bufo calamita* in a river floodplain. Herpetological Journal 6:83–86.

Closed drift fences, bow-nets and a telemetric system were used to study hibernation sites of two toad species in a floodplain. Both species hibernated terrestrially. *Bufo bufo* hibernated in meadows, thickets and woods/bushes on sand or clay in the higher as well as the lower parts of the floodplain. *Bufo calamita* clearly preferred sandy habitats in the higher parts where heaps of brick-debris were specially used. Both species selected their hibernation sites based on characteristics of vegetation and substrate, rather than in relation to the risk of flooding. (Authors' abstract)

Bowers, M. A., S. F. Matter, J. L. Dooley, J. L. Dauten, and J. A. Simkins. 1996. Controlled experiments of habitat fragmentation: a simple computer simulation and a test using small mammals. Oecologia 108(1): 182–191.

Habitat fragmentation involves a reduction in the effective area available to a population and the imposition of hard patch edges. Studies seeking to measure effects of habitat fragmentation have compared populations in fragments of different size to estimate an area effect but few have examined the effect of converting open populations to closed ones (an effect of edges). To do so requires a shift in spatial scope — from comparison of individual fragments to that of fragmented versus unfragmented landscapes. Here we note that large-scale, "controlled" studies of habitat fragmentation have rarely been performed and are needed. In making our case we develop a simple computer simulation model based on how individual animals with home ranges are affected by the imposition of habitat edges, and use it to predict population-level responses to habitat fragmentation. We then compare predictions of the model with results from a field experiment on *Peromyscus* and *Microtus*. Our model treats the case where home ranges/territories fall entirely within or partially overlap with that of sample areas in continuous landscapes, but are restricted to areas within habitat fragments in impacted landscapes. Results of the simulations demonstrate that the imposition of hard edges can produce different population abundances for similar-sized areas in continuous and fragmented landscapes. This edge effect is disproportionately greater in small than large fragments and for species with larger than smaller home ranges. These predictions were generally supported by our field experiment. We argue that large-scale studies of habitat fragmentation are sorely needed, and that control- experiment contrasts of fragmented and unfragmented microlandscapes provide a logical starting point. (Authors' abstract)

Bragg, A. N. 1960. Feeding in the Houston toad. Southwestern Naturalist. 5(2):106.

Brown, L. E. 1967. The significance of natural hybridization in certain aspects of the speciation of some North American toads (genus *Bufo*). Dissertation, University of Texas, Austin, Texas, USA.

Brown, L. E. 1971. Natural hybridization and trend toward extinction in some relict Texas toad populations. Southwestern Naturalist 16(2): 185–199.

Natural hybridization is reported for the Houston toad, *Bufo houstonensis*, with two other species, *B. woodhousei* and *B. valliceps*, in a disjunct pine forest near Bastrop, Bastrop Co., Texas. It is very difficult to morphologically distinguish *B. woodhousei* X *B. houstonensis* hybrids from the parental species. These hybrids, however, have a mating call intermediate between those of the parental species in pulse rate, dominant frequency, and duration. *B. valliceps* X *B houstonensis* hybrids are morphologically intermediate between the parental species and have an abnormal mating call. At Bastrop all premating isolating mechanisms except mating call and body size appear to have partially broken down. Habitat destruction by man may have contributed to this breakdown.

Nine relictual populations of *B. houstonensis* have been found in south-central Texas. At most localities the species is probably near extinction. The species seems restricted to sandy areas frequently characterized by the presence of Loblolly Pine. The destruction of these habitats is probably an important cause of the reduction in numbers of *B. houstonensis*, although other factors may be involved. (Author's abstract)

Brown, L. E., and M. J. Littlejohn. 1972. Male release call in the *Bufo americanus* group. Pages 310–323 *in* W. F. Blair, editor. Evolution in the genus Bufo. University of Texas Press, Austin, Texas, USA.

The Bufonid male release call serves as a sex identification mechanism between male toads. In the species of the *B americanus* group it consists of two major components: the release vibration and the release chirp. We have attempted to determine the degree to which interspecific variation in the male release call reflects the evolution of the *B. americanus* species group. Secondary aims were to determine the effects of temperature and snout-vent length on the release call; to compare release calls with mating calls; and to examine the release calls of natural hybrids.

Temperature has a marked effect on the release call. For *B. woodhousei* and *B. houstonensis* the pulse rates for both the release vibration and the release chirp show positive correlations with cloacal temperature (highly significant F and r values). For *B. houstonensis* the dominant frequency of the release chirp has a highly significant positive correlation with temperature. In addition, the dominant frequency of the release chirp of *B. woodhousei* is negatively correlated with temperature (significant F value). Temperature is negatively correlated with the duration of the release vibration in *B. woodhousei* and *B houstonensis* (highly significant F and r values). The duration of the release chirp is also negatively correlated with temperature; the F value for *B. woodhousei* is significant, but the correlation coefficient for *B. houstonensis* is not significant.

Possible effects of body size on the release call are less evident because of narrow ranges of size variation. Nonetheless, snout-vent length does not appear to have as striking an influence as temperature. Pulse rates of both the release vibration and release chirp of *B. microscaphus* show significant positive correlations with snout-vent length; the correlation coefficients for the other species are not significant. There is a significant negative correlation between the dominant frequency of the release chirp and snout-vent length only when the data for all species are combined. Snout-vent length does not appear to affect the duration of the release vibration. It does, however, have a significant effect on the duration of the release chirp, but only when the data from all specimens are combined.

The mating calls and release calls of *B. woodhousei* differ significantly in duration, pulse rate, and dominant frequency. Mating calls and release calls of the other species do not show such clear-cut differences, although detailed comparisons were not made; however, in all species, durations of the release vibration and release chirp are shorter than those of mating calls.

Natural hybrids between *B. houstonensis* and *B. woodhousei* were easily identified by pulse rates of the release vibration, which were intermediate between those of the parental species. Morphological characteristics of the parental species overlap considerably in variation, and consequently hybrids cannot be identified strictly on this basis.

The pulse rate for the release vibration was the only useful attribute in determining evolutionary relationships. A phylogeny based on these pulse rates agrees closely with the evolutionary history proposed by W.F. Blair (1963). The pulse rates for the release vibration suggest that *B. americanus* and *B. houstonensis* are closely related, as apparently are *B. hemiophrys* and *B. microscaphus*. *B. terrestris* occupies an intermediate position between these two pairs but is closer to *B. americanus* and *B. houstonensis*. The most clearly differentiated member of the group is *B. woodhousei*. *B. microscaphus* and *B. hemiophrys* appear most closely related to *B. woodhousei*. A phylogeny of the *B. americanus* group based on the mating call pulse rates is similar. The major exception is *B. woodhousei*, which has an extremely high pulse rate for the mating call. This is perhaps because *B. woodhousei* is the only species of the group that is sympatric with other members of the group. Under sympatric conditions there should be a premium on a highly differentiated mating call because of the importance of this signal as an isolating mechanism. In contrast, the pulse rate of the release vibration in *B. woodhousei* is not nearly as divergent as that of the mating call. Conservative variation of the release call is presumably advantageous because of the possible utilization

of this signal in interspecies communication. (Author's summary)

Brown, L. E. 1975. The status of the near extinct Houston toad (*Bufo houstonensis*) with recommendations for its conservation. Herpetological Review 6(2): 37–40.

Some attempts are called for to save the Houston toad. All species are worth conserving regardless of whether or not some species might be less pleasing to the eyes of some humans. It is doubtful that anything less than determined action can save the less interesting Houston toad from extinction. The author proposes a five-step plan to be initiated to conserve the Houston toad in Bastrop County:
1. A publicity campaign to inform Texas residents about the near extinction status of *Bufo houstonensis*.
2. Use the zoning law to place all sandy habitats and land covered by pines in a conservation district.
3. Acquisition of all sandy areas and land covered by pines for a refuge.
4. Restoration of all environmentally disturbed land to an undisturbed condition.
5. Increasing the numbers of *B. houstonensis* through artificial fertilization of eggs in the laboratory. (Abstract compiled from direct quotes of author)

Brown, L. E., and R. A. Thomas. 1982. Misconceptions about the endangered Houston toad (*Bufo houstonensis*). Herpetological Review 13(2): p. 37.

A discussion at the November 1980 meeting of the Houston Toad Recovery Team focused on three misconceptions about the Houston toad. One misconception concerns the importance of enlarged postorbital crests as a diagnostic character of *B. houstonensis*. Another misconception is the assumption that pine trees occur at all localities where *B. houstonensis* has been found. The last misconception is the emphasis often placed on the importance of natural hybridization as a cause of the trend toward extinction. (Abstract compiled from author's direct quotes)

Cain, M. D., T. B. Wigley, and D. J. Reed. 1998. Prescribed fire effects on structure in uneven-aged stands of loblolly and shortleaf pines. Wildlife Society Bulletin 26(2): 209–218.

Structure was assessed in uneven-aged stands of loblolly (*Pinus taeda*) and shortleaf pine (*P. echinata*) that were subjected to prescribed winter burns on cycles of 0, 3, 6, and 9 years. Vegetation assessments were made in late summer of 1990, 10 years after a single hardwood control treatment (basal injection of nonpine woody plants >2.5 cm in groundline diameter with Tordon (R) 101R); 1 year after the fourth 3-year burn cycle; 4 years after the second 6-year burn cycle; and 1 year after the second 9-year burn cycle. Compared to unburned controls, prescribed burning tended to increase (P less than or equal to 0.008) percent ground cover from graminoids and composites. For understory woody plants that were >1 m tall but <2.5 cm diameter breast height (dbh), American beautyberry (*Callicarpa americana*) had the greatest percent ground cover on burned and unburned plots. Horizontal cover between 0 and 3-m height tended to average less (P less than or equal to 0.002) with more frequent prescribed burning and with shorter time since burning. There were no burn treatment differences in density (P = 0.199, beta = 0.853) or basal area (P = 0.477, beta = 0.898) for sapling-size stems (2.5–8.9 cm dbh), but species diversity of saplings was lower (P = 0.002) on plots prescribe burned at 3-year intervals as compared to other treatments. (Authors' abstract)

Campbell, L. 1996. Endangered and threatened animals of Texas: their life history and management. University of Texas Press, Austin, Texas, USA.

This is a complete book detailing the endangered and threatened animals in Texas, with a section on the Houston toad.

Chambers, B. Q., and M. J. Samways. 1998. Grasshopper response to a 40-year experimental burning and mowing regime, with recommendations for invertebrate conservation management. Biodiversity and Conservation 7(8): 985–1012.

Grasshopper assemblages were sampled in 44 plots in each of three adjacent sites in a 40-year-old southern tall grassland experimental area in South Africa. Specific plots received particular mowing and/or burning treatments over the 40-year period. Grasshopper responses to vegetation type, and to different burning and mowing practices, were site-specific, despite the close proximity of sites. This suggests that grasshopper assemblage composition is not entirely deterministic and depends on the trajectory of plant succession. Grasshopper species richness and abundance decreased from annually to triennially burnt plots, and

increased in plots mown once per year to plots mown three times per year. Burning in the first week of August (winter) was more favorable for grasshopper assemblages than burning in autumn or after the first spring rains. Mean grasshopper species richness was highest in plots mown after the first spring rains, and the mean number of individuals was highest in plots mown early in summer. When annually burnt plots were compared with annually mown plots, grasshopper abundance and species richness were highest in the burnt plots. A rotational winter burning program, which is practical under African conditions, is recommended for the conservation of grasshoppers and other invertebrates. (Authors' abstract)

Conant, R., and J. C. Collins (1991). A field guide to the reptiles and amphibians of eastern/central North America. Houghton Mifflin, Boston, Massachusetts, USA.

Section in the field guide concerning the family Bufonidae.

Dalton, C. T., and M. G. Messina. 1995. Water relations and growth of loblolly-pine seedlings planted under a shelterwood and in a clear-cut. Tree Physiology 15(1): 19–26.

We investigated the influence of shelterwood conditions on water relations and growth of loblolly pine (*Pinus taeda L.*) seedlings on two harsh sites in eastern Texas. Site I was harvested to provide four overstory density treatments (0, 2.3, 4.6 and 9.2 m (2) of residual basal area per ha). To quantify the effects of overstory competition, trenched and nontrenched subplots, each containing 25 one-year-old seedlings, were established within each overstory treatment plot, and predawn and midday water potentials (Psi(w)), seedling growth and survival were measured during the growing season. Leaf area and seedling biomass partitioning were measured at the end of the growing season. Site II was harvested to provide two overstory density treatments (0 and 6.9 m (2) ha (-1)) and planted with one-year-old loblolly pine seedlings. Seedling Psi(w), stomatal conductance (g(wv)) transpiration flux density (E), leaf area, height and survival were determined. On Site I, seedling Psi(w) increased with increasing overstory basal area, whereas trenching only substantially affected Psi(w) of seedlings in the 9.2 m (2) ha (-1) overstory treatment. Growth was not affected by overstory treatment or trenching. On Site II, Psi(w) and g(wv) were highest during the morning hours and lowest in the afternoon, whereas E peaked in the afternoon. Vapor pressure deficits and photosynthetic photon flux density were major factors in determining g(wv) differences between treatments. On individual days, the presence of an overstory increased Psi(w) and reduced both g(wv) and E. On Site II, leaf area was affected by overstory treatment throughout most of the study. We conclude that the presence of an overstory can have ameliorative effects on harsh sites at the western fringe of the loblolly pine natural range. (Authors' abstract)

Delis, P. R., H. R. Mushinsky, and E. D. McCoy. 1996. Decline of some west-central Florida anuran populations in response to habitat degradation. Biodiversity and Conservation 5(12): 1579–1595.

Recent reports have suggested that a global decline in amphibian populations has taken place during the past few decades. Urban development is thought to affect the richness and abundances of species and, therefore, could be an important cause of decline. We estimated the richness and abundances of anurans in wetlands at a residential development and in similar wetlands at a nearby undeveloped park. The residential development originally was pine flatwoods habitat, as is the undeveloped park currently. We also compared the anuran species' composition of the park in 1992 with the composition in 1974. Both richness and abundances of anurans in the residential development were different than those in the undeveloped park. Employing the same amount of sampling effort at both sites, we trapped or observed 11 species at the development and 15 species at the park, and trapped 569 individuals at the development and 1224 individuals at the park. The anuran species richness at the undeveloped park in 1992 was nearly the same as in 1974; a single rare species apparently was not present in 1992. Of the 15 species present in both surveys, 14 showed higher abundances in 1992 than in 1974. We suggest that the current differences between the residential development and the park have resulted from degradation of both the uplands used by many species during the dry season and the temporary wetlands used by many species for reproduction. Four species especially sensitive to such degradation, *Bufo quercicus*, *Scaphiopus h. holbrookii*, *Hyla femoralis*, and *H. gratiosa*, were the species missing from the residential development. Not all species of anurans typical of pine flatwoods appeared to be affected adversely by development. Three species of ranids, *Rana utricularia*, *R. grylio*, and *R. catesbeiana*, were found in higher abundances at the residential development than at the park. These ranid species breed in a wide variety of aquatic systems, including the permanent bodies of water that are now abundant in the development, and probably use the uplands less than other anurans. If amphibian decline is international in scope, then the decline could be attributable either to global changes caused by humans, or to local, but widespread, environmental degradation, or to a combination of

factors. While much recent popular focus has been on potential global causes of decline, we believe that this emphasis may have caused attention to be taken away from local causes that, as our study demonstrated, may be at least as important. We suggest that in many places, local environmental degradation is insidiously chipping away at amphibian diversity, and that more emphasis should be placed on these local causes than is now the case. (Authors' abstract)

Demaynadier, P. G., and M. L. Hunter. 1998. Effects of silvicultural edges on the distribution and abundance of amphibians in Maine. Conservation Biology 12(2): 340–352.

Amphibians share several biological characteristics that may cause them to be sensitive to abrupt transitions in microhabitat and microclimate that occur across forest edges. To better understand the importance of edge effects on amphibians in a forested landscape, we sampled the distribution of populations along drift fences placed perpendicular to silvicultural edges of varying contrast in central Maine. Within the community of amphibians sampled (14 species), salamanders generally were more sensitize to even-edged harvesting and associated fridge effects than were anurans, but forest habitat generalists and specialists were identified within both groups. We conservatively estimated the depth of edge effects at 25–35 m for a subset of management-sensitive species (*Plethodon cinereus*, *Ambystoma maculatum*, *A. laterale*, and *Rana sylvatica*). An index of edge contrast, calculated using ambient light penetration levels, was valuable in predicting the magnitude of edge effects among sites that included silvicultural edges of different age and origin (old field plantations versus recent clearcuts). Some structural microhabitat variables relevant to forest management were identified as potentially limiting to amphibians near forest edges, including canopy cover, litter cover, and a measure of stumps, slings, and their root channels. Our observations are consistent with the results of other work on biotic edge effects in the eastern United States and suggest that impacts from intensive forest management practices extend beyond the boundaries of harvested stands. (Authors' abstract)

Denton, J. S., S. P. Hitchings, T. J. Beebee, and A. Gent. 1997. A recovery program for the natterjack toad (*Bufo calamita*) in Britain. Conservation Biology 11(6): 1329–1338.

The natterjack toad (*Bufo calamita*) is an endangered species in Britain and has been legally protected since 1975. This amphibian suffered a major decline during the first half of the twentieth century, due partly to habitat destruction but mostly to successional changes in its specialized biotopes and anthropogenic acidification of breeding sites. In addition to site and species protection, extensive autecological research over the past 25 years has provided the foundations for an intensive, 3-year species recovery program funded by the statutory nature conservation organizations (English Nature and the countryside Council for Wales). This program was based on habitat management and reintroductions to restored sites and followed similar but less intensive efforts. Management of heath and dune habitats focused on restoration and maintenance of early stages of seral succession, initially through physical clearance of invasive scrub and woodland vegetation and later by the reestablishment of grazing regimes similar to those prevalent in earlier centuries. In some cases extra breeding pools wee provided to either increase or stabilize natterjack toad populations that had become reliant on one or very few pools at small sites or to promote range expansion within large habitat areas. By 1995 proactive conservation work had been carried out at 29 (69%) of the 39 sites with extant native populations, including 8 during the recovery program. Twenty reintroductions also had been attempted, including nine during the program. At least six reintroductions resulted in the foundation of expanding new populations, and an additional eight have shown initial signs of success. Conservation methods developed for *Bufo calamita* should provide a useful precedent for long-term conservation of early successional habitats and species. (Authors' abstract)

Dixon, J. R. 1983. Survey of the Houston toad at the Caldwell, Texas, site. Caldwell, Texas, U.S. Fish and Wildlife Service. Texas A&M University, College Station, Texas, USA.

During the Houston toad breeding season, occasional visits were made to the Caldwell site (Lake Woodrow) in 1977, 1978, 1979, 1980, and 1981. Houston toads were neither seen nor heard during those visits. In 1983, eighteen visits were made to the Lake Woodrow site, which has been extremely dry during the past several years. The absence of the Houston toad during the visits and the lack of breeding sites suggested that the Houston toad may have been extirpated from the area. (Abstract compiled mainly from author's direct quotes)

Dixon, J. R., N. D. Dronen, J. C. Godwin, and M. A. Simmons. 1990. The amphibians, reptiles, and mammals of Bastrop and Buescher State Parks: with emphasis on the Houston toad (*Bufo houstonensis*) and the short-tailed shrew (*blarina* sp.). Texas Parks and Wildlife. Texas A&M University, College Station, Texas, USA.

The Houston toad has been known to occur in Bastrop State Park and vicinity since 1965. The acquisition of the South Shore of Lake Bastrop by the Texas Parks and Wildlife Department required that the authors access the area for the presence or absence of Houston toads. Surveys were conducted to ascertain whether or not the toad was present and to evaluate the condition of the habitat. No Houston toads were found in the area, probably due to soil type and fire ants. (Abstract compiled mainly from authors' direct quotes)

Dixon, J. R. 2000. Amphibians and reptiles of Texas. Texas A&M University Press, College Station, Texas, USA.

A complete book detailing the amphibians and reptiles in Texas.

Dodd, C. K., and B. S. Cade. 1998. Movement patterns and the conservation of amphibians breeding in small, temporary wetlands. Conservation Biology 12(2): 331–339.

Many amphibians breed in water but live most of their lives in terrestrial habitats Little is known, however, about the spatial distribution of these habitats or of the distances and directions amphibians move to reach breeding sites. The amphibian community at a small, temporary pond in north central Florida was monitored for 5 years. Based on captures and recaptures of more than 2500 striped newts (*Notophthalmus perstriatus*) and 5700 eastern narrow-mouthed tends (*Gastrophryne carolinensis*), we tabulated the angles of orientation that these amphibians entered and excited the pond basin. Our results showed that movements of these species between the pond and terrestrial habitats were nonrandom in orientation but that narrow corridors did not appear to be used. Differences between the species likely reflect differences in habitat preferences, whereas intraspecific differences among years and between the sexes likely reflect variation among individuals. For terrestrial buffer zones to be effective at conserving pond-breeding amphibian communities, they need both a distance and a directional component. The determination of a directional component may be obscured if studies are carried out over a short time span Conservation efforts for wetland-breeding amphibians that concentrate solely on the wetland likely will fail without consideration of the adjacent terrestrial habitat. (Authors' abstract)

Fahrig, L., J. H. Pedlar, S. E. Pope, P. D. Taylor, and J. F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 73(3): 177–182.

We studied the effect of traffic intensity on local abundance of anurans. We counted dead and live frogs and toads per km and estimated frog and toad local abundances using breeding chorus intensities on similar roads through similar habitats, but with different levels of traffic intensity. After correcting for effects of date, local habitat, time, and region, our analyses demonstrated that (I) the number of dead and live frogs and toads per km decreased with increasing traffic intensity; (2) the proportion of frogs and toads dead increased with increasing traffic intensity; and (3) the frog and toad density, as measured by the chorus intensity, decreased with increasing traffic intensity. Taken together, our results indicate that traffic mortality has a significant negative effect on the local density of anurans. Our results suggest that recent increases in traffic volumes worldwide are probably contributing to declines in amphibian populations, particularly in populated areas. (Authors' abstract)

Fair, W. S., and S. E. Henke. 1997. Effects of habitat manipulations on Texas horned lizards and their prey. Journal of Wildlife Management 61(4): 1366–1370.

The effects of habitat manipulations on Texas horned lizards (*Phrynosoma cornutum*) and their main prey, harvester ants (*Pogonomyrmex spp.*) were studied in South Texas. The relative abundance of lizards, their seat, and active harvester and mounds was assessed on 1-ha plots that were manipulated with either prescribed bunting, disking, burning and disking combination, grazing, or land in the Conservation Reserve Program (CRP). We determined differential habitat use or avoidance using Chi-square analysis and Bonferroni Z-statistics to control the experiment-wise error probability at 10%. Lizards used burned plots disproportionately more, were neutral in their use of the disked and grazed plots, and under-utilized the burned and disked combination and CRP plots. Analysis of scat led to similar conclusions in relation to burned, grazed, and CRP plots, but seats were distributed on combination plots pro rata to availability and were underrepresented on the disked plots. No difference was detected in the relative abundance of active ant mounds among the 5 land management practices. Even though Texas horned

lizards preferentially used areas that wore recently burned, the process of burning may harm them due to the shallow depths in which they hibernate. (Authors' abstract)

Findlay, C. S., and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11(4): 1000–1009.

We examined the relationship between the richness of four different wetland taxa (birds, mammals, herptiles, and plants) in 30 southeastern Ontario, Canada wetlands and two anthropogenic factors: road construction and forest removal/conversion on adjacent lands. Data were obtained from two sources: road densities and forest cover from 1:50,000 Government of Canada topographic maps and species lists and wetland areas from Ontario Ministry of Natural Resources wetland evaluation reports. Multiple regression analysis was used to model the relationships between species richness and wetland area, road density, and forest cover. Our results show a strong positive relationship between wetland area and specie richness for all taxa. The species richness of all taxa except mammals was negatively correlated with the density of paved roads on lands up to 2 km from the wetland. Furthermore, both herptile and mammal specie richness showed a strong positive correlation with the proportion of forest cover on lands within 2 km. These results provide evidence that at the landscape level, road construction and forest removal on adjacent lands pose significant risks to wetland biodiversity. Furthermore, they suggest that most existing wetland policies, which focus almost exclusively on activities within the wetland itself and/or a narrow buffer zone around the wetland perimeter, are unlikely to provide adequate protection for wetland biodiversity. (Authors' abstract)

Fischer, J., and D. B. Lindenmayer. 2000. An assessment of the published results of animal relocations. Biological Conservation 96:1-11.

We reviewed 180 case studies and a number of theoretical papers on animal relocations published in 12 major international scientific journals over the last 20 years. The study focused on re-introductions, supplementations and translocations (sensu IUCN, 1996. IUCN/SSC Guidelines for Re-introductions. 41st Meeting of the IUCN Council, Gland, Switzerland, May 1995. Http://iucn.org/themes/ssc/pubs/policy/hinte.htm.). We did not assess introductions. Re-introductions were the most common type of relocation (116/180); three quarters of these were conducted for conservation purposes. Supplementations (48/180) and translocations (36/180) occurred less frequently, and both were commonly carried out for reasons other than conservation. Simple descriptive statistics were used to analyse factors influencing relocation success. Translocations that aimed to solve human–animal conflicts generally failed. Re-introduction success was not found to have changed over the last two decades, but re-introductions appeared to be more successful when the source population was wild, a large number of animals was released (n>100), and the cause of original decline was removed. More complex trends were found for the effect of predation and the use of supportive measures such as provision of food or shelter, or predator control prior to release. The success of 47% of re-introductions was uncertain at the time case studies were published in journals. This was partly due to the lack of generally accepted and widely applied criteria to assess success. Very few case studies (3%) reported the cost of the relocation attempt. We conclude that there were three primary aims for animal relocations. These were to solve human–animal conflicts, to restock game populations, and conservation. Our extensive review of the present literature leads us to conclude that the value of animal relocations as a conservation tool could be enhanced through (1) more rigorous testing for the appropriateness of the approach in a given case, (2) the establishment of widely used and generally accepted criteria for judging the success or failure of relocations, (3) better monitoring after a relocation, (4) better financial accountability, and (5) greater effort to publish the results of relocations, even ones that are unsuccessful. (Authors' abstract)

Fisher, R. N., and H. B. Shaffer. 1996. The decline of amphibians in California's Great Central Valley. Conservation Biology 10(5): 1387–1397.

Declines in amphibian populations are rarely reported on the community or ecosystem level. We combined broad-scale field sampling with historical analyses of museum records to quantify amphibian declines in California's Great Central Valley. Overall, amphibians showed an unambiguous pattern of decline, although the intensity of decline varied both geographically and taxonomically. The greatest geographical decline was detected in the counties of the Sacramento and San Joaquin Valleys. Two species, *Rana aurora* and *Bufo boreas* were identified as the most affected by decline, whereas *Pseudacris regilla* was the least affected. The Coast Range counties have little or no detectable decline. We provide new evidence implicating introduced predators as a primary threat. Introduced predators occur at lower elevations that native species, and our data indicate that for some native species there has been significant restriction to higher elevation sites from a formerly broader distribution. Our historical approach provides a strategy for identifying declining amphibian communities that complements more detailed, long-term monitoring programs and provides an

assessment of the pattern of change that is a necessary prerequisite for the development of field experiments that test hypothesized mechanisms of change. (Authors' abstract)

Ford, W. M., M. A. Menzel, D. W. McGill, J. Laerm, and T. S. McCay. 1999. Effects of a community restoration fire on small mammals and herpetofauna in the southern Appalachians. Forest Ecology and Management 114(2–3): 233–243.

As part of the Wine Spring Creek ecosystem management project on the Nantahala National forest, North Carolina, we assessed effects of a community restoration fire on small mammals and herpetofauna in the upper slope pitch pine (*Pinus rigida*) stands, neighboring midslope oak (*Quercus spp.*) stands and rhododendron (*Rhododendron maximum*) dominated riparian areas during 1995 and 1996. Using drift-fence arrays with pitfalls and snap-trapping, we collected these small mammals: masked shrew (*Sorex cinereus*), smoky shrew (*S. fumeus*), water shrew (*S. palustris*), pygmy shrew (*S. hoyi*), northern short-tailed shrew (*Blarina brevicauda*), deer mouse (*Peromyscus maniculatus*), white-footed mouse (*II leucopus*), golden mouse (*Ochrotomys nuttalli*), southern red-backed vole (*Clethrionomys gapperi*), pine vole (*Microtus pinetorum*) and woodland jumping mouse (*Napaeozapus insignis*). Herpetofauna collected from drift-fence arrays and time-constrained searches included: eastern newt (*Notophtalmus viridescens*), seepage salamander (*Desmognathus aeneus*), mountain dusky salamander (*D. ochrophaeus*), Blue Ridge two-lined salamander (*Eurycea wilderae*), spring salamander (*Gyrinophilus porphyriticus*), Jordan's salamander (*Plethodon jordani*), wood frog (*Rana sylvatica*), five-lined skink (*Eumeces fasciatus*), eastern garter snake (*Thamnophis sirtalis*), and northern ringneck snake (*Diadophis punctatus*). Prior to the prescribed community restoration fire in the spring of 1995, there were no significant differences in small mammal or herpetofauna collections between burned and control areas. Post-treatment in 1995 and 1996, showed no significant differences among collections of most species between burned and control areas. Slope position accounted for more variation among the species of greatest abundance than did burning. Concern for the effects of prescribed fire as a management tool on small mammals and herpetofauna in the southern Appalachians seems unwarranted. (Authors' abstract)

Freed, P. S., and K. Neitman. 1988. Notes on predation on the endangered Houston toad, *Bufo houstonensis.* Texas Journal of Science 40(4): 454–456.

In this paper, the authors report the first observation of predation on tadpoles of the Houston toad by two species of colubrid snakes, as well as predation on newly-metamorphosized toads by the red imported fire ant, *Solenopsis invicta*. The study was conducted in the spring of 1986 with toads that were released at the Attwater's Prarie Chicken National Wildlife Refuge in Colorado County, Texas. (Abstract composed mainly from author's direct quotes)

Garza, N. E., and W. H. Blackburn. 1985. The effect of early winter or spring burning on runoff, sediment, and vegetation in the post oak savannah of Texas. Journal of Range Management 38(3): 283–287.

A replicated small plot (1.8 m X 22.1 m) study was conducted on the Texas A&M University Native Plant and Animal Conservancy in Brazos County, Texas. The purposes of the study were to determine the effects of seasonal burning on runoff and sediment and to describe vegetal differences resulting from the burning treatments. A grass-dominated community and a brush-dominated community were studied. Mean runoff from both communities tended to be greater from unburned plots than from burned plots although differences were seldom significant. Mean sediment export (kg/ha) was similar from the treatments during the 15-month study. However, nonsignificant trends suggested that plots burned in the spring lost less sediment than did unburned plots or those burned in early winter. Most sediment loss occurred during June, September, and November as a result of highly intense thunderstorms. Burning did not adversely affect runoff or sediment. Changes in vegetative composition and vigor did not occur and these changes appeared to be compatible with most management objectives. Percent foliar cover of live vegetation was greater on burned than unburned plots; however, total foliar cover was greatest on unburned plots. Burning in early winter favored growth of forbs, whereas spring burning tended to favor the production of grasses. (Authors' abstract)

Gibbs, J. P. 1998. Amphibian movements in response to forest edges, roads, and streambeds in southern New England. Journal of Wildlife Management 62(2): 584–589.

If management of landscape linkages is to be promoted as a means of conserving amphibian populations, it must be demonstrated that amphibian dispersal does not occur independently of ecosystem edges and other salient landscape features. I used drift fences and pitfall traps to intercept dispersing amphibians and examine amphibian movements relative to roads, forest edges, and streambeds in a forest tract in southern Connecticut. Capture rates of 3 species (marbled salamander, *Ambystoma opacum*; red-spotted newt, *Notophthalmus viridescens*; pickerel frog, *Rana palustris*) were influenced by forest borders and streambeds, whereas captures of 3 other species (spotted salamander, *Ambystoma maculatum*; redback salamander, *Plethodon cinercus*; wood frog, *R sylvatica*) were not. Across all species, the relative permeability of forest- road edges was much reduced in comparison to the forest interior and to edges between forest and open land. The data suggest that landscape-level conservation strategies aimed at amphibians should account for such filters and conduits to amphibian movement. (Author's abstract)

Goater, C. P. 1994. Growth and survival of postmetamorphic toads: interactions among larval history, density, and parasitism. Ecology 75(8):2264–2274.

I examined growth and survival of the European toad, *Bufo bufo*, from hatching to the approximate time of first hibernation. I varied tadpole density in experimental ponds such that individuals from low-density ponds emerged 48.5% larger than those from high-density ponds. In the laboratory, metamorphs from both pond densities were maintained in containers at densities of one or six. Nine weeks after metamorphosis they were exposed to 0 or 80 larvae of the lungworm, *Rhabdias bufonis*. A factorial experiment aimed to determine (1) the extent to which conditions experienced by larvae carried over to the terrestrial stage and (2) the effects of resource limitation and past history on a host's response to a potential pathogen.

The density of metamorphs had the strongest effect on growth and survival: 18 weeks after metamorphosis, those raised alone were approximate to 80% heavier than those in groups and they had 31% higher survival. However, larval history also affected growth and survival and affected how metamorphs responded to density. First, single toads emerging from low-density ponds were 14.5% larger at the time of hibernation than those from high-density ponds. The mechanism for this growth advantage probably lies in the consistently higher growth rates of single toads from low-density ponds, especially during the first 3 weeks after metamorphosis. Second, survival in group containers was higher for toads from low-density ponds, especially during the first few weeks after metamorphosis when most deaths involved toads from high-density ponds. These results support a carry-over effect between larval history and subsequent performance in an organism with a complex life cycle.

Infection with lungworms had no detectable effect on metamorph growth or survival. This result contrasts earlier studies on this system, possibly due to the relatively low worm burdens or low statistical power. Yet, the results may also indicate that the predicted impact of infection on hosts, especially those limited by resources, is not as straightforward as theoretical studies suggest. (Author's abstract)

Greenberg, C. H., and A. McGrane. 1996. A comparison of relative abundance and biomass of ground-dwelling arthropods under different forest management practices. Forest Ecology and Management 89(1–3): 31–41.

Habitat structural characteristics and relative abundance and biomass of ground-dwelling arthropods were compared among four replicated stand treatments: intense burning and salvage logging; clearcutting followed by roller-chopping (100% soil surface disturbance); clearcutting followed by bracke seeding (30% soil surface disturbance); and naturally regenerated mature, forested sand pine scrub. Arthropods were classified by taxa and by mean maximum width. Monthly trends in abundance and biomass of arthropods captured are described. Mature forest differed from the three disturbance treatments in most habitat structural features, but disturbance treatments were similar. Total numbers and dry weight did not differ among treatments but more individuals and biomass of arthropods less than 5 mm mean maximum width occurred in burned sites. There were significantly more arthropods 10 mm or less in mean maximum width than over 10 mm, but arthropods 5-10 mm had the highest biomass. The relative abundance of some taxa differed among treatments, and taxa differed in monthly capture rates. Total numbers and biomass of captured arthropods were greatest from late May through November. (Authors' abstract)

Grubb, J. C. 1970. Orientation in post-reproductive Mexican toads, *Bufo valliceps*. Copeia 4: 674–680.

Nonbreeding Mexican toads, *Bufo valliceps*, in Austin, Texas, were fitted with trailing devices and displaced up to 237 m from their capture site in the early fall of 1967 and 1968. Seventeen of 24 displacements with normal toads resulted in movement back toward the capture site. Toads displaced after

the destruction of vision or olfaction showed similar homing behavior. However, toads with both senses destroyed simultaneously did not home. It was concluded that homing toads were able to use both visual and olfactory cues. (Author's abstract)

Grubb, J. C. 1973. Olfactory orientation in breeding Mexican toads, *Bufo valliceps*. Copeia 3: 490–497.

Breeding male toads, *Bufo valliceps*, were collected from or en route to breeding sites and tested in an olfactometer for the ability to discriminate and respond to the odor of water from their home breeding habitats. Six of seven populations tested demonstrated a preference for this odor. Alternatives discriminated against included slightly humidified air and odors of distant and adjacent bodies of water, either temporary or permanent, all of which were used for breeding by conspecifics. The response diminished through time but could not be revived by injection of gonadotropins. Toads in breeding condition which had not been exposed to their breeding habitat for at least one month responded positively to its odor. Tests for celestial orientation yielded no evidence of either a nocturnal or diurnal celestial-compass mechanism. (Author's abstract)

Guttman, S. I. 1967. Evolution of blood proteins within the cosmopolitan toad genus *Bufo*. Dissertation, Univetsity of Texas, Austin, Texas, USA.

Guttman, S. I. 1969. Blood protein variation in the *Bufo americanus* species group of toads. Copeia 1979(2): 243–249.

The transferrin and hemoglobin components of the six species of toads of the *Bufo americanus* group were polymorphic. Thirteen molecular types of transferrin and ten hemoglobin components appeared in the individuals examined. In several instances interspecific hybridization may be responsible for the individual variation in these components. (Author's abstract)

Halley, J. M., R. S. Oldham, and J. W. Arntzen. 1996. Predicting the persistence of amphibian populations with the help of a spatial model. Journal of Applied Ecology 33(3): 455–470.

1. We have used a stochastic population model with immigration to calculate extinction rates for two amphibian species: the common toad, *Bufo Bufo*, and the crested newt, *Triturus cristatus*. 2. Population models for amphibians are difficult to parameterize. It was not possible to measure all the relevant parameters for the model. The other parameters were obtained from other studies or estimated on the basis of similar species. 3. Contour maps for persistence were generated using the model. The persistence of populations associated with a pond is affected both by the pond's internal dynamics and its proximity to a source pond. On a 20-generation time scale, toad ponds that were initially occupied were relatively unaffected by the proximity of a source. Persistence was almost certain (>95%) when the average carrying capacity of a pond was greater than 30 adult females. Initially unoccupied toad-ponds were equally likely to persist if they lay within 4 km of a source and could support more than 50 adult females. Initially occupied newt ponds were likely to persist if they supported more than 40 females or lay within 0.5 km of a typical source pond. Initially unoccupied newt ponds were mainly dependent upon immigration rates. Very small ponds (N-k <10) could persist if they lay within 0.75 km of a source pond, while large ponds (N-k much greater than 10) only needed to be within 1.5 km of a source pond. 4. This model allows us to use the data available, to make predictions about the criteria which must be met by a landscape to ensure the survival of amphibian populations. It offers the possibility of better predictions when the data is refined. The model also suggests directions for further research such as the statistical study of environmental variation, the nature of minimum viable populations for toads and the statistics of long-range dispersal. (Authors' summary)

Hanlin, H. G., F. D. Martin, L. D. Wike, and S. H. Bennett. 2000. Terrestrial activity, abundance and species richness of amphibians in managed forests in South Carolina. American Midland Naturalist 143(1): 70–83.

We determined the relative abundance, days of surface activity and indices of species diversity, evenness and richness for amphibians inhabiting three differently managed forests surrounding a Carolina lay in South Carolina following restoration, We collected animals daily for 3 y (Oct. 1993–Sept. 1996) using drift fences with pitfall traps in three forest types: loblolly pine (*Pinus taeda*), slash pine (*P. elliotta*) and mixed hardwoods (predominantly oak, *Quercus spp.* and hickory, *Carya spp.*). Captured animals were marked and

recaptures were recorded but not included in statistical analyses, except in our evaluation of activity. We compared results to those of a more limited study conducted before restoration. Amphibians were significantly more numerous and more active in the mixed hardwood forest than in the pine forest types. However, the hardwood forest had the lowest species diversity in 2 of the 3 y of the study. The slash pine habitat had the highest diversity in all 3 y and for the 3, combined. Because the evenness index (J') values differ in step with the species diversity index (H') it appears that the evenness component of diversity, rather than the richness component, is what is determining H' variation. A summer subset of these data and summer data from an earlier study of 1977– 1978 is in marked contrast with yearlong patterns. For our summer data each forest type had the highest H' value in one of the years of the study and again the J' values parallel the differences in H'. Large numbers of southern toads (*Bufo terrestris*) reduced evenness, and therefore species diversity, for all three habitats particularly the mixed hardwoods where this species was especially abundant. Proportionally lower numbers of *B. terrestris* in the summer samples increased J' and H' indices. Overall lower abundance and H' values in the summers of 1994–1996, compared with 1977–1978 may be the result of habitat alteration during the restoration of the Carolina bay. (Authors' abstract)

Harpole, D. N., and C. A. Haas. 1999. Effects of seven silvicultural treatments on terrestrial salamanders. Forest Ecology and Management 114(2–3): 349–356.

We compared the relative abundance of terrestrial salamanders before and after application of seven regeneration treatments in a low-elevation, southern Appalachian hardwood forest in southwest Virginia. Treatments included understory removal, group selection, two shelterwoods, leave-tree, clearcut, and a control. Salamander relative abundance was significantly lower after harvest on the group selection ($p=0.005$), shelterwoods ($p=0.007$ and $p=0.015$), leave-tree ($p=0.001$), and clearcut treatments ($p=0.001$). There was no significant difference in relative abundance during the same period on the control ($p=0.788$) or understory removal ($p=0.862$) treatments. (Authors' abstract)

Hecnar, S. J., and R. T. M'Closkey. 1997. The effects of predatory fish on amphibian species richness and distribution. Biological Conservation 79: 123–131.

Amphibian communities at 178 ponds across southwestern Ontario, Canada, were studied to determine if presence of predatory fish was related to altered amphibian species richness or distribution on a geographic scale. Ponds are an important amphibian habitat in the study area and many have been stocked with fish. Surveys conducted over three years were used to construct amphibian species lists for individual ponds. Species richness and presence/absence were compared among ponds classified by the type of fish present. Amphibian species richness was significantly lower at ponds having predatory fish present than at non-predatory, or fish-free, ponds. Not all amphibian species were negatively affected by the presence of predatory fish. Those having either large bodies or clutch size co-occurred with predatory fish more frequently than those with small bodies or clutch size. Introduction of predatory fish by humans has likely resulted in altered amphibian species assemblages and reduced community diversity on a geographic scale. (Authors' abstract)

Hillis, D. M., A. M. Hillis, and R. F. Martin. 1984. Reproductive ecology and hybridization of the endangered Houston toad (*Bufo houstonensis*). Journal of Herpetology 18(1): 56–72.

Initiation of breeding activity of *Bufo houstonensis* followed a rise in minimum air temperature in January or February to above approximately 14 C. Rain was not a direct necessary stimulus to breeding in this species; additional site-specific stimuli apparently are necessary; rapid algal growth may be such a stimulus.

Amplectant male *B. houstonensis* were significantly larger than non-amplectant males. Based on growth data from recaptured males, it is likely that older male *B. houstonensis* are more likely to achieve amplexus than are first season males. Data on breeding behavior and movements to and from breeding sites are presented.

Natural hybrids between *B. houstonensis* and *B. woodhousei* and between *B. houstonensis* and *B. valliceps* were identified morphologically and electrophoretically. Only one suspected backcross product was found. Hybridization among these species was minimal in the study areas - in all cases less than 1% of the parental populations. The primary isolating mechanisms are temporally offset breeding seasons (of *B. houstonensis* and *B. valliceps*) and habitat isolation (*B. houstonensis* and *B. woodhousei*).

The population sizes of *B. houstonensis* in Bastrop Co., Texas, are larger than previously reported; present population sizes in this area appear not to be critically low. The restricted range of the species coupled with habitat destruction seem to be the primary factors in the endangerment of *B. houstonensis*. (Authors' abstract)

Hillis, D. M., and A. H. Price. 1993. Endangered and threatened species conservation — Houston toad taxonomic relationships. Texas Parks and Wildlife Department, Austin, Texas, USA.

The products of 20 enzyme-coding loci were examined for 147 toads representing 4 of the 6 members of the *Bufo americanus* species group, including the endangered *Bufo houstonensis*. No diagnostic alleles were found for any of the taxa examined. The data support previously hypothesized phylogenetic relationships and reflect current zoogeographic positions of the taxa involved. A pattern of reticulate hybridization among taxa and between populations in historic times is suggested. The data do not refute the hypothesis that *Bufo houstonensis* is a distinct evolutionary lineage. They also do not suggest genetic divergence between isolated populations of *B. houstonensis*. Examination of sequence or restriction-site variation in nuclear and mt-DNA is required to reveal in detail the extent of reticulation among the lineages examined in this study. (Authors' abstract)

Houston Toad Recovery Team. 1984. Recovery plan for the Houston toad (*Bufo houstonensis*). U. S. Fish and Wildlife Service, Albuquerque, New Mexico, USA.

The Houston toad (*Bufo houstonensis*) declined sharply in distribution and abundance primarily because of Texas' severe drought of the 1950s and secondarily because of loss of habitat from land development. Continued loss of habitat supresses recovery of Houston toad populations during wet years and the secretive nature of the species makes it difficult to find previously unreported populations as well as known, but diminished, populations.
Three principal types of recovery actions are proposed herein: 1) Search for additional Houston toad populations in areas of likely habitat; 2) reestablish Houston toad populations in suitable habitat in the historic range of the species, and 3) determine if *Bufo houstonensis* is the same animal as *B. americanus charlesmithi*. (Authors' summary)

Jacobson, N. L. 1989. Breeding dynamics of the Houston toad. Southwestern Naturalist 34(3): 374–380.

The houston toad, *Bufo houstonensis*, is an explosive breeder. During the spring of 1982 at a stock pond in Bastrop Co., Texas, I followed an aggregation through a breeding season that lasted 4 months. I found females only 15 nights and evidence of oviposition on 7 nights. Mean size did not differ between non-amplectant males and amplectant males or, for amplectant males, between males found on ovipositing females and those that were not. On the night of peak density, there was more movement by those males that were amplectant some time during that breeding period than by non-amplectant males. A displacement level of 8% (5 of 64 recaptured amplectant females) was estimated. Males marked during the previous season (1981) that returned in 1982 were found more often on ovipositing females than were other males. (Author's abstract)

Kennedy, J. P. 1962. Spawning season and experimental hybridization of the Houston toad, *Bufo houstonensis.* Herpetologica 17: 239–245.

This report presents the results of a single experimental cross between a female *Bufo houstonensis* and a male *Bufo valliceps* and includes pertinent observations on the spawning season and ecology of a local population of *houstonensis* living on the coastal prairie in Houston, Harris County, Texas. The results of the cross indicate that the gametes of a female *houstonensis* and a male *valliceps* are compatible and are capable of producing a viable F1 hybrid, but there is considerable reduction in development from this combination. (Abstract compiled from author's direct quotes)

Knutson, M. G., J. R. Sauer, D. A. Olsen, M. J. Mossman, L. M. Hemesath, and M. J. Lannoo. 1999. Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, USA. Conservation Biology 13(6): 1437–1446.

Management of amphibian populations to reverse recent declines will require defining high-quality habitat for individual species or groups of species, followed by efforts to retain or restore these habitats on the landscape. We examined landscape- level habitat relationships for frogs and toads by measuring associations between relative abundance and species richness based on survey data derived from anuran calls and features of land-cover maps for Iowa and Wisconsin. The most consistent result across all anuran guilds was a negative association with the presence of urban land. Upland and wetland forests and emergent wetlands tended to be positively associated with anurans. Landscape metrics that represent edges and patch diversity also had generally positive associations, indicating that anurans benefit from a complex of habitats that include wetlands. In Iowa the most significant associations with relative abundance were the length of the edge between wetland and forest (positive) and the presence of urban land (negative). In Wisconsin the two most significant associations with relative abundance were forest area and agricultural area (both positive). Anurans had positive associations with agriculture in Wisconsin but not in Iowa.

Remnant forest patches in agricultural landscapes may be providing refuges for some anuran species. Differences in anuran associations with deep water and permanent wetlands between the two states suggest opportunities for management action. Large-scale maps can contribute to predictive models of amphibian habitat use, but water quality and vegetation information collected from individual wetlands will likely be needed to strengthen those predictions. Landscape habitat analyses provide a framework for future experimental and intensive research on specific factors affecting the health of anurans. (Authors' abstract)

Laan, R., and B. Verboom. 1990. Effects of pool size and isolation on amphibian communities. Biological Conservation 54(3): 251–262.

An investigation of the presence of amphibians was carried out in 38 old and 39 recently constructed pools. In order to assess the possible effects of pool size and isolation on the number of species, characteristics of the pools and the surrounding landscape were analyzed by means of (stepwise) multiple regression analysis. In all analyses we corrected for habitat variables concerning the pool. Significant effects of pool size were found for old pools only. In both old and new pools species number turned out to be positively influenced by the vicinity of a wood. Woodland is considered here as an element increasing the connectivity of a landscape and as a part of the land habitat of amphibians. Pool age was the best predictor of species number in the new pools. The three most abundant species displayed differences in colonization rate. These differences turned out to be related to their abundance. (Authors' abstract)

Laurance, W. F., and E. Yensen. 1991. Predicting the impacts of edge effects in fragmented habitats. Biological Conservation 55(1): 77–92.

We proposed a protocol for assessing the ecological impacts of edge effects in fragments of natural habitat surrounded by induced (artificial) edges. The protocol involves three steps: (1) identification of focal taxa of particular conservation or management interest, (2) measurement of an 'edge function' that describes the response of these taxa to induced edges, and (3) use of a 'Core-Area Model' to extrapolate edge function parameters to existing or novel situations. The Core-Area Model accurately estimates the total area of pristine habitat contained within fragments. Moreover, it can be used to predict the amount of unaltered habitat preserved within any hypothetical fragment, such as a planned park or nature reserve, regardless of its size or shape. The model is simple, requiring two edge function parameters and the area and perimeter length of the fragment. Model simulations revealed that for any edge-sensitive species and habitat type there exists a critical range of fragment sizes in which the impacts of edge effects increase almost exponentially. This critical size range cannot be predicted without empirical measurement of the edge function. (Authors' abstract)

Lehtinen, R. M., S. M. Galatowitsch, and J. R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands 19(1):1–12.

Landscape-level variables operating at multiple spatial scales likely influence wetland amphibian assemblages but have not been investigated in detail. We examined the significance of habitat loss and fragmentation, as well as selected within-wetland conditions, affecting amphibian assemblages in twenty-one glacial marshes. Wetlands were located within urban and agricultural regions of central and southwestern Minnesota, USA and were distributed across two ecoregions: tallgrass prairie and northern hardwood forest. We surveyed amphibian assemblages and used a geographic information system to quantify land-use variables at three scales: 500, 1000, and 2500 m. Ten species of amphibians were detected, the most abundant being *Rana pipiens*, *Ambystoma tigrinum*, and *Bufo americanus*. Amphibian species richness was lower with greater wetland isolation and road density at all spatial scales in both ecoregions. Amphibian species richness also had a negative relationship with the proportion of urban land-use at all spatial scales in the hardwood forest ecoregion, and species richness was greater in wetlands with fish and *Ambystoma tigrinum*. These biotic relationships are less consistent and more difficult to interpret than are land-use relationships. The data presented here suggest that decreases in landscape connectivity via fragmentation and habitat loss can affect amphibian assemblages, and reversing those landscape changes should be an important part of a regional conservation strategy.

Lemckert, F. 1999. Impacts of selective logging on frogs in a forested area of northern New South Wales. Biological Conservation 89(3): 321–328.

Counts of frogs were performed at 52 streams and 33 ponds in the Dorrigo area of northern New South Wales, Australia. Three measures of logging disturbance and seven other environmental features were recorded for each site to determine if any of these factors significantly influenced species richness (number of species) or abundance of individuals breeding at either streams or ponds. Species were also categorized into five guilds and the number of species of

each guild compared to the same factors. Altitude and longitude were found to have the greatest influence on total species richness. The percentage of undisturbed forest was also a significant variable with species richness increasing in more disturbed areas. Increasing numbers of logging events increased the species richness of tree frogs and generalist species at streams and more recent disturbances appeared to increase the richness of generalists at ponds. No single habitat feature was found to consistently explain individual species abundances at ponds or streams. Logging activities appeared to favor several species, but negative effects of logging were also recorded for three species. The great barred frog *Mixophyes fasciolatus* decreased in numbers in more recently logged areas, the giant barred frog *Mixophyes iteratus* decreased in abundance in recently-logged areas and at sites where little undisturbed forest was available and the tusked frog *Adelotus brevis* appeared to be dependant on patches of undisturbed forest. The results indicate that selective logging has little impact on many frog species, but large forest-dependent species and terrestrial breeders are more likely to be negatively affected. (Author's abstract)

Licht, L. E. 1967. Growth inhibition in crowded tadpoles: intraspecific and interspecific effects. Ecology 48(5): 736–745.

Tadpoles are inhibited in growth when raised in water previously crowded by other larger tadpoles. The 'alga-like' cells described in earlier crowding studies were found in the fecal material and intestinal tracts of inhibited tadpoles. Results of 38 crowding experiments using 17 species of tadpoles show that the effects of the inhibitory cell are nonspecific. Water (with cell-laden fecal matter) from crowded tadpoles of one suborder can inhibit the growth of grassy tadpoles of a different suborder. There is no decreasing level of inhibition with phylogenetic distance. *Bufo woodhousei* is the only one of 17 anuran species tested that seems immune to these inhibitory effects. Tests with *Bufo woodhousei* indicated the existence of a possible intraspecific growth-promoting substance. The substance may also inhibit some species, and may not affect others. Metamorphosing tadpoles may release a nonspecific growth-stimulating substance (thyroxine?) into the water, which may alleviate the effect of inhibitory substances. (Author's abstract)

Licht, L. E. 1976. Initial appearence of the parotoid gland in three species of toads (genus *Bufo*). Thesis, University of Texas, Austin, Texas, USA.

Lloyd-Reilley, J., C. J. Scifres, and W. H. Blackburn. 1984. Hydrologic impacts of brush management with tebuthiuron and prescribed burning on post oak savannah watersheds, Texas. Agriculture Ecosystems & Environment 11(3): 213–224.

Selected hydrologic variables were evaluated following conversion of heavily wooded sites to open grassland with an herbicide — prescribed burning treatment sequence in east-central Texas. Terminal infiltration rates and sediment production 3 years after aerial application of tebuthiuron pellets at 2.2 kg ha -1 (active ingredient) for brush management differed little from values for untreated (wooded) areas. Prescribed burning in the winter (December – February) temporarily decreased infiltration rates and increased sediment production. Infiltration rates had equilibrated among brush management treatments with re-instatement of the herbaceous cover 5.5 months after burning. Sediment production was generally greater from burned than unburned plots after 5.5 months, but the absolute amount of sediment produced on the near-level (1-3% slope) fine sandy loam sites was not great, regardless or treatment. Moreover, sediment production from burned sites was not significantly different from that of untreated sites 1 year after burning. The brush management treatments had no effect on nitrate concentrations in runoff. However, in one of two experiments, total unfiltered nitrogen and phosphorous contents in runoff were greater during the growing season following burning than from unburned sites. (Authors' abstract)

Mader, H. J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29(1): 81–96.

Small forest mammals were reluctant to venture onto road surfaces when the distance between forest margins was more than 65.6 ft; of 742 beetle recaptures only 1 crossed a 23 ft. highway; populations isolated by parking loops were effectively isolated; Stenotopic woodland carabids avoid penetrating the road verges and never or rarely crossed the road; roads constitute an effective hindrance to movement for forest-inhabiting mice; the mice are able to cross the road within a few seconds but none of the recaptured animals were shown to do so; even forest roads closed to the public seemed to be a real obstacle. (Summary written by Lisa O'Donnell; composed mainly from author's direct quotes)

Margules, C. R., G. A. Milkovits, and G. T. Smith. 1994. Contrasting effects of habitat fragmentation on the scorpion *cercophonius-squama* and an amphipod. Ecology 75(7): 2033–2042.

Populations of the scorpion *Cercophonius squama* and the terrestrial amphipod, Family Tallitridae, were monitored by pitfall trapping in southeastern Australia for 8 yr as part of a field experiment to study the effects of habitat fragmentation and remnant habitat patch size on biological diversity, for 3 years prior to the fragmentation treatment, and 5 years thereafter. The abundance of scorpions did not change significantly with habitat fragmentation and there was no discernible effect of remnant size. The abundance of amphipods in the remnants relative to that in the controls decreased markedly after fragmentation, more so on smaller remnants than on larger ones. By reason of their ecological and biological characteristics, scorpions seem resistant to the changed ecological conditions brought about by habitat fragmentation, at least in the short term, whereas amphipods are more susceptible. It is not yet possible to generalize about the responses of species to habitat fragmentation. Management of fragmented ecosystems to maintain biological diversity should be directed at populations of species because different species respond differently. (Authors' abstract)

Martin, W. F. 1967. The mechanism and evolution of sound production in the toad genus *Bufo*. Thesis, University of Texas, Austin, Texas, USA.

Martin, R. F. 1973. Osteology of North American *Bufo*: The *americanus*, *cognatus*, and *boreas* species groups. Herpetologica 29(4): 375–387.

The osteology of 11 species of North American *Bufo* of the *americanus*, *cognatus*, *boreas* and *valliceps* species groups was examined. The *americanus*, *cognatus* and *boreas* groups display narrow frontoparietal bones, elevated neurocrania, and a frontoparietal-prootic suture. The former groups possess cranial crests; the latter does not. *B. valliceps*, by contrast, displays broad frontoparietals, a depressed neurocranium, and frontoparietal-prootic fusion. Considerable intraspecific variation in dermal cranial elements suggests that dermal bone reduction, a major trend in the evolution of anurans, may be continuing in *Bufo*. Striking morphological divergence, even within the genetically cohesive *americanus* group, indicated considerable osteological plasticity. These factors suggest caution in the use of morphology as an unaided systematic tool in this genus. (Author's abstract)

Mays, S. R., and P. S. Freed. 1985. *Bufo houstonensis* (Houston toad) coloration. Herpetological Review 16(4): 108–109.

Two Houston toads reared at the Attwater's Prarie Chicken National Wildlife Reserve metamorphosized into a light beige color and then became gray-white adults. Both of the toads' eyes lightened as well. Despite their differences, however, the toads seemed to live normal lives.

McAlister, W. H. 1959. The mechanism of sound production and the biological significance of the mating call in North American *Bufo*. Thesis, University of Texas, Austin, Texas, USA.

McLeod, R. F., and J. E. Gates. 1998. Response of herpetofaunal communities to forest cutting and burning at Chesapeake Farms, Maryland. American Midland Naturalist 139(1): 164–177.

The distribution and abundance of amphibians and reptiles in forest stands subjected to salvage cutting and prescribed burning were compared with their unmanaged counterparts. The study was conducted on the Atlantic coastal plain at Chesapeake Farms near Chestertown, Maryland, Three herpetofaunal trapping arrays were systematically located in each of four forest stand types: hardwood (Hardwood), cut-over hardwood (Cut), mixed pine-hardwood (Pine) and prescribed hum pine (Burn). A total of 3931 individuals representing 29 species were captured in 30,540 trap nights during the spring and summer 1992 and 1993. Felling of hardwoods and prescribed burning of pine resulted in similar responses from the herpetofaunal communitites; Hardwood had the most distinctive herpetofaunal community of the four stands. Adults and young-of-the-year (YOY) of six amphibian species significantly more abundant in Hardwood than Cut. Only one amphibian species, *Pseudacris triseriata*, was less abundant in Hardwood than Cut. Total ranid captures did not differ between Hardwood and Cut. Snake and total reptile captures, and *Elaphe obsoleta* and *Eumeces faciatus* abundances were significantly less in Hardwood than Cut. Hardwood also had fewer small mammals than Cut, particularly *Microtus pennsylvanicus* and *Zapus hudsonius* that might serve as pry for large snakes. Adults of four amphibian species, YOY of five amphibian species, and three reptiles (*Carphophis amoenus*, *Storeria dekayi* and

Thamnophis sirtalis) were significantly more abundant in Pine than Burn; two reptile species (*Coluber constrictor* and *Lampropeltis getula*) were significantly less abundant. Potential small mammal prey of the latter two snakes were nut significantly different between Pine and Burn; however, *Zapus hudsonius* was less abundant in Pine than in Burn. More amphibians were captured in Hardwood and Pine stands than in their respective logged and burned counterparts. Tile trend for reptiles tended to depend on the mix of species present and their habitat preferences. Greater canopy core and depth of leaf litter in Hardwood and Pine stands likely had a moderating effect on temperature and helped to maintain a moist microenvironment for mesophilic species. Disturbance of a small patch of forest could locally decrease herpetofaunal diversity but diversity on a much larger scale would likely increase. (Authors' abstract)

Minton, S. A., Jr. 1968. The fate of amphibians and reptiles in a suburban area. Journal of Herpetology 2(3–4): 113–116.

Between 1949 and 1958, two species of salamanders, six species of anurans, six species of turtles and seven species of snakes were recorded from a suburban area on the edge of Indianapolis, Indiana. Most were terrestrial or semiaquatic species of broad ecological tolerance. At least 11 species bred within the area during this period. During 1963 and 1964 only two species of anurans, one species of turtle and four species of snakes were recorded, and there was no evidence of amphibian breeding. Modification of aquatic habitat appears to have been the most important factor in reducing the number of species inhabiting the area. (Author's abstract).

Morin, P. J., and E. A. Johnson. 1988. Experimental studies of asymmetric competition among anurans. Oikos 53: 398–407.

Experimental manipulations of the densities of two larval anurans, *Hyla crucifer* and *Rana sylvatica*, show that they compete asymmetrically in artificial ponds. The competitive superiority of *R. sylvatica* was correlated with its larger body size, faster growth, greater per capita competitive impact on cospecifics, and greater reduction in the availability of a trophic resource, periphyton. Laboratory experiments where *Hyla* tadpoles were grown in water conditioned by different densities and species of tadpoles provided no evidence that the observed asymmetric interspecific competition involves interference via growth inhibitors. Instead, the asymmetric interspecific competition is consistent with different impacts of species on resource availability, and these differences are predictable from patterns of intraspecific competition. Previous studies of competition among larval anurans indicate a preponderance of asymmetric competitive outcomes, which are either associated with the allopatric distributions of competitors, or with conditions that reduce the impact of competition. (Authors' abstract)

Paquin, P., and D. Coderre. 1997. Deforestation and fire impact on edaphic insect larvae and other macroarthropods. Environmental Entomology 26(1): 21–30.

Three sites representative of forest successions in the Lake Duparquet region (situated in the southern part of the boreal forest, Abitibi, PQ, Canada) were chosen for this experiment: (1) a 47-yr-old deciduous forest, (2) a 144-yr-old mixed forest, and (3) a 231-yr-old coniferous forest. Each site included a plot that was deforested 1 yr before experimentation. The sampling that was carried out permitted an analysis of the effects of deforestation on the communities of the 3 sites. Abundance decreases on average by 55% and richness by 52%. Predators are less affected than decomposers by edaphic variations resulting from deforestation. Forest fires were simulated to determine the immediate impact on edaphic macroarthropod communities. The fires caused, on average, a 95.5% reduction in abundance of organisms. Survivors, however, were found; thus confirming the small-scale mosaic effect of the fire. In the short and long term, disturbance regimes shape edaphic communities and the structure of communities peculiar to each forest successional stage. (Authors' abstract)

Pechmann, J. H. K. 1995. Use of large field enclosures to study the terrestrial ecology of pond-breeding amphibians. Herpetologica 51(4): 434–450.

The terrestrial stage of pond-breeding amphibians has been the subject of few ecological field experiments, partly because terrestrial individuals of many species are difficult to capture, observe, and manipulate. I tested a new strategy for sampling terrestrial, fossorial, pond-breeding amphibians within large field enclosures. *Ambystoma opacum* and *A. talpoideum* were placed in 225 m (2) enclosures shortly after metamorphosis. Pitfall traps were placed along the enclosure walls to recapture individuals when they reached maturity and attempted to migrate to a breeding pond. Data were obtained on survival to, age at, and size at first reproduction comparable to data obtained from natural populations using terrestrial drift fences with pitfall traps located at breeding ponds. Doubling density in the enclosures by adding an equal number of either the same or the other species had no statistically significant effect on survival to first reproduction of *A. opacum.* (Author's abstract)

Pechmann, J. H. K., and H. M. Wilbur. 1994. Putting declining amphibian populations in perspective — natural fluctuations and human impacts. Herpetologica 50(1): 65–84.

Human impacts obviously have reduced or eliminated many populations of amphibians and other organisms. Recent reports, however, have suggested that declines and disappearances of amphibian populations over the last two decades represent a distinct phenomenon that goes beyond this general biodiversity crisis. We review the literature on natural temporal and spatial variation in population sizes and examine techniques for analyzing trends in abundance. Whether the recent declines and extinctions of isolated, protected amphibian populations exceed expected natural fluctuations remains equivocal. The suggestion that amphibians are particularly sensitive bioindicators of anthropogenic stresses has not received adequate study, and to our knowledge, no evidence has been presented to substantiate it. Although concern about the status of amphibian populations is clearly warranted, formulation of appropriate null hypotheses and further study are needed. (Authors' abstract)

Peterson, A. G., C. M. Bull, and L. M. Wheeler. 1992. Habitat choice and predator avoidance in tadpoles. Journal of Herpetology 26(2): 142–146.

Larvae of *Ranidella signifera* and *Litoria ewingi* are common members of tadpole communities of temporary ponds in southeastern Australia, where odonate larvae are the major predators. In field surveys, *R. signifera* was found more often on the pond substrate than was *L. ewingi*. This difference in habitat choice was documented further in laboratory aquaria, including a simulated pond edge. For both species, substrate use increased in the dark phase of a 12:12 photoperiod. In the laboratory, *L. ewingi* suffered heavier predation from the corduliid odonate *Hemicordulia tau*, a benthic predator, than did *R. signifera*. Predation on *L. ewingi*, but not on *R. signifera*, declined as water depth increased, implying that *L. ewingi* use the water column to escape benthic predators. Overall predation rate was greater in the dark phase when the predators were more active, and when tadpoles used the substrate more. (Authors' abstract)

Petranka, J. W., M. P. Brannon, M. E. Hopey, and C. K. Smith. 1994. Effects of timber harvesting on low elevation populations of southern Appalachian salamanders. Forest Ecology and Management 67(1-3): 135–147.

We examined the effects of timber harvesting on southern Appalachian salamander communities in a managed watershed in Pisgah National Forest, western North Carolina, USA. Salamander abundance and species richness were lowest in very young stands and highest in stands more than 120 years old. Comparisons of recent clearcuts less than 5 years old with mature stands more than 80 years old suggest that terrestrial salamanders are completely eliminated or reduced to very low numbers when mature forests are clear cut. Comparisons of stand age categories further suggest that salamander abundance in local communities slowly increases for a century or more after stands are intensively harvested. We roughly estimate that logging during the last century by both the private and public sector has resulted in a 70% decline in salamander numbers within the study area as a whole. Implementation of an ecosystem-management strategy which reverses the current trend of having landscapes dominated by early and mid-successional forests would help restore depleted populations to levels where salamanders better fulfill their ecological roles as forest- floor insectivores. Other management techniques that would benefit salamanders include leaving buffers along headwater streams, and using harvesting techniques which assure that the basic structure and function of forests remain intact following timbering operations. (Authors' abstract)

Quinn, H. 1980. Captive propagation of endangered Houston toads. Herpetological Review 11(4): 109.

Small section on the Houston Zoo's captive propagation and release program for the Houston toad. Toads that were raised outdoors grew faster and had a significantly lower death rate than those toads raised indoors. Controlled experiments are being conducted to determine why the toads survive better outside than those housed inside. (Abstract compiled mainly of author's direct quotes)

Quinn, H., G. Ferguson, and A. N. Barrass. 1984. Release program for captive-raised and wild-caught Houston toads, *Bufo houstonesis*. Houston Zoological Gardens, Houston, Texas, USA.

This constitutes the report for accomplishments of fieldwork from January through July 1984 under sponsorship by the Zoological Society of Houston. Objectives were:
1. Release Houston toads representing several life stages from Bastrop, Texas to the Attwater's Prarie Chicken National Wildlife Refuge (APCNWR).
2. Monitor the released Houston toads.
3. Standardize procedures of environmental monitoring.

Results:
1. Three categories of toads were released: a) wild-collected eggs, b) captive-raised adult toads, and c) captive-raised newly metamorphosized juvenile toads.
2. Most eggs developed normally and hatched a few days after the release. Tadpoles were uncommonly seen, but those that were alive seemed to be developing normally. None of the released adults or newly metamorphosized juveniles were seen again during the study period.
3. Air temperature, water temperature, rainfall, relative humidity, water depth, water quality, and predators and competitors were recorded. (Abstract compiled mainly from author's direct quotes)

Quinn, H., G. Ferguson, and S. Mays. 1987. Captive propagation/release and relocation program for the endangered Houston toad, *Bufo houstonesis.* Houston Zoological Gardens, Houston, Texas, USA.

Little monitoring for released Houston toads to APCNWR was done due to funding restraints. Therefore, conclusions regarding the survival of this year's released toads cannot be drawn. However, during the trips made, the tadpoles were abundant but no adults were seen or heard.
Surveys will be made to the release site over the next ten years to see if the population will survive. (Abstract compiled mainly from author's direct quotes)

Reed, C. C. 1997. Responses of prairie insects and other arthropods to prescription burns. Natural Areas Journal 17(4): 380–385.

The results of many field studies provide ample evidence that burning has a major influence on the presence and persistence of arthropod species on prairie sites. The variation in fire tolerance of species and the changes in the physical environment and plant communities following burns result in the development of distinctly different arthropod communities on frequently burned sites compared to sites protected from burning. Changing successional stages following burns also support distinctive arthropod species and groups. In general, a landscape containing sites at different successional stages, and sites varying in burn frequency, will support the most species; if a single site is burned at intervals, a cycle of arthropod species richness, species composition, and numbers of individuals will occur. It is possible to predict the responses of a prairie arthropod community or of a single species to a controlled burn or a series of burns if the fire history of the site, and the burn tolerance, colonizing ability, and basic biology of the species present, are known. (Author's abstract)

Reh, W., and A. Seitz. 1990. The influence of land-use on the genetic-structure of populations of the common frog *Rana temporaria.* Biological Conservation 54(3): 239–249.

In order to find out the influence of land use and topographic distance on the genetic structure of populations of the common frog *Rana temporaria L.* in the Saar-Palatinate lowlands (Federal Republic of Germany), tissue of larvae was examined by means of horizontal starch gel electrophoresis. A total of 24 loci coding for 14 different enzymes were studied. Genotype frequencies, allele frequencies and mean heterozygosity were calculated, and genetic distances using Nei's formula. Strong deviations from the Hardy-Weinberg equilibrium were found; the degree of homozygosity was higher than expected.
Separation by highways reduced average heterozygosity as well as genetic polymorphism of local populations.
One area surrounded by roads had high genetic distances to other sampling stations. A multiple regression analysis showed that motorways and railways have a significant ($p=0.03$) barrier effect on frog populations within 34 km. Meadowland apparently enabled individual exchange in a range between 2 and 7 km. Consequences for the design of biotope systems are discussed. (Authors' abstract)

Rudolph, D. C., and J. G. Dickson. 1990. Streamside zone width and amphibian and reptile abundance. Southwestern Naturalist 35(4): 472–476.

Forest conservation alters vertebrate communities, particularly amphibians and reptiles. Terrestrial animals were more abundant in the narrower streamside zones with well-developed herbaceous vegetation compared to wider zones with sparse herbaceous vegetation. There were fewer amphibians and reptiles in narrow (0-25 m) streamside zones than in wider zones (30-95 m). The wider zones were characterized by an intact overstory and midstory, sparse shrub and herbaceous vegetation, and abundant leaf litter. In contrast, the narrow treatments lacked these characteristics and had dense shrub and herbaceous vegetation, similar to that of adjacent pine plantations. In this study it appears that the higher abundance of amphibians and reptiles in streamside zones was associated with a closed canopy and leaf litter ground cover. Recommends retaining streamside zones of mature trees at least 30 m wide and preferably wider when forest stands are harvested. (Summary written by Lisa O'Donnell; compiled mainly from authors' direct quotes)

Russell, K. R., D. H. Van Lear, and D. C. Guynn. 1999. Prescribed fire effects on herpetofauna: review and management implications. Wildlife Society Bulletin 27(2): 374–384.

Sanders, O. 1953. A new species of toad, with a discussion of morphology of the *Bufonid* skull. Herpetologica 9: 25–47.

There occurs in the vicinity of Houston, Harris County, Texas, and adjoining counties, as species of toad which differs from other toads of Texas. In certain features, it resembles *Bufo terrestris* (Bonnaterre) and, in others, it is more like *Bufo americanus* (Holbrook). It has accordingly been thought of as being one or the other of these species, the former by Harwood and the latter by Wright and Wright. More recently, though not supported by publication, it has been regarded as *Bufo terrestris americanus* (Holbrook) by various herpetologists who consider *Bufo americanus* and *Bufo terrestris* as a subspecies of each other. It is the purpose of this paper to describe the Houston, Texas, form as a distinct new species. (Abstract comiled from author's direct quotes)

Sanders, O., and J. C. Cross. 1964. Relationships between certain North American toads as shown by cytological study. Herpetologica 19(4): 248–255.

This cytological study suggests greater diversity between the interorbitally bossed and non-bossed forms of *Bufo woodhousei* than currently accepted. Broad chromosomal differences exist between the subspecies of *Bufo boreas* studied. There is an affinity between *Bufo americanus* and *Bufo b. halophilus. Bufo houstonensis*, *Bufo woodhousei velatus* and *Bufo valliceps* are separate entities but more closely related to each other than they are to the other species studied. The concept of subspecific relationship between *Bufo houstonensis* and *Bufo americanus* or between *Bufo w. velatus* and *Bufo fowleri* is not acceptable. The diploid chromosome number of males of *Bufo houstonensis* is 21 chromosomes and constitutes a new number for the genus. (Abstract compiled from author's direct quotes)

Saunders, D. A., R. J. Hobbs, and C. R. Margules. 1991. Biological consequences of ecosystem fragmentation — a review. Conservation Biology 5(1): 18–32.

Research on fragmented ecosystems has focused mostly on the biogeographic consequences of the creation of habitat islands of different sizes, and has provided little of practical value to managers. However, ecosystem fragmentation causes large changes in the physical environment as well as biogeographic changes. Fragmentation generally results in a landscape that consists of remnant areas of native vegetation surrounded by a matrix of agricultural or other developed land. As a result, fluxes of radiation, momentum (i.e., wind), water, and nutrients across the landscape are altered significantly. These in turn can have important influences on the biota within remnant areas, especially at or near the edge between the remnant and the surrounding matrix. The isolation of remnant areas by clearing also has important consequences for the biota. These consequences vary with the time since isolation, distance from other remnants, and degree of connectivity with other remnants. The influences of physical and biogeographic changes are modified by the size, shape, and position in the landscape of individual remnants, with larger remnants being less adversely affected by the fragmentation process. The dynamics of remnant areas are predominantly driven by factors arising in the surrounding landscape. Management of, and research on, fragmented ecosystems should be directed at understanding and controlling these external influences as much as at the biota of the remnants themselves. There is a strong need to develop an integrated approach to landscape management that places conservation reserves in the context of the overall landscape. (Authors' abstract)

Schmidt, B. R., and B. R. Anholt. 1999. Analysis of survival probabilities of female common toads, *Bufo bufo*. Amphibia-Reptilia 20:97–108.

Scifres, C. J. 1982. Woody plant control in the post oak savannah of Texas with hexazinone. Journal of Range Management 35(3): 401–404.

Hexazinone, applied as spheres or pellets (1.27 cm in diameter) in grid patterns (1.5 or 3 m spacings) at 2 or 4 kg/ha effectively controlled post oak and blackjack in east central Texas. The herbicide also appeared promising for the control of water oak, American elm, and downy hawthorne. Willow baccharis and winged elm appeared to be moderately susceptible to 2 kg/ha of the herbicide and were controlled by 4 kh/ha. Yaupon canopies were initially reduced by the herbicide but had begun to recover by the second or third growing season after application and replaced the oaks as the primary limitation to range improvement following treatment, regardless of hexazinone rate applied. Saw greenbriar, mustang grape, southern dewberry, American beautyberry,

and wollybucket bumelia were not controlled with hexazinone. (Author's abstract)

Semlitsch, R. D. 1998. Biological delineation of terrestrial buffer zones for pond- breeding salamanders. Conservation Biology 12(5): 1113–1119.

Many semi-aquatic organisms, such as salamanders, depend on both aquatic and terrestrial habitats to complete their life cycle and maintain viable populations. But current U.S. federal and state regulations protect only the wetland itself or arbitrarily defined portions of terrestrial habitat, if any. Part of the reason terrestrial habitats adjacent to wetlands are not protected is the lack of a clear understanding of the distances from shorelines that are biologically relevant to wetland fauna. Such information is critical for delineation of terrestrial buffer zones for wetlands, and thus for the conservation of semi-aquatic organisms. I summarized data from the literature on terrestrial habitat use by one group of pond- breeding salamanders, especially distances individuals traveled away from ponds. The results provide a basis for setting terrestrial buffer zones determined from actual habitat use by adult and juvenile salamanders. The mean distance salamanders were found from the edge of aquatic habitats was 125.3 m for adults of six species and 69.6 m for juveniles of two of these species. Assuming that the mean distance encompasses 50% of the population, a buffer zone encompassing 95% of the population would extend 164.3 m (534 ft) from a wetland's edge into the terrestrial habitat. Data from other amphibians suggest that this buffer zone is applicable to a range of species, but caution should be taken for taxa suspected to be more fragile. Wetland managers and policymakers must recognize the special needs of semi-aquatic organisms during their entire life cycle, not just during the breeding season. To maintain viable populations and communities of salamanders, attention must be directed to the terrestrial in and peripheral to all wetlands. Data on habitat use from salamanders and other semi-aquatic species make it increasingly apparent that maintaining the connection between wetlands and terrestrial habitats will be necessary to preserve the remaining biodiversity of our vanishing wetlands. (Author's abstract)

Siemann, E., J. Haarstad, and D. Tilman. 1997. Short-term and long-term effects of burning on oak savanna arthropods. American Midland Naturalist 137(2): 349–361.

We investigated the effects of prescribed burning on the composition, abundance, species richness and diversity of oak savanna arthropod communities in a replicated, large-scale, 30- y experiment We employed four sampling methods over 3 y and caught 11,215 arthropods of 551 species. Species had varied and often negatively correlated short vs. long-term responses to burning. In the years savannas were burned, species richness and abundance of arthropods, especially Homoptera and Lepidoptera, were reduced and species compositions were sometimes more similar. However, despite its major effect on vegetation, frequency of burning did not affect arthropod abundance and species richness, but sometimes caused savannas to be similar in species or taxonomic order composition. The Shannon diversity index was unaffected by burning. On the whole, prescribed burns necessary to maintain grasslands and savannas do not appear to be harmful to, or to greatly impact, the arthropod fauna. (Authors' abstract)

Sinsch, U. 1987. Orientation behavior of toads (*Bufo Bufo*) displaced from the breeding site. Journal of Comparative Physiology 161: 715–727.

Toads were displaced from their breeding pond and radiotracked to record migration of individuals. In both years of the study, toads headed to the breeding site with the same precision at all release sites. The study results indicate that initial orientation is based mainly on olfactory and magnetic cues, with visual control of straightness. All release sites were in pine forest with similar ground structure. Toads returned to the breeding pond even after it had been filled with earth. (Summary written by Lisa O'Donnell; compiled from mainly author's direct quotes)

Soule, M. E., A. C. Alberts, and D. T. Bolger. 1992. The effects of habitat fragmentation on chaparral plants and vertebrates. Oikos 63(1): 39–47.

The effects of fragmentation in a scrub habitat in California on three taxa (plants, birds, and rodents) are concordant. Extinctions within the habitat remnants occur quickly and the sequence of species disappearances of birds and rodents is predictable based on population density in undisturbed habitat. Distance effects on species diversity are weak to non-existent, and habitat area effects are strong. Edge effects and cumulative habitat loss following isolation of the remnants are correlated with loss of species diversity. Recolonization in these taxa occurs rarely. Rodents appear to be extremely susceptible to extinction. Small, old patches retain a predictable subset of bird and rodent species, reinforcing the principle that larger reserves are generally superior. (Authors' abstract)

Spradling, S. L., J. K. Olson, R. N. Coulson, and C. N. Lovelady. 1998. A geographic information system approach to evaluating the effects of the endangered species protection program on mosquito control. Journal of the American Mosquito Control Association 14(2): 137–147.

The purpose of this study was to assess what impacts on organized mosquito control the implementation of an Endangered Species Protection Program for the Houston toad might have in Chambers and Harris counties, Texas. The study was also intended to demonstrate the value of using geographic information system (GIS) techniques and methodologies in making such assessments to those in mosquito control who are unfamiliar with GIS and its applications. Using the GIS, Geographical Analysis Support System (GRASS), databases were developed on the habitats and patterns of mosquito control insecticide usage occurring in Chambers and Harris counties. These databases were then employed by means of various utilities associated with GRASS and computer-supported, rule- based reasoning processes to create maps depicting the amount and locations of toad habitat and the areas treated annually with insecticides by districts in Chambers and Harris counties. This map information was then used via other GRASS utilities to identify and depict zones of overlap or coincidence between toad habitat and areas treated with insecticides for mosquito control in the 2 counties. As compared to existing maps for toad habitat, our resulting GIS-generated maps gave more precise, easy-to-use information that could be used to make decisions as to how to protect the toad in the zones of coincidence in each county without causing undue disruption to mosquito control activities in these zones. (Authors' abstract)

Taylor, S. K., E. S. Williams, E. T. Thorne, K. W. Mills, D. I. Withers, and A. C. Pier. 1999. Causes of Mortality of the Wyoming toad. Journal of Wildlife Diseases 35(1):49–57.

Wyoming toads (*Bufo baxteri*) that died from January 1989 to June 1996 were submitted to the Wyoming State Veterinary Laboratory (Laramie, Wyoming, USA) for postmortem evaluation. These consisted of 108 free-ranging toads and 170 animals from six captive populations. Ninety-seven (90%) of 108 free-ranging toad carcasses were submitted during September and October. From 1989 to 1992, 27 (77%) of 35 mortalities in the captive populations occurred in October, November, and December. From 1993 to 1996, mortality in captive toads occurred without a seasonal pattern and coincided with changes in hibernation protocols that no longer mimicked natural cycles. Cause of mortality was determined in 147 (53%) of the 278 cases. Mycotic dermatitis with secondary bacterial septicemia was the most frequent diagnosis in 104 (71%) of 147 toads. *Basidiobolus ranarum* was found by microscopic examination of skin sections in 100 (96%) of 104 of these mortalities. This fungus was isolated from 30 (56%) of 54 free-ranging and 24 (48%) of 50 captive toads. This research documents the causes of mortality for both free-ranging and captive endangered Wyoming toads over a 7 yr period. (Authors' abstract)

Tejedo, M. 1993. Size-dependent vulnerability and behavioral responses to tadpoles of two anuran species to beetle larvae predators. Herpetologica 49(3): 287–294.

I studied size-dependent vulnerability and behavioral responses of tadpoles to predaceous diving beetle larvae (*Dytiscus pisanus*) in two anuran species (*Bufo calamita and Pelobates cultripes*) that breed in temporary ponds. Experiments revealed that large tadpoles of *B. calamita* were preferentially selected by the beetle larvae. Moreover, the average number of strikes to grasp a small tadpole was higher than for large tadpoles. However, in *P. cultripes*, large tadpoles were less likely to be captured than were small tadpoles. Both species differed in growth history; *B. calamita* has a short growth period and a small tadpole that is unable to avoid predation, whereas *P. cultripes* grows to a large size that reduces predation rate. Tadpoles *of B. calamita* show a reduction in mobility in the presence of the predator, whereas tadpoles of *P. cultripes* do not show it. Phylogenetic constraints restricting size at metamorphosis for *B. calamita* may lead to the adoption of alternative antipredatory strategies, such as a reduction in activity or habitat segregation. (Author's abstract)

Thomas, R. A., S. A. Nadler, and W. L. Jagers. 1984. Helminth-parasites of the endangered houston toad, *Bufo houstonensis* Sanders, 1953 (amphibia, Bufonidae). Journal of Parasitology 70(6): 1012–1013.

Thomas, L. A., and J. Allen. 1997. *Bufo houstonensis* (Houston toad) behavior. Herpetological Review 28(1): 40–41.

Juvenile *Bufo houstonensis* were studied at two sites in Bastrop State Park, Bastrop Co., Texas, USA from 7 June-15 July 1993.

SIte 1 was a large, partly sunny ravine contiguous with a man-made 4ha lake located at the northeast end of the park. Site 2

was an old dump area with five small, temporary rain-filled pools scattered throughout the area. The juvenile *B. houstonensis* observed at Site 2 were dispersed more than those at Site 1. Toads were not found at night at either site. Imported red fire ants (*Solenopsis invicta*) appeared to be absent from Site 1 and present at Site 2. The absence of *S. Invicta* within the ravines may play an important part in the survival of the young toads. If this is the case, toads metamorphosizing within the ravine have a better chance of survival than toads emerging from drier, upland areas. More research is needed to indicate whether ravines within *B. houstonesis* habitats are indeed critical to their survival.
Two types of feeding behavior were observed: sit-and-wait and active search. Sit-and-wait behavior involved digging into the sand and waiting for prey. The toads would lunge out with their hind legs, scoop up the food item with their tongue, and ingest it. Active search behavior consisted of hopping or crawling within a small area foraging for prey.
Juvenile *B. houstonensis* were found to be entirely diurnal. (Abstract composed mainly from authors' direct quotes)

Thornton, O. W., and R. A. Thomas. 1976. The status of the Houston toad, *Bufo houstonensis.* Herpetological Review 7(2): 98–99.

The Houston toad, *Bufo houstonensis*, is probably on the verge of extinction. A concerted effort in the spring of 1975 to locate and define extinct populations revealed only two existing populations in Bastrop and Burleson Counties, Texas. The toad has not been observed at any of the other previously known localities since 1967. Endangered status is probably due to habitat manipulation and hybridization. During the spring, 1976, a study was conducted to correlate environmental parameters with the toad's breeding activity. Data reveal that a number of factors appear to be involved in stimulating activity. (This is the entire work from Herpetological Review. It is an abstract of a study done at Texas A&M University)

Tihen, J. A. 1962. Osteological observations on new world *Bufo*. American Midland Naturalist 67(1): 157–183.

Skeletons of 51 recognized New World forms of *Bufo* have been examined. Five major species groups are recognized on the basis of skeletal characteristics. The monotypic *hematiticus* group possesses a skull of usual Bufonid proportions, moderately extensive dermal ornamentation, an occipital canal, and independent frontoparietals and prootics. The *valliceps* group includes the majority of other forms outside the United States; it differs from the *hematiticus* group primarily in the fusion of the frontoparietals with the prootics: three distinct subgroups are recognized. The Andean *spinulosus* group agrees with the *valliceps* group in the fusion of the frontoparietals with the prootics, but the extent of dermal ornamentation and of some dermal bones are markedly reduced, with correlated exposure of the occipital groove. The *americanus* group is limited to the United States and adjacent Mexico and Canada. The skull is distinctly elevated, dermal ornamentation somewhat reduced, the occipital canal partailly or completely exposed, and the frontoparietal and prootics are independent. The *boreas* group, limited to western North America, differs from the *americanus* group in having typical skull proportions and virtually no dermal ornamentation. The *spinulosus* group was probably derived from the *valliceps* group; with this exception, it is unlikely that any one of the major groups gave rise to any other. All could have developed from a common ancestral stock with essential characteristics similar to those of *regularis* and related African forms. The *boreas* group may not have arisen directly from such a stock, but be related to *B. Bufo*, which in turn was derived from a *regularis*-like ancestor. If so, the entry of the *boreas* group into this hemisphere was probably independent from, and much later than, the entry of the ancestral stock of the other groups. (Author's abstract)

Turner, F. B. The demography of frogs and toads. The Quarterly Review of Biology 37: 303–314.

Quantitative studies of natality, mortality, and age-distributions of anuran populations are reviewed. Specific problems involve estimates of (1) the age of individuals, (2) age-specific fertility, (3) natality of populations, (4) larval survival, and (5) age-specific post-metamorphic survival. Some possible differences in the comparative demography of north temperate and neotropical anurans are suggested. (Author's abstract)

U. S. Fish and Wildlife Service. 1991. Wyoming toad recovery plan. Denver, Colorado, USA.

The Wyoming toad (*Bufo hemiophrys baxteri*) was common into the early 1970's, but the populations crashed in the middle 1970's. The Wyoming toad was listed as endangered in January 1984. The only known population of this species is located southwest of Laramie, Wyoming. Surveys in 1987 and 1988 indicated that this population was healthy, reproducing, and maintaining itself. However, recent reproduction has been low and red leg bacteria was discovered in 1990 which caused a reduction in the adult population. This recovery plan outlines life history, habitat requirements, recovery objectives and criteria, and actions needed for the

Wyoming toad. (Abstract compiled from author's direct quotes)

Valigura, R. A., and M. G. Messina. 1994. Modification of Texas clear-cut environments with loblolly-pine shelterwoods. Journal of Environmental Management 40(3): 283–295.

The near-surface (within 0.30 m of the surface) environments of a clear-cut and a loblolly pine (*Pinus taeda L.*) shelterwood in east Texas were instrumented to determine treatment effects on the radiation, thermal, humidity and wind components of microclimate. The shelterwood produced lower net radiation and photosynthetically-active radiation loads, lower daytime air temperatures, the same or slightly lower daytime vapor pressures and lower wind speeds than the clear cut. Although sunfleck incidence in the shelterwood allowed net radiation and photosynthetically-active radiation (PAR) to increase briefly to levels similar to those measured in the clear cut, seedlings within the shelterwood were subjected to sunflecks for only a short period of time before the sunfleck dissipated and shade returned. Air temperature differences between treatments were not great and soil temperature differences were negligible. The influence of the shelterwood on all environmental factors was primarily due to the partial overstory canopy, which dissipated incident radiation before it reached the near-surface environment where it could significantly alter the microclimate. (Authors' abstract)

Van Auken, W. O., A. L. Ford, and A. Stein. 1979. A comparison of some woody upland and riparian plant communities of the southern Edward's Plateau. Southwestern Naturalist 21(1): 165–180.

Van Auken examined the woody component of only the woodland/grassland mosaic community. His densities for plants less than 3 cm show habitat areas for replacement and Minimun Viable Populations would likely be in the range of 25 acres to get the major dominants and subdominants only and up to 60 acres to capture the majority of woody species present in the community type. (Summary written by Lisa O'Donnell; compiled mainly from authors' direct quotes)

Van Gelder, J. J. 1973. A quantitative approach to the mortality resulting from traffic in a population of *Bufo Bufo l.* Oecologia 13: 93–95.

During the breeding migration of *Bufo Bufo* in 1971 the number of males killed by traffic on an asphalt road was counted with about 10 cars/hour. By counting egg-strings the total number of females was estimated too. By comparing the data it appeared that 30% of the females passing the road were run over. For males a similar percentage is expected. (Author's abstract)

Vos, C. C., and J. P. Chardon. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog *rana arvalis.* Journal of Applied Ecology 35(1): 44–56.

1. The effects of habitat fragmentation on the distribution pattern of the moor frog, *Rana arvalis*, were investigated. Also, the possible isolation effects of the road network were taken into account. 2. Indications were found that habitat fragmentation partly explains the distribution pattern of the moor frog. The statistical models showed a positive effect of pond size (or marsh area) and a negative effect of road density on the probability of occupation of a moorland pond. 3. Because of the strong correlation between habitat quality variables and isolation variables, no unambiguous effects of isolation, described as the amount of suitable terrestrial habitat (moorland) in the surroundings of a moorland pond in a radius of 100-2000 m, could be demonstrated. 4. Spatial differences in road density can play a role in the selection of optimal locations for nature protection areas. The regression model used in this study predicts a reduced occupation probability in 55% of the study area. In the part of the study area adjacent to a motorway, occupation probability is lowered to less than 30%. 5. European studies of habitat fragmentation on amphibian species revealed a mean distance between occupied ponds of <1 km in all studies. This could be a general rule of thumb for persistent amphibian populations. Effects of pond size on the probability of occupation were more variable. 6. When discussing the effects of habitat fragmentation on amphibians and other ground dwelling species, the negative effects of roads are often underestimated. (Authors' summary)

Watt, P. J., S. F. Nottingham, and S. Young. 1997. Toad tadpole aggregation behaviour: evidence for a predator avoidance function. Animal Behaviour 54: 865–872.

Two sets of experiments were conducted to determine whether aggregation behavior, commonly observed in tadpoles of the

common toad, *Bufo bufo*, had a predator avoidance function. In the first set of experiments, the distribution of toad tadpoles, of single or mixed sibship, was monitored in large artificial pools, one with fish chemical cues and one without. Aggregation behavior was determined on the basis of the distribution of the tadpoles under these treatments by using two indices of cohesion: variance/mean ratio and a newly developed swarming index. The two indices were highly correlated. Tadpole groups were more cohesive (1) in the presence of fish chemical cues and (2) with other individuals from a single sibship. In the second set of experiments, tadpoles in different densities and distributions were presented to fish predators in a floating arena which allowed strike rate to be monitored but prevented the fish from capturing any tadpoles. Total strike rate per group increased with increasing group size, but strike rate per individual decreased, implying individuals gain from being in a larger group through dilution, but the group as a whole loses. These results are discussed in terms of selfish herd or cooperative group theories on the behavior of aggregations. (Authors' abstract)

Weist, J. A., Jr. 1977. Anuran succession at temporary ponds in a post oak-savanna region of Texas. Thesis, Texas A&M University, College Station, Texas, USA.

Study of anuran reproduction in temporary ponds in a Texas post oak savanna region. Discusses calling, breeding, and larval periods of nine species, but not the Houston toad.

Welsh, H. H. 1990. Relictual amphibians and old-growth forests. Conservation Biology 4(3): 309–319.

Looked at three species (2 salamanders and a frog) that depend on old growth forest. Timber harvesting is not necessarily compatible with survival of wildlife species; with careful consideration of the basic requirements of sensitive species such as those discussed here, it should be possible to design and execute timber harvest plans that would not adversely affect these amphibians and their microhabitats. Buffer strips and the elimination of harvesting adjacent to all aquatic habitats would remove a small portion of the total harvestable area in a given watershed and provide the necessary protection for these species. (Summary written by Lisa O'Donnell; compiled mainly from author's direct quotes)

Werner, E. E. 1991. Nonlethal effects of a predator on competitive interactions between two anuran larvae. Ecology 72(5):1709–1720.

I examine the nonlethal effects of a predator, an odonate larva (*Anax junius*), on competitive interactions between two species of anuran larvae (bullfrog, *Rana catesbeiana*, and green frog, *R. clamitans*). The anurans coexist in permanent ponds, which sometimes contain high densities of *A. junius*. Laboratory experiments indicated that in the absence of the predator, the two species were similar in competitive abilities and grew at virtually identical rates. In the presence of caged *A. junius*, however, the bullfrog grew to be larger and the green frog much smaller than when the predator was absent. Both species reacted to the presence of *A. junius* by reducing activity and altering space use. I argue that the reductions in activity in the presence of the predator affected the two species differently, which in turn changed competitive interactions. I discuss the relation between activity level and competitive ability, and the potential for predators to alter competitive relations by affecting activity levels of syntopic species (a higher order interaction). Vulnerability to predators also increases with activity, and I discuss the implications of an activity-mediated trade-off between growth rate and predation risk to interactions among anuran larvae. Finally, I present a method for quantitatively evaluating the net balance of (negative) direct mortality effects and (sometimes positive) indirect effects that alter competitive ability. (Author's abstract)

Wigley, T. B., and T. H. Roberts. 1997. Landscape-level effects of forest management on faunal diversity in bottomland hardwoods. Forest Ecology and Management 90(2-3): 141–154.

Forest management activities potentially influence ecosystems at many spatial scales. For most forest systems, influences at the stand level have been most intensively studied and are best understood. Management impacts at the larger, landscape scale are poorly understood and many hypotheses regarding landscape- level effects remain untested. This lack of knowledge is particularly acute in bottomland hardwood forest (BLH) ecosystems. Most hypotheses regarding landscape-level impacts were derived from theories about island biogeography and metapopulations. Thus, species presence and productivity sometimes are viewed as functions of patch characteristics such as size, shape, amount of edge, degree of isolation from larger, similar habitats, time since isolation, and dispersal, immigration, and extinction rates. Recommendations for mitigating fragmentation effects often include maintenance of reserves, increasing patch size, reducing edges, and enhancing connectivity through the use of corridors. While many of these theories are intuitively sound, there are few data to demonstrate their effectiveness in landscapes dominated by managed forests, including BLH forests. We suggest that high priority be given to using adaptive management to simultaneously test hypotheses about

how biotic communities function in managed, BLH landscapes. Such information would help managers understand the consequences of their activities, provide them with more flexibility, and improve their ability to protect biological diversity while also meeting society's needs for forest resources. (Authors' abstract)

Yanes, M., J. M. Velasco, and F. Suarez. 1995. Permeability of roads and railways to vertebrates - the importance of culverts. Biological Conservation 71(3): 217–222.

The movement of vertebrates through 17 culverts under roads and railways in Central Spain was analyzed over the course of an annual cycle. Passage was detected for amphibians, lizards, snakes, small mammals, rats, hedgehogs, rabbits and several species of carnivorous mammals, including *Felis sylvestris* and *Genetta genetta*. The intensity of animal movement, which varied considerably among the groups, was influenced by various factors such as the culvert dimensions, road width, height of boundary fence, the complexity of the vegetation along the route, and the presence of detritus pits at the entrance of culverts. It is concluded that adequately designed culverts can aid the conservation of vertebrate populations. (Authors' abstract)

Yantis, J. 1990. Houston toad distribution and habitat status. Texas Parks and Wildlife Department, Austin, Texas, USA.

1990 survey of Houston toad populations. Houston toads were located in 5 new sites in Austin, Burleson, Freestone, and Colorado (2 sites) Counties. The Freestone County find represented a new county record. The findings in Austin and Colorado Counties reverified the occurrence of the toad in those counties, but at clearly different locations than the historic locations. The probability is low of the toad occurring in Chambers, Fort Bend, Harris, or Wood Counties, based on a substantial survey effort in those counties with no Houston toads being found.

Habitat from the new locations is consistent with the profile developed from the previous findings.

Breeding call parameters did not indicate a difference between the Houston toad and the American toad; the true taxonomic status of the Houston toad remains in question. (Summary compiled from author's direct quotes)

Yantis, J. 1992. Houston toad distribution and habitat status. Texas Parks and Wildlife Department, Austin, Texas, USA.

In 1992 no new Houston toad populations were located. One new breeding pond was located in Robertson County approximately 2200 meters from an already known breeding pond. Surveys were conducted in Dewitt, Goliad, Grimes, Harris, Lavaca, Montgomery, and Victoria Counties. None of these counties appeared to have suitable habitat except Lavaca (which has a known population) and Dewitt. However, in Dewitt County the gulf coast toad was very abundant. It is unlikely that the Houston toad could exist under such competitive conditions unless it breeds much earlier in that area. (Summary compiled from author's direct quotes)