How frogs and humans interact: Influences beyond habitat

destruction, epidemics and global warming

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**Abstract**. We review various ways that anurans have been of service to mankind, as well as threats to

frog species from human activity beyond habitat destruction, global warming, and epidemic diseases.

Over the centuries frogs have been a subject of fascination and entertainment, food, sources of

medicinal preparations, and model organisms in biological research. For years many species were

used in teaching anatomy, physiology and pharmacology, and in pregnancy testing. Current research

has revealed antibiotic peptides, anti-tumour agents, analgesics and adhesive compounds in frog skin.

There are also volatile compounds released from their skin; these chemicals repel various predators

and may prove useful to humans. The global decline of amphibian populations is a major concern.

Habitat destruction, global warming, and pandemic diseases are increasingly suspect in the decline of

frog populations, but difficult to control. Restrictions in the food and pet trade are areas in which better

enforcement could benefit anurans. However, not all human interactions have been deleterious to all

species. The mechanics of highway building in North America commonly has created areas of run-off

that provide breeding sites for select species. Similarly, in arid northern Australia, frogs aggregate in

large numbers at artificial sites where human activity has provided stable water sources.

Key words: Anurans; beneficial interactions; deleterious interactions; food; frogs; knowledge;

medicinal applications; peptides; pets; roads.

Introduction

Frogs (here defined broadly to include all anurans) are a conspicuous component

of many ecosystems. They are found on every continent except Antarctica, and in

virtually every habitat that provides access to water. It is estimated that there are

more than 5,200 species of frogs (Frost et al., 2006), with substantially more to be

discovered. This worldwide distribution, along with our (human) common need for

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water, has resulted in a close association of humans and frogs. In fact, nowadays,

just about anyone can recognize a frog. Frogs have even made the phenomenal leap

into human popular culture, for there is hardly a puppet more popular and better

recognized than Kermit.

Since antiquity, when Aristotle was enthralled that frogs and humansshare similar

organ systems and biological needs, humans have been studying the lives of our

amphibian neighbours (Holmes, 1993; Nussbaum and Oksenberg Rorty, 1995). Be

they haute cuisine or a source of new medicinal drugs, it is clear that frogs have had

an impact on our way of living (Tyler, 1997; Grenard, 1994, Adler, 2003).

For the last 25 years, evidence has accumulated demonstrating extinctions and

major declines of many frog species (e.g., Stuart et al., 2004; Lips et al., 2006;

Pounds et al., 2006). Although there is increasing evidence that there are several

causes of these demographic changes (Johnson, 2006), the role of humans in this

process is evident in terms of both direct habitat destruction and the introduction of

exotics. Global warming is increasingly suspect as a problem on a planetary scale,

but not one that can be easily or quickly managed. Here we attempt to review some

of the specific ways that humans have an impact on frogs beyond the major factors

of international concern such as habitat destruction, global warming, and pandemic

diseases. We, in turn, present some solutions to alleviate the immediate risks to frogs

brought on by excessive human use for food and interaction.

We also highlight some of the achievements humans have made off the frog’s back

and the knowledge we have learnt from studying frogs. In light of frog declines, we

mention a few specific situations in which human activity has benefitted select frog

populations. We work on the pragmatic premise that if benefits to the human race

can be demonstrated from frog conservation, there is a better chance of influencing

politicians and the general public to undertake steps to conserve populations and

species.

Use in Drug Development

A wide range of novel chemical compounds occurs in the granular glands of

anuran skin. Their isolation, identification, and characterisation have led to the

development of drugs for human and veterinary use. This focus will increase. These

glands are dispersed throughout the dorsal surface (rarely on the ventral) and often

aggregated to form prominent structures which Duellman and Trueb (1986) term

“macroglands”. The parotoid glands of Bufo species and the tibial glands of some

Limnodynastes species are examples.

Early (and some current) investigations sacrificed the donor and removed and

homogenised the skin to extract the granular gland secretions. It remains essential

to inactivate skin proteases, because degradation of peptides can commence in 10

minutes. However, sacrifice is no longer required because it is possible to obtain the

secretions by electrically stimulating the skin, using a square-wave stimulator and a

bipolar electrode (Tyler et al., 1992). However, it is imperative that investigators

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do not contribute to the further decline of frog populations. “Fixing” isolated

skins is no better for extracting peptides than adding methanol to the wash-off of

secretions obtained by electrical stimulation. Grant and Land (2002) have described

the circuitry and use of an economically assembled stimulator.

Peptides and alkaloids

Caerulein (a case study). In the decade following 1960, many international drug

companies directed particular attention to the source and development of anti-

hypertensive compounds for human use. Professor Erspamer and his colleagues

in Italy, in conjunction with the drug company Farmitalia, became involved in

natural products pharmacology, and particularly the examination of peptides derived

from the skin of frogs. In collaboration with Dr R. Endean of the University of

Queensland, they focussed particular attention upon the large green tree frog Litoria

(at that time Hyla) caerulea. The species was selected because Endean had noticed

that his cat used to eat most frogs with impunity, but that it always vomited after

eating L. caerulea. He reasoned that the frog must have unusual pharmacological

activity (R. Endean, pers. comm. to M.T.). To further this research, the skins of

hundreds of frogs were sun-dried and the secretions then extracted in methanol.

As a result of the above studies, it was demonstrated that the predominant

polypeptide (which they named caerulein) could produce a significant and sustained

fall in blood pressure when introduced intravenously in pentobarbitone-sedated

dogs at concentrations of 10-100 ng/kg (Bertaccini et al., 1968). In terms of

its anti-hypertensive potential, it was unfortunate that not all smooth muscle

reacted similarly and caerulein was found to cause a potent stimulation on the

musculature of the gastrointestinal tract in situ. They noted, “. . . vomiting and

diarrhoea occur in the dog, abdominal discomfort, borborygmi and awareness of

intestinal movements in man, and pseudo-antidiuresis due to pylorospasm in the

rat”. Although these side effects precluded the possibility of the polypeptide being

used as an oral anti-hypertensive drug, it has been used as a stimulant to restore

gut motility following surgical induced atony and to dilate the gall bladder prior

to cholecystography. It is now available in a synthetic form under the trade names

of Ceruletid, Takus, Ceosunin, Cerulex and Tymtran. More recently, the effects of

caerulein as a cholecystokin octapeptide (CCCK-8) receptor has been examined by

Harro et al. (1990). This work led to the conclusion that endogenous CCCK-8 and

CCK-8 receptors are involved in the neurochemical basis of anxiety. There are also

indications that caerulein can provide relief for sufferers of chronic schizophrenia

(Maroji et al., 1982; Watanabe et al., 1984). The implication of this finding is that

caerulein or an analogue is to be found in mammals, probably in the intestinal wall,

but it has yet to be detected.

Caerulein is estimated to have an analgesic property several thousand times more

potent that morphine. However, there is no available evidence that it has any affinity

for the receptors of opioids, despite the fact that the analgesic effect is blocked by

the morphine antagonist Naloxone (de Castiglione, 1982; Erspamer and Melchiorri,

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(a) (b)

Figure 1. Chinese pharmaceuticals. (a) Skinned and eviscerated Bufo species for preparation of a

tonic. (b) Modern tonic tablets.

1973). Erspamer (1994) has prepared a major review of the variety of bioactive

compounds in frog skin.

Antibiotic compounds. The use of topical preparations derived from frog skin

for antibiotic purposes probably antedates researched history, and is perpetuated in

current, traditional Chinese medicine. Samples of ancient and modern preparations

are shown in fig. 1. Studies during the past 40 years, on frogs and toads from

many continents, have revealed the existence of antibiotic peptides and alkaloids

(Preusser et al., 1975; Cevikbas, 1978; Suzuki et al., 1995; Clarke, 1997; Nicholas

and Mor, 1995; Stone et al., 1992; Clarke et al., 1994). Amongst the most promising

antibiotics are the Magainins derived from Xenopus laevis and reported by Zasloff

(1987), and the antiviral action of the Caerins from Australian frogs of the genus

Litoria (Van Compernolle et al., 2005).

Although the future applications for antibiotic skin secretions look promising,

many compounds prove to be haemolytic. It is the exceptions that are potentially

applicable for medical and veterinary purposes.

Hallucinogens. Bufotenine, a compound found in the parotoid glands of some

Bufo species has powerful hallucinogenic properties. Users express the secretions

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upon glass in the sun and scrape it off when it is dry. It is then smoked. Legislation to

outlaw the practice varies from declaring Bufotenine a prohibited substance in New

York (Chamakura, 1994), to prohibiting the possession of a Bufo species (marinus)

in Queensland, Australia.

Anti-tumour agents. One of the traditional Chinese medicines is Ch’an Su,

which is produced from the skin secretions of local toads, such as Bufo gargarizans

and B. melanostictus. Ch’an Su is available in large quantities. Recently it has been

shown to include several novel bufadienolides, which are variously active against

nine cancer cell lines (Nogawa et al., 2001). Currently deep frozen B. marinus are

being exported from Australia to China for similar pharmaceutical applications.

Analgesics. In addition to the reported analgesic attributes of caerulein, another

potent analgesic is Epibatidine, representing a new class of alkaloids and derived

from the skin of the Ecuadorian frog Epipedobates tricolor (Spande et al., 1992;

Elguero et al., 1996). Curiously, the morphine antagonist Naloxone did not restore

pain sensitivity, contrary to that of caerulein. Problems associated with its toxicity

may limit its systemic use (Shen, 1995).

Anti-inflammatory compounds. Steroids are commonly found in anuran skin

secretions. Their use for anti-inflammatory purposes has a long history in folk

medicine. An example was observed in the former Czechoslovakia where a woman

suffered multiple bee stings to her face. A doctor directed local children to collect

frogs. The frogs were killed and their dorsal surface was laid upon the patient’s face;

this relieved the pain and swelling.

There has been only limited research upon anuran steroids and they have not been

subjected to any modern review.

Natural adhesives. Several species of frogs produce skin exudates that have

considerable shear and tensile strength. The adhesive strengths of secretions of five

species were reported by Evans and Brodie (1994). More recently Graham et al.

(2005, 2006) described the composition of the glue and its strength in the Australian

species Notaden bennetti. Almost as strong as polyacrylate glues but non-toxic, the

N. bennetti secretion has considerable potential for use in surgery.

Volatiles. In addition to non-volatile compounds, many frog species produce

odorous compounds (Smith, 2001; Smith et al., 2003, 2004a, 2004b). Although

more work is needed to characterise the biological function of these volatiles, the

odorous secretion of Litoria caerulea is repellent to mosquitoes (Williams et al.,

2006). The volatile secretion of L. ewingi has antimicrobial action and is repellent

against a range of potential predators and parasites, including snakes, rats, and

mosquitoes (Smith, 2001; Tyler and Smith, 2001).

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Spermicidal compounds. In contrast to their use as a means of diagnosing

pregnancy (see below), anurans have been investigated for an opposing purpose;

the synthetic Magainin peptides have been found to have spermicidal properties

(Edelstein et al., 1991).

Teaching

The use of frogs in teaching basic anatomy to high school and tertiary students

has been a standard practice for more than 150 years. By far the best-known

and complete dissection guide is that of Ecker (1864) on European Rana species,

a work translated into English by Haslam (1889). A second and equally well

illustrated work was produced by Hoffman (1873-1878), differing in having a more

comparative approach.

Rana species continued to be the most popular subjects and Marshall (1882,

and numerous revisions) and Whitehouse and Grove (1930) were the most popular

guides in the U.K. In contrast, Xenopus was used in South Africa (Millard and

Robinson, 1945-1955: three editions). More detailed studies of Xenopus anatomy

are provided by Deuchar (1975), and Nieuwkoop and Faber (1994). Studies using

Xenopus have become increasingly popular, to the point at which it has largely

replaced Rana as the laboratory anuran.

Frogs and toads have also been the most popular subjects for teaching physiology

and pharmacology. Two preparations have been used most commonly: one is the

isolated, perfused, rectus abdominis muscle, which responds to the neurotransmitter

acetylcholine with a slow contractile response. The second is the isolated, perfused,

sciatic nerve/gastrocnemius muscle preparation. Stimulation of the sciatic nerve

with a square-wave stimulator causes the gastrocnemius muscle to contract. Nerve-

muscle transmission was demonstrated by adding atropine to the perfusate, so

preventing transmission at the muscle endplate. These are classical experiments that

originally contributed to an understanding of basic physiology in vertebrates.

Pregnancy Testing

Galli-Mainini (1948) of Argentina described a human pregnancy test, which in-

volved injecting male Bufo arenarum subcutaneously with a small quantity of urine

from the patient. Pregnancy could be confirmed by the release of spermatozoa into

the frog’s bladder and cloaca. A pipette was introduced into the cloaca to obtain a

sample. The test was accurate, rapid (taking 3-4 hours for a result), and inexpensive.

Previously there were two tests available: the Ascheim-Zondek and Friedman. Both

required the use of mammals, there was a delay of many days for a response, and

they were relatively expensive because of the need to maintain laboratory colonies

of the animals.

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Throughout the world the amphibian test was adopted; many other anuran species

were substituted for B. arenarum, and were found to respond similarly: Rana species

globally, Xenopus laevis in Europe and Africa and, in Australia the introduced cane

toad, B. marinus (Bettinger and O’Loughlin, 1950; McDonald and Taft, 1953).

The use of anurans for pregnancy testing was a standard technique for 20 years.

Figures to indicate the extent of their use are generally unavailable, but 11,000 were

known to have been imported into South Australia predominantly for this purpose

in 1962, which at that time had a human population of only 987,000 (Australian

Bureau of Statistics). Extrapolating globally suggests that the worldwide use must

have been huge.

Advancing Science: Nobel (and Ig Nobel) Pursuits

As described previously, frogs have provided and continue to provide an important

learning platform for man. In fact, a number of significant scientific breakthroughs

can be attributed to studies with frogs. To date, approximately 10% of the Nobel

prizes in physiology and medicine have resulted from investigations using frogs

(see http://nobelprize.org/).

Two aspects of amphibian biology have been particularly important in advancing

biology and medicine. Because development in most anuran species is external and

their eggs are large (compared to the more common aquatic vertebrates; i.e., fish),

they have been model organisms in experimental embryology (extensively reviewed

in Callery, 2006). Hans Spemann’s experimental manipulations, which won him

the Nobel Prize in 1935, would not have been possible without the large eggs of

the amphibians he worked on. Those studies established the organizer effect in

embryonic development.

Because it is easier to do transgenic manipulations with anuran eggs than

mammalian eggs, anurans, particularly Xenopus and its close diploid cogener

Silurana, have continued to be important model organisms for developmental

biology research in the modern era of molecular biology (Sparrow et al., 2000).

The other biomedical area to which amphibians have contributed significantly

(and Nobel winning science) is neuromuscular physiology. The fact that anurans

are ectothermic means that when their tissue is cool, they can survive for hours

to days as in vitro preparations. Thus, amphibians are ideal organisms for certain

studies in physiology. Although fish are similarly cold blooded, they do not have

muscles in the extremities that can be so easily isolated. Nor are fish as similar to

humans in their basic body plan. The ability both to maintain alive and to isolate

tissues and organs has clearly been a critical factor in the research of John Eccles,

Alan Hodgkin, and Andrew Huxley. Their work on ionic involvement in excitation

and inhibition in neural transmission won them the Nobel Prize in 1963.

The study of frog neuromuscular tissue has also played an important role in

physics and our understanding of electricity. A chance observation by the famous

anatomist Luigi Galvani (1737-1798) led him to discover “animal electricity” in

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1786. Galvani found that when the leg of a dead frog was touched with a metal knife,

the leg twitched violently. Galvani thought that the muscles of the frog must contain

electricity. Although slightly misguided in his hypothesis, Galvani’s observation

was the cornerstone for the study of neuromuscular physiology and ultimately the

understanding of electrical (ionic) conductance in nerve and muscle fibres.

By 1792 another Italian scientist, Alessandro Volta, disagreed with Galvani’s

hypothesis that muscles contained electricity. Volta realised that the main factors

in Galvani’s discovery were the two different metals — the steel knife and the tin

plate — upon which the frog was lying. Volta showed that when certain solutions

come between two different metals, electricity is created. This led him to invent the

first electric battery, the voltaic pile, which he made from thin sheets of copper and

zinc separated by moist pasteboard (Pera, 1992).

Galvani’s observation and Volta’s invention of the battery were fundamental to the

study of electricity and magnetism. Experiments dealing with these two phenomena

were described by philosophers hundreds of years before Christ. However, for

nearly 2000 yearsthose experiments dealt mainly with static electricity. The absence

of a source of continuous electrical energy posed a severe limitation in the progress

of understanding the underlying physics of the observed electrical and magnetic

phenomena (Visser, 2005).

Many other notable experiments in physics, biology, and chemistry have been

achieved through the study of frogs. Some have received recognition primarily

because of a perceived humorous aspect of frogs. In the last decade, three Ig Nobel

prizes have been awarded to work on frogs. Two of them were awarded in 2000;

one for the taste of tadpoles, another for the magnetic levitation of a frog. The

last was awarded in 2005 for the smell of adult anurans. The Ig Nobel prizes

are awarded for research that first makes you laugh and then makes you think

(see http://www.improb.com/ig/). The awards were instigated to help communicate

science to the general public in both a fun and informative way.

In all these cases, the actual phenomena studied (taste, smell, and the physics of

magnetic fields) are not so exotic to be worthy of an award, least of all, one with

a humorous edge. The humour therefore lies in the organisms that were involved

in the experiments and not the topic itself. Thus, it is worth asking why frogs are

perceived in this way. Many factors may apply: the shortest, squattest bodies in the

vertebrate world; a surprising saltatory gait; large eyes; tailless adults; a general

harmlessness, etc. Collectively, the body plan of anurans is so distinctive as to make

them exceptional among vertebrates (Handrigan and Wassersug, in press). Being

both bizarre and benign helps build some intrinsic whimsy into these beasts.

Use in Taxonomy and Systematics

Unfortunately, the use of anurans for humankind in almost all cases requires some

collecting of specimens from nature. The taking of adequate samples to be placed in

museum collections is essential for the study of taxonomy and systematics, which

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in turn have a role in conservation. The same applies to tissue samples for molecular

studies. Unfortunately it is clear that the ethical issue of limiting samples to numbers

that do not affect the continued viability of a local population, has not always been

observed.

An example of over-collecting brought to our attention was that of a collector

who took 650 adult calling males of one species from an isolated locality. The

following year he took 97 and expressed surprise that subsequently there was none

at the site. The species no longer can be heard or seen there. This example may be

exceptional but it demonstrates the need for herpetologists to minimise their impact

on study animals. In the light of evidence of declining populations (Stuart et al.,

2004; Pound et al., 2006), collection policy is an issue that has been addressed.

In many jurisdictions, there are now regulations requiring permits for collecting.

Unfortunately, whereas scientists are likely to abide by such judicial constraints,

ecologically sound prohibitions on one’s collecting are either not in place or not

enforced in many regions. This problem is most severe in the poor tropical countries

that have the highest diversity of anuran species.

The Pet Trade

There is no doubt that trade in frogs for pets (much of it illegal) is having a huge

impact upon some natural populations. Whereas possession of exotic species is

highly attractive to many keepers, the fundamental issue in some European countries

is a ban on keeping local endemic species. Many leading European herpetologists

approve this ban, which increases pressure upon the fauna of other continents. Hohn

(2003) demonstrated that in New York, trade in local species included some that

were of conservation concern. Elsewhere trade is almost entirely in exotic species.

For example, in Europe, Martens and Jelden (1992) reported that 54% of anurans in

the pet trade are Dendrobates species and 27% Phyllobates species.

Bizarre species, such as Ceratobatrachus guentheri of the Solomon Islands and

several species in Madagascar, are threatened by their demand overseas as pets

(Glaw and Vences, 1992). Local governments may perceive their export as valuable

means of income, without any regard for their conservation in perpetuity.

The pet trade will continue. All that can be hoped for is an international approach

to providing approved breeding establishments, where frogs can be bred to provide

stock for private keepers and zoos. This action needs to be combined with increased

penalties to deter the illegal trade that is rife at present.

Human Consumption

In most parts of the world, the consumption of the hind legs of frogs has been a

traditional food source, but at such a level that it had little impact upon the viability

of local frog populations (Cooke, 1989). However, the novelty of the food as a

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gourmet item created a demand in Europe (particularly France and Switzerland)

that could only be satisfied by importations from Asia. Beebee (1996) stated that

in the mid-1980s, Bangladesh, India, and Indonesia were each exporting 3,000 tons

of legs every year, and calculated that the developed world consumed 6,500 tons of

legs per year. Local extinctions have resulted from the practice, and several Asian

countries have placed embargoes on further exports (see Oza, 1990). Kusrini and

Alford (2006) reported that Indonesia exported around 5,600 tons of frog legs in

1992 and around 3,900 tons in 2002. Of these exports 83.2% went to Europe.

Frog farming probably started in the USA where it was promoted as a “get rich

quick” activity (fig. 2). The reality was that it is not economically feasible on a

small scale. Modern frog farms, such as the Jurong Frog Farm in Singapore breed

tadpoles of the North American species Rana catesbeiana in large concrete ponds.

Disease, cannibalism, and maintenance of adequate water quality remain significant

problems (Lutz and Avery, 1999), but Rana catesbeiana has been introduced into

several countries as a food source (Lever, 2003).

Indonesia, Singapore, Taiwan, Brazil, and Uruguay also are countries where frog

farms are being developed. In Indonesia, local Rana limnocharis and R. cancrivora

are farmed, and Susanto (1989) provided considerable detail on their husbandry.

Food for frogs in a pelletised form is manufactured in Taiwan and exported to many

countries.

It is clear that the provision of frogs for the restaurant trade is a major threat

to frog populations on two accounts. One is the excessive hunting of frogs for

human consumption. The other is the threat to local species by the escape of the

American bullfrog, where it has been introduced for frog farming. Competitive

pressure on native species from the introduced bullfrogs in California is well

documented (Kupferberg, 1997). One of us (RW) collected tadpoles from several

sites on both sides of Japan’s main island where feral bullfrog larvae are the most

common tadpoles encountered. Despite the lack of evidence that bullfrogs have

helped either the economy or human nutritional status in Japan in any way, public

demand and economic considerations are likely to cause bullfrog introductions to

continue around the world.

Trade in Brazil was described by Rocha-Miranda et al. (2006) as follows:

“Currently there are about eight large companies farming bullfrogs, with 600

establishments in Brazil . . . . The estimated meat production of 400 tons/year is

destined almost entirely for the domestic market, but isstill thought to be insufficient

to meet demand . . . 1500 to 4000 animals are slaughtered daily to provide meat, liver

(in the form of paté), skin (for diverse products), oil (for the perfume industry); what

is left is recycled as frog food.”

Biological Control

Lever (2001) listed 137 introductions of the cane toad into different countries,

principally for the purpose of biological control of insect pests of agricultural

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Figure 2. Advertisement promoting frog farming. Circa 1925.

significance. By far the most disastrous of these was the entry of 102 Bufo marinus

into Australia in 1935 in an attempt to control insect pests ofsugar cane. To date A$7

million has been spent by the State and Federal governments in an attempt to control

the introduced predator, which now occupies an area of more than 1,000,000 km2.

Currently, the toad is advancing across northwest Australia at a rate of more than

100 km each year, and desperate efforts are being made to halt its spread (fig. 3).

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Figure 3. One of many Australian posters.

Beneficial Impacts

The impact of humans on frog populations might be interpreted as entirely delete-

rious. However, such an interpretation would be incorrect and should be challenged

for several reasons.

Tyler and Watson (1998) examined the impact following observations at an

isolated cattle station in the Northern Territory of Australia and the more populated

farming communities of Victoria in the southeast of the continent. In the Northern

Territory, they were able to demonstrate that the construction of out-houses,

providing showers and toilet facilities for staff, created environments where vast

numbers of frogs were able to survive during arid periods. Without these refuges

the frog population would have been much lower. At one site, 24 Litoria caerulea

were found in a single toilet cistern and more that 100 L. rothii in a shower block.

In retrospect, the invasion of Litoria at this site is not surprising, given how

closely humans and frogs are in both time and space just because of their common

dependence on fresh water. How they interact varies greatly, and often depends

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on the ways in which humans manage water flow and water bodies. Clearly,

draining rivers and streams, introducing predatory fish, and agricultural chemicals

have vastly restricted the ranges of species in areas where humans and frogs may

otherwise co-exist. Environmental augmentations that have helped selected species

on a large scale have occurred, however, and this has happened on a much greater

scale in North America.

For example, spring peepers (Pseudacris crucifer) are doing fine despite the

massive decline of anuran species from many tropical and montane regions. This

species breeds in temporary pools overgrown with grass and cattails, but not

otherwise canopied (Skelly et al., 2002, 2005; Halverson et al., 2003). In North

America, this habitat is commonly found along the edges of roads, tens of thousands

of kilometres of which have been built up and paved since the advent of the

automobile.

In building highways in North America, earth from the side of the road is scooped

up to elevate the roadbed. The resulting roadbed drains well, which makes it safer

for auto traffic. The construction also creates ditches at the sides of the road, and the

ditches become new seasonal pools in which frog species such as P. crucifer that

are “open canopy specialists” (Skelly et al., 2005) can breed. In addition the roads

have right-of-ways that usually include the ditches. These public lands are typically

separated by fences from adjoining private land, particularly in areas where farm

animals graze and could be killed if they wandered on to the road. Those fences

also, however, help keep cattle and other farm animals out of the ditches.

It may not be obvious that the automobile has in any such indirect way helped any

frogs; particularly considering the great mortality of anurans on highways (Hels and

Buchwald, 2001). It should be acknowledged though, that the high rate of crushed

frogs on roads in many areas is, in part, the result of the abundance of breeding sites

for frogs produced by humans right along the margins of those roads.

This symbiotic association of humans, and their roads, with certain frogs and

their breeding sites is far less common in Europe, where most roads pre-date the

automobile. Two things in Europe work against frogs. For centuries, as Europeans

have improved the farmland along river courses, they have drained temporary

puddles and pools that otherwise would have been breeding sites for frogs. They

have redirected the flow of just about every waterway that is near agricultural land

in order to control flooding. Many of the major roads date back to the Romans and

are built at the margins of floodplains, which means that runoff naturally drains back

into neighbouring streams and rivers.

Neither the Romans nor the modern Europeans have elevated their highways to

the extent that the North Americans have. Similarly, the typical open-herding of

farm animals, i.e., moving them from one patch of grazing land to another, is more

typical in Europe than North America. This is perhaps because the long history

of land ownership in Europe results in many families owning multiple small and

separate plots of land. Few people (even wealthy people) in Europe ever acquire

large contiguous blocks of grazing land. Within this setting, fences are an obstacle to

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Figure 4. Toad tunnel at Newhaven, UK. Reproduced with permission of ACO Polymer Products.

efficient ranching rather than structures that might protect ponds and pools, in which

anurans breed, from large grazing mammals. One simply sees far fewer fences in

Europe than along the roads of North America.

In sum, without elevated roads, which would produce new roadside ditches, and

fences to isolate cattle from the few ponds and pools that are left, European anurans

have few safe places to breed. The few ponds that are left are on floodplains, in areas

heavily used by humans.

It is thus not surprising that Europeans have been at the vanguard of promoting

and installing toad tunnels under their roads (Langton, 1989). The need in Europe

for these structures is most obvious in mountainous regions. In North America,

where there are hills above roads there are often man-made aquatic sites between

the hills and the roads proper. This is far less common in Europe, where amphibians

coming down from the hills and heading to the few remaining ponds and pools in

the floodplain almost always have to cross a major road. Toad tunnels can provide

safe access to water for amphibians where they must cross highways to move from

elevated feeding habitat to lower-lying breeding sites (fig. 4).

On a continental scale these tunnels are still, however, so rare as to be of greater

symbolic than substantive significance to anurans. Nonetheless, in some regions of

central Europe, toad tunnels may be the only hope that anurans have of surviving

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in the patchy landscapes that have been heavily modified for millennia by human

farming and occupation.

As much as crossing roads is a hazard for most anurans, roads can also facilitate

dispersal when species elect to follow rather than cross them. Recent data show that

toads follow roads, and this is helping the current rapid westward dispersal of the

cane toad in Australia (Brown et al., 2006).

Conclusions

There is considerable reciprocity in the impacts between anurans and humans.

A few negative impacts by humans, such as their sacrifice for physiological or

other scientific purposes, have diminished substantially in recent years. However,

these pale in comparison to the numbers lost from habitat destruction and large-

scale environmental degradation. In rare cases, such as with highway construction

in North America, human habitat modification may help a few species. But most

human-frog interactions continue to be detrimental to anurans.

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