

## ZOO VIEW

*Herpetological Review*, 2017, 48(1), 241–260.  
© 2017 by Society for the Study of Amphibians and Reptiles

# History of Captive Management and Conservation Amphibian Programs Mostly in Zoos and Aquariums. Part I—Anurans

“I HAVE ALWAYS LIKED FROGS. I LIKED THEM SINCE BEFORE BECOMING A ZOOLOGIST, AND NOTHING I HAVE HAD TO LEARN ABOUT THEM SINCE HAS MARRED THE ATTACHMENT. I LIKE “LOOKS” OF FROGS AND THEIR OUTLOOK, AND ESPECIALLY THE WAY THEY GET TOGETHER IN WET PLACES ON WARM NIGHTS AND SING ABOUT SEX.”

ARCHIE CARR, UNIVERSITY OF FLORIDA PROFESSOR OF ZOOLOGY (1955)

### INTRODUCTION

In 1989 at the First World Congress of Herpetology in Canterbury UK, prominent amphibian biologists began discussing similarities of declines in their study populations. A short time thereafter, the IUCN/SSC Declining Amphibian Populations Task Force (DAPTF) was created by Dr. George Rabb, director of Brookfield Zoo, and other biologists to create an ad hoc three-year program to see if these shrinkages were normal population fluctuations or unknown factors. One of us (JBM) was asked to become a board member and watched the evolution of our understanding over a span of 16 years that this loss was beyond natural phenomena (see Heyer and Murphy 2005 for history).

At the start there was a considerable debate about whether this was a normal pattern or a suite of etiological agents requiring further study. After three years, it was clear that no cause had been found, so the DAPTF was extended indefinitely to identify reasons for these declines. Over 12,000 papers were published on amphibian conservation between 2005–2015, of which a thousand focused specifically on chytridiomycosis (Thompson Reuters 2016).

Compared to the number of contributions dealing with reptiles, few papers were published on amphibians by zoo workers over the years. This deficit is changing, due to realization that amphibians are compromised and many are at serious risk of disappearing forever. Over the past two decades, a number of zoos and aquariums have supported *in situ* and *ex situ* amphibian projects. Since its establishment in 1989 through its 16-year existence, much of the financial support for DAPTF

was generated from the zoo and aquarium community, either through direct donations or through contacts supplied by the staffers. These monies were critical in funding the newsletter *FROGLOG* by Detroit Zoological Institute (see Zippel and Snider 2001). The Amphibian Survival Alliance Seed Grant program supplied small startup grants to begin research initiatives, often in developing countries. International Coordinator Tim Halliday (pers. comm.) found that for each US dollar, 20 were generated from outside sources—an impressive return indeed. Perhaps the most important aspect was to alert the world that amphibian populations were crashing and the causes remained enigmatic. DAPTF has now been subsumed as the research arm of the Amphibian Specialist Group (ASG) of IUCN—The World Conservation Union. ASG has taken over publishing *FROGLOG* online and in color. This is the perfect way to follow the fluid state of amphibian conservation and research.

Much progress has been made in understanding the causes of amphibian declines. Zoo Miami’s Steven Whitfield, with Karen Lips and Maureen Donnelly, published a recent review describing amphibian decline and conservation in Central America. They listed threats—habitat modification, habitat fragmentation, diseases, pollution, UV-B radiation, climate change, overharvesting, invasive species, chytridiomycosis, ranavirus, and other emerging diseases, and synergistic interaction among stressors—all of which are applicable to amphibians globally. The paper identified conservation actions—monitoring, network of protected areas, captive assurance colonies, relict populations, reintroductions, and building in-country capacity. Amphibian Ark (AArk) is an organization working to coordinate captive efforts globally and assist with capacity-building efforts, and is interacting with 64 organizations in 28 countries that are focused on conserving 115 anuran species (AArk 2016). In terms of zoos responding to the crisis, some respectable incremental progress has been made with a 57% increase in the number of species between 2007–2014 with an increasing emphasis on imperiled species (Dawson et al. 2015; Harding et al. 2016). However, just 6.7% of known amphibians are represented in zoos and this figure is woefully inadequate when compared with other classes of vertebrates, and much work needs to be done (Dawson et al. 2015).

Captive programs may take time to establish, incur significant long-term costs, and face many pitfalls, including poor prioritization and difficulty raising funds for effective capacity building (Wiese and Hutchins 1994; Gratwicke et al. 2012; Tapley et al. 2015). Recent progress has been made on prioritizing amphibian conservation programs based on probability of success (Gratwicke et al. 2016), and Amphibian Ark has developed a decision-making tool to help conservation workers

#### JAMES B. MURPHY

Division Amphibians & Reptiles Smithsonian’s National  
Museum of Natural History, 10<sup>th</sup> and Constitution Ave NW  
Washington, DC 20013, USA  
e-mail: murphyjb@si.edu

#### BRIAN GRATWICKE

Smithsonian’s National Zoological Park and Conservation  
Biology Institute, 3001 Connecticut Ave NW  
Washington, DC 20008, USA  
e-mail: gratwickeb@si.edu

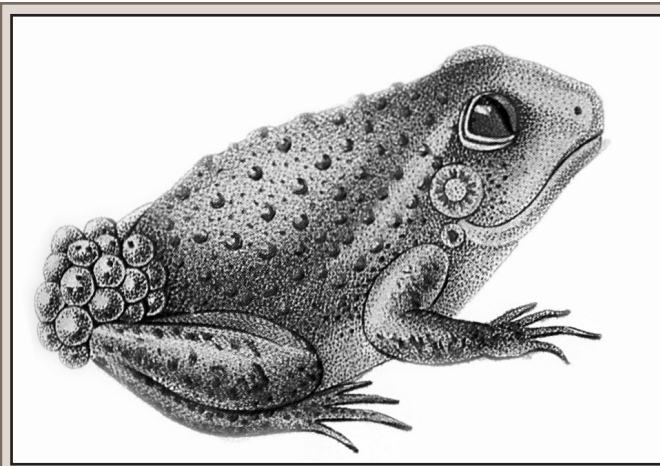


FIG. 1. Midwife Toad (*Alytes obstetricans*) from *Zoologie classique, ou, Histoire naturelle du règne animal* by Félix-Archimède Pouchet in 1841. Roret, Paris. Be sure to read *The Case of the Midwife Toad* by Arthur Koestler.

conduct a needs assessment that may help steer them away from some common pitfalls (see <http://www.conservationneeds.org>). Many of these newly established programs need time to establish solid founder populations able to support production for release programs, but there are several examples of successful amphibian reintroduction efforts where a threat has been identified and reversed (Griffiths and Pavajeau 2008).

Several important papers and books—historical and recent—are noted here. J. V. Fischer (1883, 1884) published early reports of captive care of amphibians. Flower (1927, 1936) discussed memory and life spans of amphibians. One of the first accounts was by J. M. Bechstein who discussed maintaining frogs (Heichler and Murphy 2004). Water quality and facility design were addressed by Browne et al. (2007), Odum (1984), and Odum and Zippel (2008). Pough (1991) recommended techniques for captive maintenance. Gehrman (1987, 1994) and Antwis and Browne (2009) discussed light quality. Chad Peeling (2013) suggested ways of exhibiting amphibians, based on his experience with a splendid traveling exhibit called “Frogs—A Chorus of Colors.” Behler and Behler (2005) wrote a companion book with the same name. Pramuk and Gagliardo (2008) wrote a comprehensive amphibian husbandry chapter that is a useful guide for captive management. Hiler (1985) provided an overview of the amphibian collection at the Steinhart Aquarium as an introduction to amphibian care. Honegger (1979) offered marking procedures. Griffiths and Pavajeau (2008) discussed captive breeding, reintroduction, and the conservation of amphibians. Some animal behaviorists do not believe that amphibians should live in an enriched captive environment, but an interesting paper by Michaels et al. (2014) suggests otherwise. Santiestevan and Neff (2015) described a citizen-science initiative called FrogWatch & Listen where groups of interested persons monitor anuran calls in the wild to determine density. Gagliardo et al. (2008) provided principles of rapid response for amphibian conservation, using the programs in Panama as an example. Gascon et al. (2007) published the Amphibian Conservation Action Plan. IUCN/SSC Amphibian Conservation Summit 2005 USA. Zippel et al. (2011) described Amphibian Ark for *ex situ* conservation of amphibians. Longevities may be found in Slavens (1989), and Snider and Bowler (1992).

Brattstrom (1963) discussed anuran thermal parameters. Kauffeld (1942) gave tips for raising frog tadpoles at Staten Island



FIG. 2. “Batrachia” in *Art Forms in Nature* by Ernst Haeckel in 1904.

Zoo and Smith and Paine (1989) at Buffalo Zoo. At Memphis Zoo, Kouba et al. (2009) described artificial fertilization for amphibian conservation. Maruska (1986) reviewed zoo breeding programs. Nace (1977) discussed procedures used at the Amphibian Facility, University of Michigan. Raphael (1993) presented information on medical management. Browne and Zippel (2007) offered suggestions for reproduction and larval rearing of amphibians. Martins et al. (2013) analyzed differential effects of dietary protein on early lifehistory and morphological traits in Natterjack Toad (*Epidalea calamita*) tadpoles reared in captivity. McWilliams (2008) provided nutrition recommendations for some captive amphibian species. At National Aquarium in Baltimore, Hadfield et al. (2006) proposed successful nutritional support of amphibians. Michaels et al. (2015) studied impacts of UVB provision and dietary calcium content on serum vitamin D<sub>3</sub>, growth rates, skeletal structure and coloration in captive Oriental Fire-bellied Toads (*Bombina orientalis*). Verschooren et al. (2011) described the efficacy of Ultraviolet B radiation (UV-B) on growth and skeletal development of the Amazonian Milk Frog (*Trachycephalus resinifictrix*). Sim et al. (2010) compared oral and topical vitamin A supplementation in African Foam-Nesting Frogs (*Chiromantis xerampelina*) at Disney’s Animal Kingdom in Bay Lake, Florida.

The late Kevin Wright at the Phoenix Zoo and Brent Whitaker at the National Aquarium in Baltimore, published a critical book, *Amphibian Medicine and Captive Husbandry*, covering husbandry, diagnosis, and treatment of diseases. Bloxam and Tonge (1995) at Durrell Wildlife Conservation Trust rightly

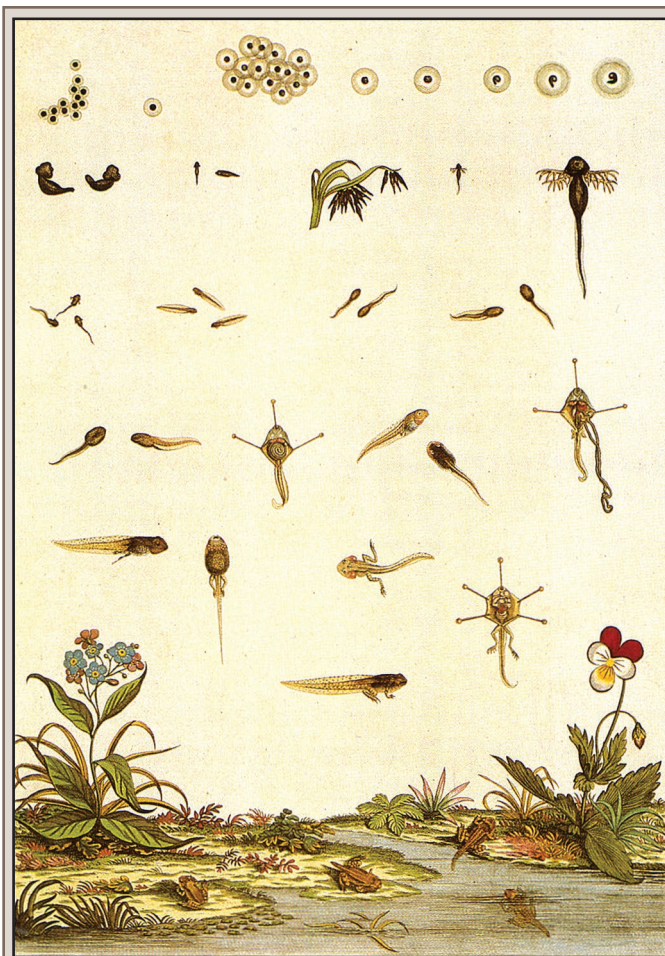


FIG. 3. Some of the most beautiful plates in the history of herpetology were in August Johann Roesel von Rosenhof's *Historia Naturalis Ranarum Nostratum* in two parts in 1753 and 1758. The complete life cycle of all species of German frogs and toads were contained in this book—amplexing adults, developmental stages of tadpoles, anatomy and osteology.

noted that amphibians were acceptable candidates for breeding-release programs. An example is the recovery program for the Mallorcan Midwife Toad (*Alytes muletensis*) outlined by König and Schluter (1991), Mallinson (1998), and Buley and Garcia (1997). Based on observations at Zoological Gardens at Halle, Hinsche (1928, 1939, 1941) recorded anti-predator behavior of various anurans directed toward snakes: death shamming, defense, defensive attack, and exaggerated postures. As an aside, Arthur Koestler wrote *The Case of the Midwife Toad* and we highly recommend this superb intellectual thriller (Fig. 1).

There are a number of books and papers that are critical references for the amphibian keeper: Association of Zoos & Aquariums (2007) *Amphibian Conservation Resource Manual*; Coburn (1992) *The Proper Care of Amphibians*; Crump (2000) *In Search of the Golden Frog*; Collins and Crump (2009) *Extinction in our Times: Global Amphibian Decline*; Duellman and Trueb (1986) *Biology of Amphibians*; Hall and Wake (eds.) (1999) *The Origin and Evolution of Larval Forms*; Heatwole (1994) *Amphibian Biology*; Jamieson (2003) *Reproductive Biology and Phylogeny of Anura*; Klingelhöffer (1955–1959) *Terrarienkunde*; Lannoo (2008) *Malformed Frogs. The Collapse of Ecosystems*; McDiarmid and Altig (eds.) (1999) *Tadpoles: The Biology of Anuran Larvae*; Miller (2000) *Nature's Fading*



FIG. 4. Illustration in Gotthilf Heinrich von Schubert's *Naturgeschichte des Thierreichs. . .*, published in 1869. There are several nice herpetofaunal drawings in this series.

*Chorus: Classic and Contemporary Writings on Amphibians*; Nietzke (1969) *Die Terrarientiere*; Noble (1954) *The Biology of the Amphibia*; Phillips (1994) *Tracking the Vanishing Frogs: An Ecological Mystery*; Ryan (ed.) (2001) *Anuran Communication*; Semlitsch (ed.) (2003) *Amphibian Conservation*; Smith and Sutherland (2014) *Amphibian Conservation: Global Evidence for the Effects of Interventions*; Souder (2000) *A Plague of Frogs: The Horrifying True Story*; Staniszewski (1995) *Amphibians in Captivity*; Stebbins and Cohen (1995) *A Natural History of Amphibians*; Vogel (1964) *Reptiles and Amphibians. Their Care and Behaviour*; Wells (2007) *The Ecology and Behavior of Amphibians*; Elke and Helmut Zimmermann (1983, 1994, 1992, 1981, 1987). J. M. Glime created an ebook with five chapters covering the relationship between anurans and bryophytes. There are many excellent photographs and information on frog taxa rarely seen: Chapter 1: Anuran Adaptations; Chapter 2: Anuran Conservation Issues; Chapter 3: Ground-Dwelling Anurans; Chapter 4: Anurans: Waterfalls, Treefrogs, and Mossy Habitats; Chapter 5: Central and South American Mossy Habitats. A unique feature is a suite of photographs with the large variety of color morphs of Darwin's Frog.

It is overwhelming to count the number of anurans at risk in the book called *Threatened Amphibians of the World* (Stuart et al. 2008)—page after page of beautiful animals (Figs. 2, 3, 4). We have noticed that many biologists find human interventions to save species likely to be costly and ineffective (see Dodd and

Seigel 1991). Their point is that relocation, repatriation, and translocation may be unsuccessful. If nothing is done to address these declines, the end point is certainly extinction. Card et al. (1998) asked if zoo herpetology has a future to deal with conservation issues. A good starting point is reading the Association of Zoos & Aquariums' *Amphibian Conservation Resource Manual*. Chiszar and Smith (2005) and Garrett (2005) suggested approaches to develop collaborations between zoos and academic institutions and Chiszar et al. (1993) and Murphy and Chiszar (1989) provided a research agenda to deal with shrinking biodiversity.

It is inconceivable to us that restaurants still offer frog legs on menus in view of the multiple threats to anurans, yet every year the legs of 100–400 million frogs are traded internationally. Including figures for domestic farm production, an estimated 0.8–3.2 billion frogs are consumed (Gratwicke et al. 2010). When we mention to restaurant owners that serving these legs is irresponsible and contributes to the dramatic shrinkage of some species and the spread of diseases, we are ignored. As a result, we no longer patronize these establishments. Some ethnic food markets and wholesale suppliers offer live frogs in prodigious quantities, along with many other reptiles such as lizards, turtles, and snakes. JBM visited a restaurant supplier in Jakarta and was astonished by the sheer number of animals available for sale. Hundreds of frogs filled large garbage cans. Virtually all had been collected in West Irian and included many taxa of interest to herpetologists and herpetoculturists. It was surprising to see small New Guinea and Estuarine crocs, green tree pythons and other pythonids, a number of poorly known varanids, Fly River and small sea turtles, and venomous snakes.

In spite of increased attention, some groups of amphibians remain virtually unknown, the most dramatic being caecilians. This paper is divided into two parts; the first covers anurans and the second will cover salamanders and caecilians. We follow the taxonomy outlined in *Amphibian Species of the World* (Frost 2016).

#### HISTORY OF ANURAN STUDIES

“THOSE WHO CARE FOR THE STUDY OF AMPHIBIA AND REPTILES—THE HERPETOLOGISTS, TO GIVE THEM THEIR SCIENTIFIC TITLE—HAVE NEVER BEEN NUMEROUS; BUT MOST OF THEM HAVE BEEN SERIOUS STUDENTS. ONE REASON FOR THE FACT THAT THIS BRANCH OF NATURAL HISTORY IS NOT VERY POPULAR, IS A PREJUDICE AGAINST CREATURES SOME OF WHICH ARE CLAMMY AND COLD TO THE TOUCH, AND SOME OF WHICH MAY BE POISONOUS. PEOPLE WHO DELIGHT IN KEEPING NEWTS OR FROGS, TORTOISES, OR SNAKES, ARE, AS A RULE, CONSIDERED ECCENTRIC.”

HANS GADOW (1901)

The Reverend Gregory Bateman (1897) had a love affair with these fascinating animals, “The Batrachians are exceedingly interesting creatures, and most of them will live for a very long time in a properly arranged Vivarium. As a rule, they are more easily provided with food than many of the Reptiles, and they do not require so much artificial heat, when any, as the latter animals.” In his study of menageries, Loisel (1912) mentioned a few references to amphibians in captivity: some amphibians in the Menagerie of the Museum of Natural History in Paris in 1839 had a large center exhibition section called “Aquarium Hall,” containing freshwater fishes and amphibians (see Murphy and Iliiff 2004 and Murphy 2009 a,b); 24 amphibians in Menagerie of the Imperial Cabinet of Natural History in Vienna around 1847; three species in Kyoto Zoo in Japan in 1908; some amphibians

in Amsterdam Zoo in 1908; Breslau Zoo in Germany had 79 amphibians of 14 species in 1909; 122 amphibians representing 25 species in 1910 at Rotterdam Zoo; 10 species of amphibians in Gizeh Zoo in 1911; some amphibians at Philadelphia Zoo in 1911; Hannover Zoo had a collection of 16 amphibians numbering seven species in 1911; Schönbrunn Menagerie in 1912; European amphibians at Frankfurt Zoological Garden; Copenhagen Zoo had a small terrarium for amphibians; Carnegie Aquarium in Edinburgh and Blackpool Tower Aquarium, and zoos in Bristol, Paignton, and Belfast, United Kingdom (Schomberg 1957). Alfred Leutscher in *Vivarium Life. A Manual on Amphibians, Reptiles and Cold-Water Fish* (first published in 1952) noted, “Toad Hall ...A name like this speaks for itself—a house for amphibians, from which there is no escape, such as may occur in the walled reptiliary. Such a house was made and used for many years by the British herpetologist, Mr. L. G. Payne, and proved to be an excellent community centre for a variety of frogs and toads, tree frogs and salamanders” (Fig. 5). Jon Coote (2001) provided a history of captive maintenance before the 20<sup>th</sup> century. Murphy and McCloud (2010) followed the evolution of keeping captive amphibians and reptiles, as well as another paper written the same year listing dealers who specialized in selling herpetofauna over many years.

Toads (Bufonidae) comprise one of the largest families of frogs that fill the conservation spectrum from invasive pests to highly endangered animals. Hugh Quinn (1980) and associates (Harwell and Quinn 1982; Quinn and Mengden 1984; Mays and Peterson 1996) reproduced the endangered Houston Toad (*Anaxyrus houstonensis*) at Houston Zoo, which included medical management and reintroduction—their current 1200 sq ft facility produced 600,000 eggs for release into the wild in 2015 as part of a Species Survival Plan (SSP) (Houston Zoo 2016; see also Conway 1985). Taylor et al. (1994) reviewed causes of mortality in the captive population of the endangered Wyoming Toad (*Anaxyrus baxteri*) at Cheyenne Mountain Zoo. Browne et al. (2006) used hormonal priming, induction of ovulation, and in-vitro fertilization for these toads and the Memphis Zoo produced 1700 tadpoles by artificial fertilization which were released in Wyoming. Burton et al. (1995) offered experiences on managing these animals at the Cheyenne Mountain Zoo, and multiple zoos now participate in an SSP providing offspring for ongoing field release trials (Polasik et al. 2015). Boreal Toads (*Anaxyrus boreas*) are also managed by the Colorado Division of Fish and Wildlife and partner zoos like the Cincinnati Zoo working together to develop assisted reproduction methods for this species (see Roth et al. 2010). The toads are being bred for field releases—USGS biologists developed an adaptive management framework to identify numbers required for successful release trials in the presence of continued threats like *Bd* (Muths et al. 2014). Satellite colonies were started at Sacramento Zoo and Chaffee Zoological Gardens to conserve the Yosemite Toad (*Anaxyrus canorus*) according to Martin (1991). Paine et al. (1989) explained the AZA SSP recovery program for the Puerto Rican Crested Toad (*Peltophyrne lemur*), which is supported by many zoos, but genetic rescue was required because of inbreeding (Beauclerc et al. 2010). Africam Safari in Mexico has had some success with a captive assurance colony of Large-crested Toad, *Incilius cristatus* and has begun releases (Hernández Díaz 2013). Vogt (1974) from Krefeld Zoo, Burchfield (1975) from Gladys Porter Zoo, Smith and Fischer (1975) from Los Angeles Zoo, and Pawley (1988) from Brookfield Zoo reproduced the Blomberg Toad (*Rhaebo blombergi*) from Colombia.

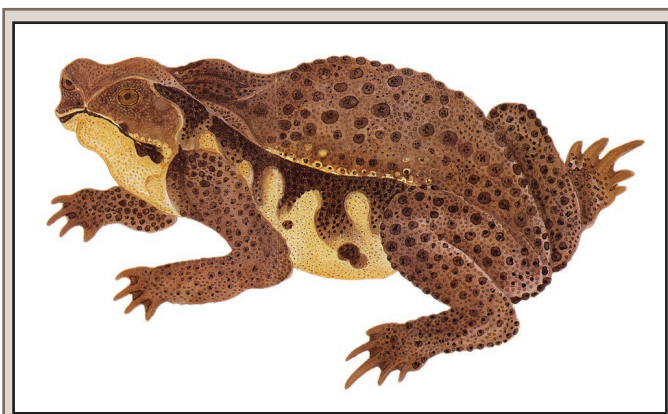


FIG. 5. Japanese Toad from *Honzozusetsu* by Shunzan Takagi ca. 1852.

La Marca et al. (2005) described catastrophic population declines and extinctions in Neotropical harlequin frogs (Bufonidae: *Atelopus*), a genus now showing only remnants of a once common frog clade (Fig. 6). Several centers in Latin America work on conservation breeding programs. In Ecuador, the Centro Jambatu de Investigación y Conservación de Anfibios and the Balsa de Sapos at the Pontificia Universidad Católica del Ecuador and the Centro de Conservación de Anfibios at Zoo Amaru have extensive captive *Atelopus* breeding programs. In the Panama Amphibian Rescue and Conservation Project, there is a partnership involving the Smithsonian Institute, Houston Zoo, Cheyenne Mountain Zoo, and Zoo New England and there are two facilities in Panama that maintain captive assurance colonies of five of the extant *Atelopus* species in that country; a sixth species, *Atelopus chiriquiensis*, has not been seen since the 1990s and is feared extinct (Gratwicke et al. 2016). Zippel (2002) described the breeding program for the Panamanian Golden Frog (*Atelopus zeteki*) as part of Proyecto Rana Dorada, an *in situ* conservation initiative involving a number of zoos and outside herpetologists; the US population of *Atelopus zeteki* is thriving under the management of the Maryland Zoo in Baltimore. Estrada et al. (2013) edited *The Golden Frogs of Panama (Atelopus zeteki, A. varius): A Conservation Planning Workshop*, which provides a detailed roadmap for a diverse group of stakeholders to cooperate on captive breeding goals, research, and education activities needed to restore golden frogs in the wild. Becker et al. (2011, 2014, 2015) unsuccessfully applied probiotic skin bacteria to *A. zeteki* to control *Bd*, but in the process much was learned about the frog skin microbiome. DellaTogna (2015) examined structural and functional characterization of the Panamanian Golden Frog spermatazoa. Cikanek et al. (2014) evaluated group housing strategies for the *ex-situ* conservation of other species of Harlequin Frogs (*Atelopus* spp.) using behavioral and physiological indicators. Daly et al. (1997) noted the absence of tetrodotoxins in a captive-raised harlequin frog (*A. varius*); while the primary disease threat has not abated, such a loss of toxicity for an aposematically colored frog may pose additional challenges for reintroduction projects.

The Kihansi Spray Toad (*Nectophrynoides asperginis*) from Tanzania is endangered. The Wildlife Conservation Society and zoos in Detroit, Baltimore, Oklahoma City, Toledo, and Buffalo have been involved in a recovery and captive breeding initiative. Even though there has been successful reproduction to the third generation, parasitism of the founders and low survival rate of the offspring have been discouraging (see Lee et al. 2006



FIG. 6. Albert Günther was hired at the British Museum in 1857. He was the founder of "Zoological Record." Harlequin Frogs (*Atelopus varius*) from Günther's *Biologia Centrali Americana: Reptilia and Batrachia* in 1885-1902.

and Kraajick 2006 for description of program). Repatriation and reintroduction attempts began in 2012, but the species is still not secure in the wild due to parasitism and low survival (Tapley et al. 2015).

The Mallorcan Midwife Toad (*Alytes muletensis*) was rediscovered in the wild in 1980. The Durrell Wildlife Conservation Trust and Barcelona Zoo, Spain began to study these anurans in captivity and in the field (Tonge and Bloxam 1989; Buley and Garcia 1997; Roca et al. 1998; Buley and Gonzalez 2000). KraaijeveldSmit et al. (2006) studied the effects of captive breeding of this toad and the fitness of reintroduced species. They summarized their findings: "The results suggest that relatively high levels of heterozygosity and important fitness attributes can be maintained for a few generations in breeding programs for threatened species despite small numbers of founders and the absence of natural selection. Nevertheless, both fitness and heterozygosity may eventually start to deteriorate in the long term, and this may have implications for reintroduction strategies." Recent progress has been made in the *A. muletensis* field conservation programs and to date it is the world's only successful example of eradication of the chytrid fungus (Bosch et al. 2015).

Poison-dart frogs have been zoo exhibit amphibians for many years, due to bright colors, hardiness, and diurnal activity (Wagner 1987; Fig. 7). Large numbers were imported by pet wholesalers during the 1960s but the employees were often unaware and shocked upon learning that these amphibians required living prey, rather than the tropical fish flake food they offered in piles. In Tierpark Berlin, Dathe and Dedekind (1991) explored the care and breeding of Venezuelan Tree Climbers (*Mannophryne trinitatis*) and at Edinburgh Zoo, Blake (1990) outlined cage design. At Sedgwick County Zoo in Kansas, Grow (1980) described husbandry of the Orange-Striped Poison Dart Frog (*Phyllobates vittatus*). At Berlin Aquarium, Lange (1981) described the program of the Green-and-Black Poison



FIG. 7. Poison-dart frogs from "Proceedings of the Scientific Meetings of Zoological Society of London." Between 1861–1929, a continuous series of lovely drawings were produced by Zoological Society of London.

Dart Frog (*Dendrobates auratus*), resulting in 32 clutches with 173 frogs successfully reared. Knepper (1993) produced the Azure Dart-Poison Frog (*Dendrobates tinctorius*) at Chaffee Zoo in California. At Ueno Zoo in Japan, Fujitani et al. (1998) propagated the Amazonian Poison Frog (*Ranitomeya ventrimaculata*). At Durrell Wildlife Conservation Trust, Preece (1998) described captive management and breeding of poison-dart frogs. At National Aquarium in Baltimore, Jack Cover and his associates have published many significant papers on the care, maintenance, and reproduction of poison-dart and hylid frogs (e.g., Cover 1992; Cover et al. 1994), and Stoskopf et al. (1985) discussed iodine toxicity. Dugas et al. (2013) provided carotenoid supplementation to enhance reproductive success in captive Strawberry Poison Frogs (*Oophaga pumilio*).

In the Cologne Zoo journal *Zeitschrift des Kölner Zoo*, Zimmermann and Zimmermann published many reports on the biology, captive breeding, and conservation of poison dart frogs (see Zimmermann and Zimmermann 1994). A spectacular new book has been recently published that will be of considerable value to zoo and aquarium workers (Kahn et al. 2016). This tome covers common names, taxonomic comments, identification and description, identification and description of larvae and froglets, similar species, alkaloid profiles, natural history and ecology, calls and vocalizations, reproduction, distribution, threats and conservation status. The frog images by Ted Kahn are phenomenal, some of the finest examples we have ever seen. Academic and zoo biologists have studied amphibian toxins, discovering that the toxins of dendrobatids are the result



FIG. 8. White's Treefrog (*Litoria caerulea*) from *Journal of a Voyage to New South Wales...of Non Descript Animals, Birds, Lizards...* by John White in 1790. An individual lived for over 19 years at Dallas Zoo.

of dietary preferences. Captive-reared individuals denied that critical diet, such as formicine ants, are non-toxic (see Daly et al. 1992, 1994), thus presenting a significant deficit if reintroduction is attempted. The Cali Zoo in Colombia has partnered with other zoos to create a conservation breeding center for Lehmann's Poison Frog *Oophaga lehmanni*, the Golden Poison Frog *Phyllobates terribilis*, Yellow-striped Poison Frog *Dendrobates truncatus*, and three different morphs of Harlequin Poison Frog *Oophaga histrionica* (Furrer and Corredor 2008).

At Houston Zoo, Odum et al. (1983) used hormones to stimulate breeding and rearing of White's Tree Frog (*Ranoidea caerulea*), a species commonly kept in the private sector and zoos, and Bradley and Wright (2000) described captive care and breeding of this tree frog (Fig. 8). A specimen at Dallas Zoo was still alive after 19+ years. Miller (1983) noted breeding of the Red-Eyed Tree Frog (*Agalychnis callidryas*). Fenolio (1996) described captive reproduction of the Orange-Legged Monkey Frog (*Pithecopus hypochondrialis*). Augustine (2011) described the endangered Lemur Tree Frog (*Agalychnis lemur*) egg and tadpole development at Bronx Zoo. This species has been bred at Paignton Zoo in Devon, England by incorporating a rain chamber using a water pump and timer system to make it rain every few hours during the day to simulate the wet season. A total of 18 tadpoles have become full froglets. The Honduras Amphibian Rescue and Conservation Center works with the Henry Doorly Zoo & Aquarium in Omaha, Nebraska on critically endangered Exquisite Spike-thumb Frog (*Plectrohyla exquisita*), the Cusuco Spike-thumb Frog (*Plectrohyla dasypus*), and the Mossy Red-eyed Frog (*Duellmanohyla soralia*). One of the most depressing anuran stories centers on the spectacular Rabb's Fringed-Limbed Treefrog (*Ecnomiohyla rabborum*) which is now likely extinct. This large gliding treefrog was discovered and named in honor of George and Mary Rabb in 2008 (Mendelson et al. 2008). The last living representative, a male named "Toughie," died at the Atlanta Botanical Gardens on 26 September 2016 and was thought to be at least 12 years old. Tissues were sent to San Diego Zoo's "Frozen Zoo."

At the Daytona Expo some years ago, JBM and colleagues were sitting beneath a covered hotel driveway watching a hurricane roar through the city. A young woman was bemoaning that the only herp she had wanted was a Cuban Tree Frog (*Osteopilus septentrionalis*) to put in her frog terrarium but none were available for sale. She was disappointed as she had traveled a considerable distance to Florida by car but to no avail—an unsuccessful return trip sans frog would be a long, unhappy drive indeed. A few moments later, an adult Cuban Tree Frog



FIG. 9. David Dennis, co-founder of SSAR with Kraig Adler, illustrated William Duellman's *Hylid Frogs of Middle America*. From top to bottom—*Hyla miliaria*, *Hemiphractus panamensis* [= *Hemiphractus fasciatus*], *Anotheca spinosa*. All plates are offered for sale by the Society.

flew through the air and stuck to her face. After the initial shock, she emptied her popcorn box, peeled the frog off her cheek, and happily returned to her room with her new pet.

Banks et al. (2008) outlined procedures for captive management and breeding of Romer's Tree Frog, *Liuixalus romeri*. In the early 1990s, a significant portion of the range of this species was threatened by the construction of the new international airport in Hong Kong. Melbourne Zoo, Australia, partnered with the University of Hong Kong to establish a captive breeding program as part of a broader conservation initiative to secure the species in the wild. Large numbers of frogs were successfully bred at both facilities, underpinning the success of subsequent releases. At San Diego Zoo, Schafer (1981) described her techniques for rearing the Asiatic Tree Frog (*Polypedates leucomystax*). Wildenhues et al. (2011) described captive management and reproductive biology of Orlov's Treefrog (*Rhacophorus orlovi*), including larval description, color pattern variation, and advertisement call. Paine and Weinheimer (1984) discussed tube-feeding.

Gagliardo et al. (2010) observed captive reproduction of the Horned Marsupial Frog (*Gastrotheca cornuta*), and a successful founding population continues to grow in Panama at the El Valle Amphibian Conservation Center (Gratwicke et al. 2016). Centro Jambatu de Investigación y Conservación de Anfibios and the Bolsa de Sapos in Ecuador is producing surplus captive-bred *Gastrotheca riobambae* and has successfully used assisted reproduction methods with this species (Cadena Quevedo and García Romo 2012).

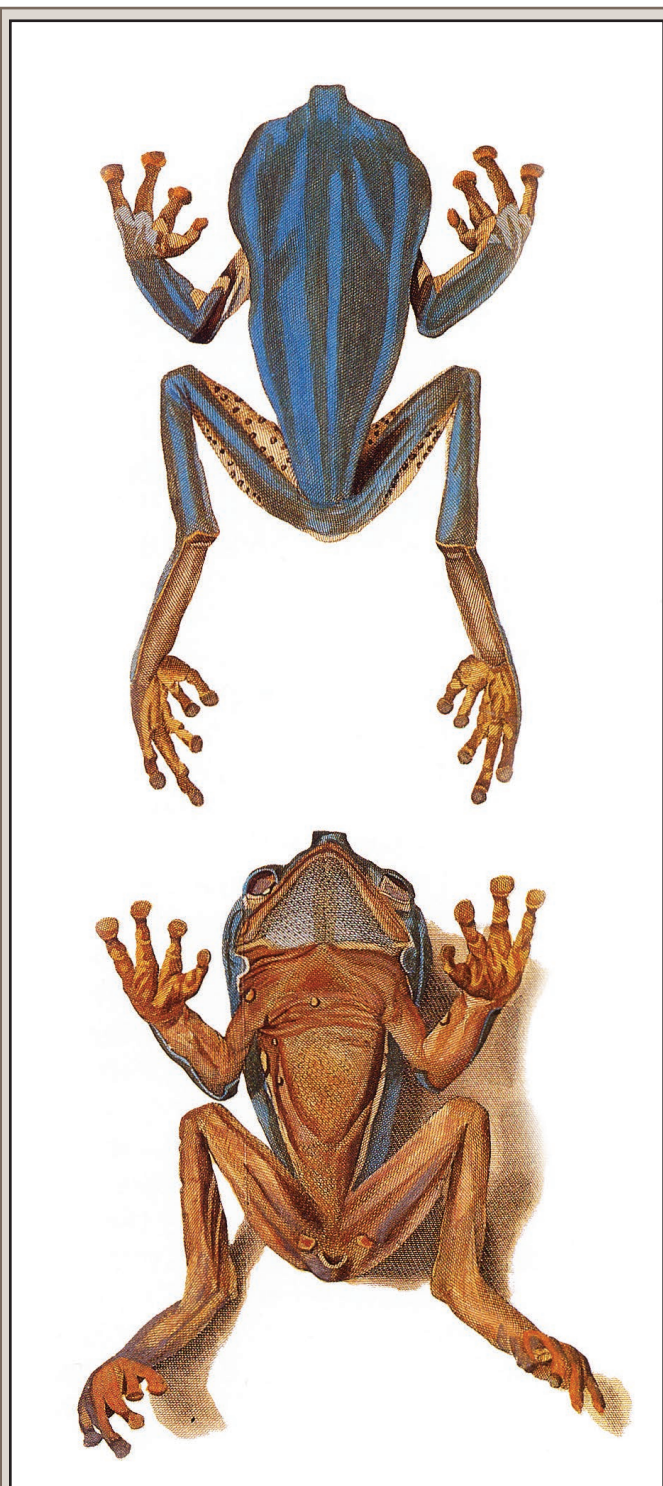


FIG. 10. Blue-and-yellow Leaf Frog (*Phyllomedusa bicolor*) from *Musaeum Schlosserianum* by Johannes Schlosser and Pieter Boddaert in 1768–1772. Be sure to read “Frog secretions and hunting magic in the upper Amazon: Identification of a peptide that interacts with an adenosine receptor” by John Daly et al. 1992 (full citation in Literature Cited).

At Dallas Zoo, amphibian keeper Thomas Jordan (1969) successfully kept a diverse collection of treefrogs including three male Spiny-Headed Treefrogs (*Anotheca spinosa*; Fig. 9), a small group of Giant Monkey Frogs (*Phyllomedusa*



FIG. 11. Horned frog (*Ceratotryps aurita*) in *Abbildungen zur naturgeschichte Brasiliens* by A. P. M. Wied-Neuwied in 1822–1831. Horned frogs use pedal movements to lure prey. See text.



FIG. 12. Frog metamorphosis from *Dissertation sur la generation et les transformations des insectes de Surinam* in 1717 by Maria Sibylla Merian.

bicolor; Fig. 10) and Orange-Legged Leaf Frogs (*Pithecopus hypochondrialis*), a couple of Fairy Treefrogs (*Charadrahyla chaneque*), Red-eyed Treefrogs (*A. callidryas*), Common Mexican Tree Frog (*Smilisca baudinii*), Shovel-headed Tree Frog (*Tripirion spatulatus*), Colorado River Toad (*Incilius alvarius*), Red-spotted Toad (*Anaxyrus punctatus*), Green Toad (*Anaxyrus debilis*), Malaysian Narrow-mouth Toad (*Kaloula pulchra*), Red-belly Toad (*Melanophryniscus stelzneri*), Boulenger's Tree Toad (*Pedostibes hosii*), several species of African Reed Frogs



FIG. 13. Heinrich Rudolf Schinz, Professor of natural history at University of Zürich, published detailed illustrations of anuran reproduction in 1833.

(*Hyperolius*), Harlequin Frogs (*Atelopus varius*, *A. chiriquiensis*, *A. cruciger*, *A. senex*, *A. zeteki*), Golden Frog (*Ranoidea aurea*), Marnock's Frog (*Eleutherodactylus marnockii*) and a number of other North American species. A number of Woodhouse's Toads (*Incilius woodhousei*) and Gulf-Coast Toads (*I. nebulifer*) lived peacefully throughout the year with a number of small US desert lizards in a large outdoor planted display at Dallas Zoo. During winter months, they all hibernated, often together, within rock crevices. Beginning in spring, when male toads began calling upon emergence and continuing until late fall these anurans basked throughout the day on flat rocks in direct sunlight. Temperatures on rock surfaces reached over 120°F (49°C) yet the toads rarely moved into shaded areas unless food was being offered. Although toad core temperatures were not taken, one possibility was to elevate body temperatures to deal with disease issues such as *Bd* (see Karavlan and Venesky 2016). It was unexpected that these toads would congregate around food pans with lizards, all taking advantage of the hordes of hymenopterans gliding in to feed on fruit. Neither lizards nor frogs appeared to be stung.

At Dallas Zoo, an adult pair of *Eleutherodactylus inoptatus* from Hispaniola laid egg jelly masses annually. The tails of embryos appeared to adhere to the jelly mass about midway during development. Froglets emerged but were difficult to feed. The Philadelphia Zoo maintains nine assurance colonies of endangered endemic Haitian *Eleutherodactylus*, and over 1500 individuals have resulted. Hill et al. (2010) described captive reproduction of Gage's Rain Frog (*Pristimantis gaigeae*). Two specimens of Tungara Frog (*Engystomops pustulosus*) lived well over seven years at Dallas Zoo.



Murphy (1976) and Radcliffe et al. (1986) observed pedal luring in horned frogs (*Ceratophrys calcarata* and *C. ornata*) (Fig. 11). It had made little sense that such heavy-bodied frogs could capture agile treefrogs and other quick prey, but one day JBM noticed an anole trying to get into the horned frog tank. The frog brought a hind limb over the dorsum toward its mouth and vibrated digits, which looked very much like living grubs. Horned frogs lured vertebrates susceptible to the deception such as frogs and small lizards but ignored invertebrates. As reported by Radcliffe et al. (1986), observations on *Odontophrynus* and *Caudiverbera* revealed that neither exhibited behavior that could be construed as luring. Schalk et al. (2014) discussed the diet of the frogs of the Ceratophryidae. Johnson (1984) bred the Bell's or Ornate Horned Frog (*Ceratophrys ornata*) without hormones. Honegger et al. (1985) discussed reproduction using hormonal injections, development and analysis of male call, and breeding of this frog.

Zippel (2006) described biology, husbandry, and oviposition in the Surinam Toad (*Pipa pipa*), and Weygoldt (1976a, 1976b) reported on the biology and reproduction of the related *P. carvalhoi*. Sclater (1895) and Bartlett (1896, see also Scherren 1905:212) observed breeding of *Pipa surinamensis*, *P. americana* (now *P. pipa*) at London Zoo. Two of the most impressive examples of early drawings of anuran metamorphosis were published by Maria Sybilla Merian and Heinrich R. Schinz, professor of zoology at University of Zürich (Figs. 12, 13). The Ueno Zoo has reproduced Surinam Toads (Shibuya 1978). George Rabb from Brookfield Zoo has published on sound production, fighting, mating behavior, development, and general reviews on pipid frogs (Rabb 1960, 1969, 1973; Rabb and Rabb 1960, 1963; Rabb and Snedigar 1960).

One potentially serious disease possibility is the broad availability of Dwarf Clawed Frogs (*Hymenochirus*) and African Clawed Frogs (*Xenopus*) offered for sale in pet shops. There is a real possibility that more of these frogs may be released into the wild. *Xenopus* has already been introduced into parts of the USA, Mexico, Indonesia, Chile, and Europe. Another issue is animal welfare as some pet shop employees are unaware that these frogs require living prey and as a result, these amphibians may be seriously emaciated and near death. Michaels et al. (2015) of the Zoological Society of London successfully bred the evolutionarily distinct Lake Oku Clawed Frog, *Xenopus longipes*, from Cameroon; this species has experienced enigmatic mortality events in the wild (Blackburn et al. 2010).

From the Duisburg Zoological Garden in Germany, Gewalt (1977) covered catching, transport, and keeping of the rare Goliath Frog (*Conraua goliath*). Gillespie et al. (1988/1989) sexed Goliath Frogs by laparoscopy at the Cincinnati Zoo. Herrmann (2003) and Herrmann and Herrmann (2002) discussed conservation challenges. Herrmann and Edwards (2006) discussed skittering locomotion. Because these frogs are nervous and are capable of jumping long distances—sometimes injuring themselves in captivity—several innovations for maintaining them have been developed. At Brookfield Zoo, an individual lived for over four years in a large semi-aquatic tank with the pool of water at the front glass. At Ft. Worth Zoo, strips of rubberized cloth were hung as a barrier throughout the enclosure should the frog leap. At Amsterdam Zoo, an adult was kept in an aquarium only slightly larger than the frog.

Gupta (1998) offered observations on rapid reproduction (Figs. 14, 15). During the period of ca. 1920–1960s, thousands of live Northern Leopard Frogs (*Rana pipiens*) and other ranids were collected annually by biological supply companies. These

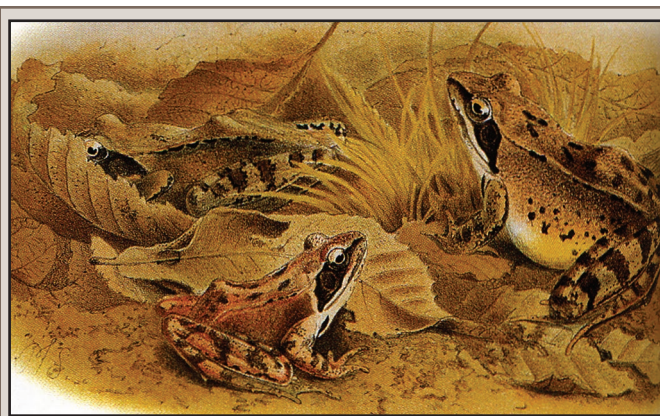


FIG. 14. George A. Boulenger was a leading taxonomist in his time and published many books such as the British Museum catalogues, and *Tailless Batrachians of Europe* in 1896–1897. Shown here is Agile Frog (*Rana dalmatina*).

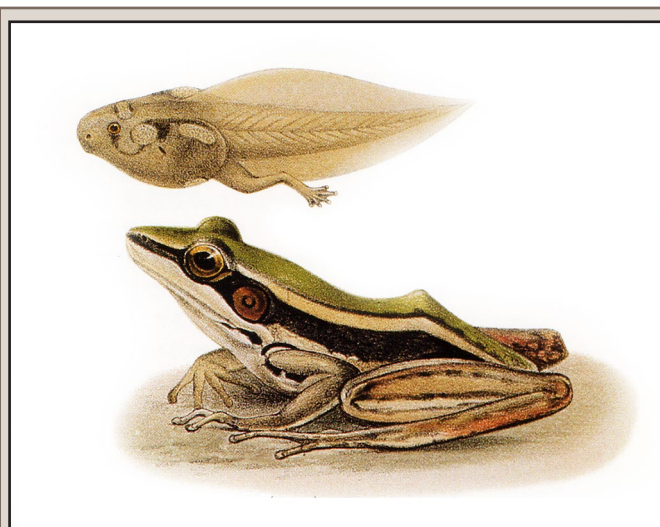


FIG. 15. Two additional examples of fine artwork supported by Zoological Society of London—Golden-lined Frog tadpole (*Rana chalconota*) and Red-eared Frog (*Rana erythraea*).

amphibians were sent to high school and college biology classes where they were immobilized by inserting a thin metal rod or dissecting needle into the brain and spinal column, a procedure known as brain pithing. The frog remains living due to respiration through the skin but without cerebral control, allowing it to be dissected while observing its beating heart, and expansion and contraction of its lungs. Each student or group of students received a dissecting tray and a packet of tools with dissecting needle, tweezers, scissors, and scalpel and was given a live frog. Naturally, many students were squeamish and felt that the procedure was inhumane. Fortunately, this practice is now rarely used in classrooms, due in part to strong anti-dissection sentiments in the 1980s. The number of frogs sacrificed over the years was astounding. There are estimates that 75–80% of US schools engaged in this practice (Semlitsch 2003).

At Smithsonian National Zoological Park (SNZP), studies are ongoing on the Lowland Leopard Frog (*Rana yavapaiensis*) to elucidate genetic responses to *Bd* with the goal of determining host responses to the fungus (Savage and Zamudio 2011; Savage et al. 2016). The Calgary Zoo is involved in a long-term monitoring project with the Northern Leopard Frog (*Rana*

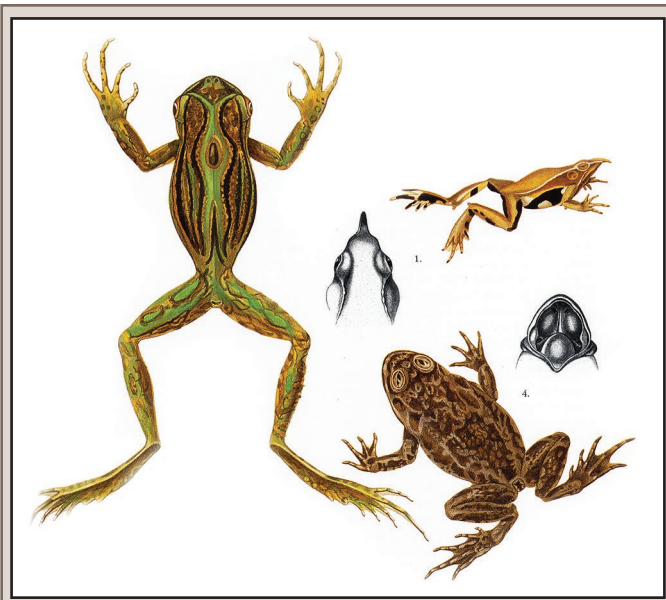


FIG. 16. Illustration from *Historia física y política de Chile...* by Claude Gay in 1844–1871. Darwin's Frog is near extinction.

*pipiens*). The Oregon Spotted Frog (*Rana pretiosa*) reintroduction program involves four participants—Woodland Park Zoo, Oregon Zoo, Northwest Trek Wildlife Park, and Cedar Creek Correctional Center in Washington. Over 5400 specimens have been released. The Atlanta Botanical Garden's newly established Center for Southeastern Conservation is formalizing a regional plant conservation network for the Southeast USA. Regionally, the Garden has worked with partners to increase the number of Georgia's rare Carolina Gopher Frogs (*Rana c. capito*) in the wild by collecting fertile eggs, raising them to small froglets in captivity, and releasing them to a protected habitat. In 2016, the San Francisco Zoo and Gardens and partners planned to reintroduce 4000 tadpoles and 500 adult California Red-Legged Frogs (*Rana draytonii*) in Yosemite National Park, part of that species' historical range but not been observed there for the last half century (AZA Connect 2016). Shiihara and Samejima (1995) propagated Ishikawa's Frog (*Rana ishikawae*) at Nagasakibana Parking Garden, Kagoshima, Japan. Their paper includes photographs of the enclosure, egg masses, tadpoles, and metamorphs.

Other anurans threatened with extinction have been reproduced in captivity. Bourke (2010) described Darwin's Frog (*Rhinoderma darwinii*) captive rearing facility in Chile (Fig. 16). At Alfred Koenig Museum in Bonn, Germany in 1989, Wolfgang Böhme showed JBM a large planted terrarium in an unheated greenhouse that housed all sizes of frogs, certainly a successful breeding program. Fenolio et al. (2011) reviewed conservation status of the Chile Mountains False Toad (*Telmatobufo venustus*) and mentioned assurance colonies of Darwin's Frogs at National Zoo in Chile and Atlanta Botanical Garden. One of the two described species (*Rhinoderma darwinii*) has declined across parts of its traditional range, particularly in the north, and the second described species (*R. rufum*) has not been seen since the 1970s and is presumed extinct, possibly due to chytridiomycosis-related declines (Soto-Azat et al. 2013a, 2013b). At least two in-country captive breeding programs exist in Chile and one of them that is associated with the National Zoo and the Austral University is keeping tabs on the spread of emergent infectious

amphibian disease across southern Chile (Danté Fenolio and William Lamar, pers. comm.).

Another high priority in the Andean region of Bolivia and Peru is the critically endangered Lake Titicaca Frog (*Telmatobius culeus*). Once common, this species has crashed precipitously. There have been a few captive-breeding programs around the lake but these have been relatively unsuccessful. The Denver Zoo has been involved in studying population estimates using distance sampling and swabbing frogs for DNA analysis of *Bd*. Should an expanded future program be envisioned, an excellent template is provided by Genova (2011). Other congeners are at risk, such as the Acancocha Water Frog (*Telmatobius jelskii*). Jessica Deichmann and Ed Smith from SNZP have been surveying populations over four seasons as part of the initiative called *Monitoring Biodiversity: Lessons from a Trans-Andean Megaproject* (Alonso et al. 2013). Recently, a new frog (*Telmatobius mendelsoni*) was named in honor of Joe Mendelson at Zoo Atlanta for his sustained efforts to save amphibians (De la Riva et al. 2012). Like others in this genus, this species is rapidly declining and the shrinkage has been associated with outbreaks of *Bd*. Arturo Muñoz Saravia from Museo de Historia Natural Alcide d'Orbigny in Cochabamba, Bolivia sent an urgent email to amphibian biologists in October 2016 updating the dire situation regarding *Telmatobius*. Probably the last male individual of *T. yuracare* exists in captivity although several trips to find females were unsuccessful. He contacted Dr. De La Riva and it seems that this is the situation for all the *Telmatobius* from mountain cloud forest habitats where previously these frogs were common but now appear to be gone.

Madagascar has a megadiverse assemblage of frogs, many of them threatened and the recent discovery of the amphibian chytrid fungus there means that existing captive collections and knowledge of their care assumes heightened importance, even though chytrid-related declines have not been confirmed (Andreone et al. 2008; Bletz et al. 2015). Several unsettling overviews of the anuran future there have been published: Andreone and Luiselli (2003), Andreone (2005), Mattioli et al. (2006), Andreone et al. (2006), Garcia et al. (2008), Lötters et al. (2011), and others. The Mitsinjo captive breeding facility has built extensive capacity and a large, prolific assurance colony of Golden Mantellas (*Mantella aurantiaca*) (Edmonds et al. 2012) and has experience breeding several other species of native frogs, including *Mantidactylus betsileanus*, whose tadpole dietary preferences are described by Soamiarimampionona et al. (2015). Scheld et al. (2013) also studied *Mantidactylus betsileanus* at Cologne Zoo. At Association Mitsinjo, Edmonds et al. (2016) reproduced the treefrog *Booophis pyrhus*. With the cooperation of Université d'Antananarivo, Département de Biologie Animale, and the Parc Botanique et Zoologique de Tsimbazaza, Segev et al. (2012) described reproductive phenology of the Tomato Frog, *Dyscophus antongili*, in an urban pond of Madagascar's east coast. De Vosjoli and Mailloux (1990) outlined the husbandry and propagation of the Malagasy Tomato Frogs, *Dyscophus antongilii* and *D. insularis*.

Yoshimi et al. (1996) maintained and bred the unusual Solomon Island Leaf Frog (*Cornufer guentheri*) at Woodland Park Zoo in Seattle, Washington. Narayan et al. (2009) worked to propagate the endangered native Fijian frog *Cornufer vitianus*. The plan was to develop methods for supplementing populations in the wild. In 2004, a captive propagation program was instituted at Kula Ecopark, Sigatoka, Fiji. Only a single froglet was reared after three years. Two years later, a more intensive program was undertaken

between the University of the South Pacific (USP), Kula Ecopark, and the community on Viwa Island. The aim of this program was to create an outdoor enclosure to mimic natural habitat conditions so the frogs could exhibit natural breeding behaviors. A total of 39 froglets was reared after one year using this approach.

Maintaining healthy captive collections of New Zealand native frogs (*Leiopelma* spp.) has been challenging for a number of reasons (Butler 1992; Bell 1985; Holyoake et al. 2001). From 2000 to 2004, approximately 252 wild *Leiopelma* were collected and brought into captivity at Canterbury University for captive propagation and research. In late 2005–2006, the 154 remaining frogs from Canterbury University were split by species and sent to different institutions. All *L. archeyi* went to Auckland Zoo, *L. hochstetteri* to Hamilton Zoo, and *L. pakeka* went to the University of Otago, Dunedin and Zealandia (previously Karori Sanctuary) in Wellington. In December 2006, 16 additional *L. archeyi* obtained from the Whareorino Forest were sent to Auckland Zoo and 12 to the University of Otago. Shaw and Holzapfel (2008) recorded mortality and Shaw et al. (2012) suggested fluorosis as a probable factor in metabolic bone disease. Shaw (2014) improved captive maintenance techniques, which have been successful. Sharbel and Green (1989) discussed captive maintenance as well.

Australia has a long history of amphibian conservation and responding to chytridiomycosis, and researchers and conservation workers have developed considerable capacity, including in captive assurance efforts. Their experiences are well summarized by Tyler (1996), Scheele et al. (2014), and Skerratt et al. (2016). Zoo Victoria works on captive assurance colonies of Baw Baw Frogs (*Philoria frosti*) (Scheelings 2015). Byrne and Silla (2010) recommended hormonal induction of gamete release and in-vitro fertilization in the critically endangered Southern Corroboree Frog, (*Pseudophryne corroboree*). The Taronga Zoo has maintained captive populations of Northern Corroboree Frogs since 2010, and release trials from a captive assurance colony have shown that captive supplementation can help population persistence, even in the presence of chytridiomycosis (McFadden et al. 2016). The Taronga Zoo and Zoo Victoria have also been heavily involved in developing captive breeding and conservation plans for several endangered *Litoria* species (McFadden et al. 2008; Scheelings 2015). Banks et al. (2014) give a detailed account of the captive propagation of Stuttering Frogs (*Mixophyes balbus*). At Melbourne Zoo, Birkett et al. (1999) kept and reared the Roseate Frog (*Geocrinia rosea*). Gollmann (1995) bred the Australian frog *Neobatrachus sudelli*.

Ivanyi (1989) reproduced the Black-Eared Frog (*Leptodactylus melanonotus*) at Arizona-Sonora Desert Museum. Gibson and Buley (2004) described foam nests on land, terrestrial tadpoles, and obligatory oophagy in the endangered Montserrat Mountain Chicken (*Leptodactylus fallax*) at Jersey Zoo. This taxon is almost extinct due to *Bd*. The species is found on Montserrat and Dominica but has virtually disappeared from both places (Hudson et al. 2016). Two frogs were collected in the wild in separate locations on Montserrat and were relocated to a site for breeding purposes by Durrell Wildlife Conservation Trust, while others were bred at the Zoological Society of London. Tapley et al. (2015) describe metabolic bone disease issues and how UV supplementation resolved them. Unfortunately, field releases have been unsuccessful, even though field treatments with the anti-fungal drug itraconazole extended survival time from 49 to 124 weeks (Hudson et al. 2016).

One day, a husband and wife team driving an eighteen-wheeler semi-trailer truck wanted to donate a group of Fire-Bellied

Toads (*Bombina bombina*) to the Dallas Zoo. The frogs that had been traveling with them for many years. The small plastic container, which was the housing, was attached to the dashboard, held in place with Velcro. Each time they stopped at a restaurant or motel, the container was peeled off the truck and carried by them indoors so the amphibians would not overheat or encounter cold temperatures. Amazingly, there were egg masses, tadpoles, froglets, and adult frogs living together. Of course, the couple suffered separation anxiety but they were assured that the group would soon go on exhibit. It turned out to be a most interesting exhibit on frog development. Its success was reminiscent of William Conway's seminal papers (1969, 1973) on how to exhibit a bullfrog.

#### CAPTIVE AND MEDICAL MANAGEMENT

Why are there declines? In 2004, Stuart et al. published a paper containing sobering information: 1) amphibians are more threatened and are declining more rapidly than either birds or mammals; 2) although many declines are due to habitat loss and overutilization, unidentified processes threaten 48% of rapidly declining species and are driving species most quickly to extinction; 3) declines are nonrandom in terms of species' ecological preferences, geographic ranges, and taxonomic associations and are most prevalent among Neotropical montane, stream-associated species; 4) hundreds of species now face extinction over the next few decades; 5) four families are particularly impacted: gastric-brooding frogs (Rheobatrachidae, now extinct), "typical" Neotropical frogs (Leptodactylidae), true toads (Bufonidae), and mole salamanders (Ambystomatidae). This information is still current.

Reichenbach-Klinke (1961) discussed amphibian disease in his book *Krankheiten der Amphibien*. Allan Pessier and associates from the Amphibian Diseases Laboratory at the San Diego Zoo have published a number of papers on amphibian maladies (Pessier et al. 2002, 2009, 2013, 2014; Baitchman and Pessier 2013; Rodríguez and Pessier 2014). Gentz (2007) described medicine and surgery at Albuquerque Zoo. Hadfield and Whitaker (2005) provided recommendations for emergency medicine and care. Wright (1996) and Wright and Whitaker (2001) provided an overview of husbandry and medicine, and Rundquist (1993) presented suggestions for future veterinary investigations. Densmore and Green (2007) provided an overview of diseases. Elkan (1976) discussed pathology. Burns from the Louisville Zoo (1995) offered suggestions for the humane euthanasia of reptiles, amphibians, and fish. Stetter and Cook (1994) presented normal and pathological ultrasonographic anatomy of amphibians. King et al. (2011) published on radiographic diagnosis of metabolic bone disease in captive bred Mountain Chicken Frogs (*Leptodactylus fallax*). Brazaitis and Watanabe (1982) recommended the Doppler, a new tool for amphibian hematological studies.

Stetter et al. (1996) used isoflurane anesthesia in amphibians and compared five application methods. Upton et al. (1992) discovered testicular myxosporidiasis in the African Flat-backed Toad (*Bufo maculatus*). Miller et al. (1992) documented an outbreak of disseminated chromoblastomycosis in a colony of Ornate-horned Frogs, and Teare et al. (1991) published on pharmacology of gentamicin in the Northern Leopard Frog (*Rana pipiens*) at SNZP. Maslow et al. (2002) reported an outbreak of *Mycobacterium marinum* infection among captive snakes and bullfrogs. Reports have documented *M. ranae* (*fortuitum*) and *M.*

*xenopi* infection in a frog and toad. A later report described an outbreak of mycobacterial infection among wild Bolivian frogs. The detection of mycobacteria among captive animals in zoos and/or aquaria raises many questions about treatment.

Drake et al. (2010) treated 13 Tomato Frogs (*Dyscophus antongilii*) with Red Leg Disease. This disease is a severe, and usually acute, bacterial infection of amphibians. Its name derives from hemorrhages of the leg (often the inner thigh) as a result of septicemia. Other parts of the body and internal organs may be affected.

Ackermann and Miller (1992) diagnosed chromomycosis in an African Bullfrog (*Pyxicephalus adspersus*). Suedmeyer et al. (1997) discovered chromomycosis in a Marine Toad (*Rhinella marina*) at the Kansas City Zoo. Duncan et al. (2004) saw renal myxosporidiosis in Asian Horned Frogs (*Megophrys nasuta*).

At SNZP, pathologist Don Nichols was instrumental in documenting respiratory diseases and cutaneous chytridiomycosis (Nichols 2000, 2003; Nichols et al. 1996, 1998, 2000, 2001). In 2003, Nichols published an article in *Herpetological Review* describing his difficulties in isolating a new pathogenic fungus first seen in California Arroyo Toads (*Anaxyrus californicus*) in 1991 and that was responsible for a fatal skin disease in frogs and toads. Until then, no chytrids had ever been recognized as pathogens in vertebrate animals. This devastating organism is now known as *Batrachochytrium dendrobatidis* (or *Bd*)—"frog chytrid of dendrobatids." This fungus has caused marked declines of wild populations of anurans in Australia, New Zealand, North America, South America, Africa, Europe, and Central America. Increasing evidence from Australia and Central America supports the hypothesis that the pattern of amphibian declines and extinctions, especially the wave-like pattern in Central America, is due to the spread of the chytrid fungus through tropical forests. Fites et al. (2013) found that this fungus paralyzes lymphocyte responses, suggesting that evasion of host immunity may explain the virulence of this pathogen. Harris et al. (2009) found that skin microbes prevent morbidity and mortality. Whittaker and Vredenburg (2014) provide an excellent overview of chytridiomycosis.

Cutaneous chytridiomycosis has been implicated as a major cause in global amphibian declines. Young et al. (2007) provided strategies to deal with amphibian chytridiomycosis for captive management and conservation. Augustine and Neff (2016) determined the prevalence of this pathogen and *Ranavirus* at Long Branch Nature Center in Arlington, Virginia. Ellison et al. (2014) described the vigorous immune response countered by pathogen suppression of host defenses in the chytridiomycosis-susceptible frog *Atelopus zeteki*. Evans et al. (2012) provided a description of an exhibit at SNZP about the Panama Amphibian Rescue and Conservation Project to highlight a conservation response to the chytrid crisis in Panama. Miller et al. (2008) described infection with ranavirus, *Bd*, and *Aeromonas* in a captive anuran colony. Spitzen-van der Sluijs et al. (2011) found that clinically healthy amphibians in captive collections and at pet fairs were a potential reservoir of *Bd*.

Claunch and Augustine (2015) provided a morphological description of Spindly Leg Syndrome in Golden Mantella (*Mantella aurantiaca*) at SNZP. This taxon is highly endangered so Steinhart Aquarium is exploring a method for reproducing this frog; over 300 have been produced and one-third of the propagules have been sent to other zoos. Driskell et al. (2009) used PCR detection of ranavirus in adult anurans from Louisville Zoological Garden. Mutschmann (1998) found evidence of *Chlamydia psittaci* infections in amphibians, obtained by

means of a specific immunofluorescence test (IFT). McNamara et al. (1999) reported crystalline inclusions associated with vomeronasal organ pathology in Red-eyed Tree Frogs (*Agalychnis callidryas*). Main (1998) saw an outbreak of mucormycosis in Slender Tree Frogs (*Litoria adelensis*) and White-lipped Tree Frogs (*Litoria infrafrenata*) at Perth Zoological Gardens. Whitaker and Poyton (1993) identified and recommended treatments for protozoans in dendrobatid frogs. Garner et al. (1995) diagnosed diseases of Solomon Island Leaf Frogs (*Ceratobatrachus guentheri*) at Woodland Park Zoo by consulting 75 necropsy cases. At Calgary Zoo in Canada, Honeyman et al. (1992) found *Bordetella* septicemia and chlamydiosis in this species. Imai et al. (2009) found rhabditid nematode-associated ophthalmitis and meningoencephalomyelitis in captive Asian Horned Frogs (*Megophrys montana*). Graczyk et al. (1996) discovered Progressive Ulcerative Dermatitis in a captive, wild-caught South American Giant Tree Frog (*Phyllomedusa bicolor*) with Microsporidial Septicemia.

*Acknowledgments.*—This contribution is dedicated to Karen R. Lips from University of Maryland and Joseph R. Mendelson III from Zoo Atlanta. Their collaborative efforts are a perfect example of a sustained research output between an academic herpetologist and zoo biologist. They have published many important papers on amphibian decline, taxonomy, systematics, biogeography, and conservation.

Judith Block reviewed an early draft and made helpful suggestions. For various courtesies, we thank Lauren Augustine, Jon Campbell, Danté Fenolio, Bill Lamar, and Ray Pawley. Read "Perspectives in Conservation: An Interview with Ray Pawley" (HR47:413–416).

Most of the historical illustrations in this presentation are from the collections of the Smithsonian Institution Libraries (the Joseph E. Cullman 3rd, Library of Natural History and the National Museum of Natural History Library). Special thanks to librarians Polly Lasker, Kristen Bullard, and Leslie Overstreet and Daria Wingreen from the Joseph E. Cullman 3rd Library of Natural History (SI Special Collections Department).

#### LITERATURE CITED

- AARK. 2016 Amphibian Ark Website: Progress of Programs. Available online at: <http://progress.amphibianark.org/progress-of-programs> (accessed 9/9/2016).
- ACKERMANN, J., AND E. J. MILLER. 1992. Chromomycosis in an African bullfrog, *Pyxicephalus adspersus*. *Bull. Assoc. Rept. Amphib. Vet.* 2:8–9.
- ALONSO, A., F. DALLMEIER, AND G. P. SERVAT (eds.). 2013. Monitoring Biodiversity: Lessons from a Trans-Andean Megaproject. Smithsonian Inst. Press, Washington DC. 429 pp.
- ANDREONE, F., AND L. M. LUISELLI. 2003. Conservation priorities and potential threats influencing the hyperdiverse amphibians of Madagascar. *Ital. J. Zool.* 70(1):53–63.
- , J. E. CADLE, N. COX, F. GLAW, R. A. NUSSBAUM, C. J. RAXWORTHY, S. N. STUART, D. VALLAN, AND M. VENCES. 2005. Species review of amphibian extinction risks in Madagascar: conclusions from the Global Amphibian Assessment. *Conserv. Biol.* 19(6):1790–1802.
- , A. I. CARPENTER, N. COX, L. DU PREEZ, K. FREEMAN, S. FURRER, G. GARCIA, F. GLAW, J. GLOS, D. KNOX, J. KÖHLER, J. R. MENDELSON III, V. MERCURIO, R. A. MITTERMEIER, R. D. MOORE, N. H. C. RABIBISOA, H. RANDRIAMAHAZO, H. RANDRIANASOLO, N. R. RAMINOSOA, O. R. RAMILJAONA, C. J. RAXWORTHY, D. VALLAN, M. VENCES, D. R. VIEITES, AND C. WELDON. 2008. The challenge of conserving amphibian megadiversity in Madagascar. *PLoS Biol.* 6, no. 5:e118.
- ANTWIS, R. E., AND R. K. BROWNE. 2009. Ultraviolet radiation and Vitamin D3 in amphibian health, behaviour, diet and conservation. *Comp. Biochem. Physiol. A: Mol. Integr. Physiol.* 154(2):184–190.

- ASSOCIATION OF ZOOS AND AQUARIUMS. 2007. Amphibian Conservation and Resource Manual, edited by Shelly Grow and Vicky A. Poole. 109 pp.
- . 2016. California red-legged frogs and western pond turtles to be restored in Yosemite National Park. Connect October 2016:14–15.
- AUGUSTINE, L. 2011. Lemur tree frog (*Hylomantis lemur*) egg and tadpole development at the Bronx Zoo. IRCF Reptiles & Amphibians 18(4):63–64.
- AUGUSTINE, L., AND M. NEFF. 2016. Determining the prevalence of amphibian chytrid fungus (*Batrachochytrium dendrobatidis*) and *Ranavirus* at Long Branch Nature Center in Arlington, Virginia. Catesbeiana 36(1):35–42.
- BARTLETT, A. D. 1896. Notes on the breeding of the Surinam water-toad (*Pipa americana*) in the Society's gardens. Proc. Zool. Soc. London 1896:595–597.
- BAITCHMAN, E. J., AND A. PESSIER. 2013. Pathogenesis, diagnosis and treatment of amphibian chytridiomycosis. Vet. Clin. Exot. Anim. 16:669–685.
- BANKS, C., R. TRAHER, AND R. HOBBS. 2014. Captive management and breeding of the stuttering frog (*Mixophyes balbus*) at Melbourne Zoo. Herpetol. Rev. 45(1):43–49.
- , M. W. N. LAU, AND D. DUDGEON. 2008. Captive management and breeding of Romer's tree frog *Chirixalus romeri*. Inter. Zoo Yearb. 42:99–108.
- BATEMAN, G. C. 1897. The Vivarium, Being a Practical Guide to the Construction, Arrangement, and Management of Vivaria, Containing Full Information as to all Reptiles Suitable as Pets, How and Where to Obtain Them, and How to Keep Them in Health. L. Upcott Gill, London. 424 pp.
- BEAUCLERC, K. B., B. JOHNSON, AND B. N. WHITE. 2010. Genetic rescue of an inbred captive population of the critically endangered Puerto Rican crested toad (*Peltophryne lemur*) by mixing lineages. Conserv. Genet. 11(1):21–32.
- BECKER, M. H., R. N. HARRIS, K. P. C. MINIOLE, C. R. SCHWANTES, L.A. ROLINS-SMITH, L.K. REINERT, R. M. BRUCKER, R. J. DOMANGUE, AND B. GRATWICKE. 2011. Towards a better understanding of the use of probiotics for preventing chytridiomycosis in Panamanian golden frogs. Ecohealth 8(4):501–506.
- , C. L. RICHARDS-ZAWACKI, B. GRATWICKE, AND L. K. BELDEN. 2014. The effect of captivity on the cutaneous bacterial community of the critically endangered Panamanian golden frog (*Atelopus zeteki*). Biol. Conserv. 176:199–206.
- , J. B. WALKER, S. CIKANEK, A. E. SAVAGE, N. MATTHEUS, C. N. SANTIAGO, K. P. C. MINIOLE, R. N. HARRIS, L. K. BELDEN, AND B. GRATWICKE. 2015. Composition of symbiotic bacteria predicts survival in Panamanian golden frogs infected with a lethal fungus. Proc. R. Soc. B Biol. Sci. 282(1805): 20142881.
- BEHLER, J. L., AND D. A. BEHLER. 2005. Frogs! A Chorus of Colors. Sterling Publishing Co., Inc., New York. 159 pp.
- BELL, B. D. 1985. Conservation status of the endemic New Zealand frogs. In G. Grigg, R. Shine, and H. Ehmann (eds.), Biology of Australian Frogs and Reptiles, pp. 449–458. Royal Society of New South Wales, Sydney.
- BIRKETT, J. R., M. VINCENT, AND C. B. BANKS. 1999. Captive management and rearing of the roseate frog, *Geocrinia rosea* at Melbourne Zoo. Herpetofauna 29(2):49–56.
- BLACKBURN, D. C., B. J. EVANS, A. P. PESSIER, AND V. T. VREDENBURG. 2010. An enigmatic mortality event in the only population of the Critically Endangered Cameroonian frog *Xenopus longipes*. Afr. J. Herpetol. 59(2):111–122.
- BLAKE, E. 1990. Cage design for the Trinidad stream frog (*Colostethus trinitatis*) at Edinburgh Zoo. R. Zool. Soc. Scotland Ann. Rep. No. 78. [1991]:55–57.
- BLETZ, M.C., G. M. ROSA, F. ANDREONE, E. A. COURTOIS, D. S. SCHMELLER, N. H. RABIBISOA, F. C. RABEMANANJARA, L. RAHARIVOLONIAINA, M. VENCES, C. WELDON, AND D. EDMONDS. 2015. Widespread presence of the pathogenic fungus *Batrachochytrium dendrobatidis* in wild amphibian communities in Madagascar. Scientific Reports 5:8633.
- BLOXAM, Q. M., AND S. J. TONGE. 1995. Amphibians: suitable candidates for breeding-release programs. Biodiv. Conserv. 4:636–644.
- BOURKE, J. 2010. Darwin's frog captive rearing facility in Chile. FROGLOG 6:6–10.
- BOSCH, J., E. SANCHEZ-TOMÉ, A. FERNÁNDEZ-LORAS, J. A., OLIVER, M. C. FISHER, AND T. W. GARNER. 2015. Successful elimination of a lethal wildlife infectious disease in nature. Biol. Lett. 11:20150874.
- BRADLEY, T. A., AND K. WRIGHT. 2000. Captive care and breeding of White's tree frog, *Pelodytes caerulea*. Bull. Assoc. Rept. Amphib. Vet. 10(2):21–24.
- BRAITSTROM, B. H. 1963. A preliminary review of the thermal requirements in amphibians. Ecology 44:238–255.
- BRAZAITIS, P., AND M. E. WATANABE. 1982. The Doppler, a new tool for reptile and amphibian hematological studies. J. Herpetol. 16:1–6.
- BREM, F., J. R. MENDELSON III, AND K. R. LIPS. 2007. Field-sampling protocol for *Batrachochytrium dendrobatidis* from living amphibians, using alcohol preserved swabs. Version 1:18.
- BROWNE, R. K., R. A. ODUM, T. HERMAN, AND K. ZIPPEL. 2007. Facility design and associated services for the study of amphibians. ILAR J. 48(3):188–202.
- , J. SERATT, C. VANCE, AND A. KOUBA. 2006. Hormonal priming, induction of ovulation and in-vitro fertilization of the endangered Wyoming toad (*Bufo baxteri*). Reprod. Biol. Endocrinol. 4(1):1.
- , AND K. ZIPPEL. 2007. Reproduction and larval rearing of amphibians. ILAR J. 48(3):214–234.
- BULEY, K. R., AND G. GARCIA. 1997. The recovery programme for the Mallorcan midwife toad *Alytes muletensis*—an update. Dodo, J. Jersey Wildl. Preserv. Trust 33:80–90.
- , AND C. GONZALEZ. 2000. The Durrell Wildlife Conservation Trust and the Mallorcan midwife toad *Alytes muletensis*—into the 21<sup>st</sup> century. Herpetol. Bull. 72:17–20.
- BURCHFIELD, P. M. 1975. Breeding the Colombian giant toad *Bufo blombergi* at Brownsville Zoo. Inter. Zoo Yearb. 15:89–90.
- BURNS, R. 1995. Considerations in the euthanasia of reptiles, amphibians, and fish. Proc. Amer. Assoc. Zoo Vet., 243–249.
- BURTON, M. S., E. T. THORNE, A. ANDERSON, AND D. R. KWATKOWSKI. 1995. Captive management of the endangered Wyoming toad at the Cheyenne Mountain Zoo. Bull. Assoc. Rept. Amphib. Vet. 5(1):6–8.
- BUSTAMANTE, M. R., AND J. R. MENDELSON III. 2008. A new frog species (Strabomantidae: *Pristimantis*) from the high Andes of southeastern Ecuador. Zootaxa 59:49–59.
- BUTLER, D. J. 1992. The role of zoos in the captive breeding of New Zealand's threatened fauna. Inter. Zoo Yearb. 31:4–9.
- BYRNE, P. G., AND A. J. SILLA. 2010. Hormonal induction of gamete release, and in-vitro fertilisation, in the critically endangered southern Corroboree frog, *Pseudophryne corroboree*. Reprod. Biol. Endocrinol. 8(1):1.
- CADENA QUEVEDO, D. M., AND D. M. GARCÍA ROMO. 2012. Fertilización asistida en rana marsupial andina *Gastrotheca riobambae* en el Centro de Investigación y Conservación de anfibios, Proyecto “Balsa de los sapos” de la Pontificia Universidad Católica del Ecuador.
- CARD, W. C., D. T. ROBERTS, AND R. A. ODUM. 1998. Does zoo herpetology have a future? Zoo Biol. 17:453–462.
- CARR, A. 1955. The Windward Road: Adventures of a Naturalist on Remote Caribbean Shores. A. A. Knopf, New York. 256 pp.
- CHISZAR, D., J. B. MURPHY, AND H. M. SMITH. 1993. In search of zoo-academic collaborations: a research agenda for the 1990's. Herpetologica 49:488–500.
- , AND H. M. SMITH. 2005. Some comments on our herpetological collaborations with zoos. Herpetol. Rev. 36:7–9.
- CIKANEK, S. J., S. NOCKOLD, J. L. BROWN, J. W. CARPENTER, A. ESTRADA, J. GUERREL, K. HOPE, R. IBÁÑEZ, S. B. PUTMAN, AND B. GRATWICKE. 2014. Evaluating group housing strategies for the ex-situ conservation of harlequin frogs (*Atelopus* spp.) using behavioral and physiological indicators. PLoS One 9 (2):1–6.
- CLAUNCH, N., AND L. AUGUSTINE. 2015. Morphological description of Spindly Leg Syndrome in golden mantella (*Mantella aurantiaca*)

- at the Smithsonian National Zoological Park. *J. Herpetol. Med. Surg.* 25(3–4):72–77.
- COBURN, J. 1992. *The Proper Care of Amphibians*. T.F.H., Nerpture City, New Jersey. 256 pp.
- COLLINS, J. P., AND M. L. CRUMP. 2009. *Extinction in our Times: Global Amphibian Decline*. Oxford University Press, Oxford and London. 273 pp.
- CONWAY, W. 1968. How to exhibit a bullfrog: a bed-time story for zoo men. *Curator* 11:310–318.
- . 1973. How to exhibit a bullfrog: a bed-time story for zoo men. *Inter. Zoo Yearb.* 13:221–226.
- . 1985. The Species Survival Plan and the Conference on Reproductive Strategies for Endangered Wildlife. *Zoo Biol.* 4:219–223.
- COOTE, J. G., 2001. A history of western herpetoculture before the 20<sup>th</sup> century. *In* W. E. Becker (ed.), 25<sup>th</sup> International Herpetological Symposium on Captive Propagation and Husbandry, pp. 19–47. International Herpetological Symposium, Detroit, Michigan.
- COVER JR., J. F. 1992. Poison-dart frogs—wild & captive. *In* M. J. Uricheck (ed.), 15<sup>th</sup> International Herpetological Symposium on Captive Propagation and Husbandry, pp. 1–4. International Herpetological Symposium, Palo Alto, California.
- , S. L. BARNETT, AND R. L. SAUNDERS. 1994. Captive management and breeding of dendrobatid and Neotropical hylid frogs at the National Aquarium in Baltimore. *In* J. B. Murphy, K. Adler, and J. T. Collins (eds.), *Captive Management and Conservation of Amphibians and Reptiles*, pp. 267–273. Society for the Study of Amphibians and Reptiles. Contributions to Herpetology, volume 11, Ithaca, New York.
- CRUMP, M. 2000. *In Search of the Golden Frog*. The University of Chicago Press, Chicago, Illinois. 299 pp.
- DALY, J. W., JR., H. M. GARRAFFO, T. F. SPANDE, C. JARAMILLO, AND A. S. RAND. 1994. Dietary source for skin alkaloids of poison frogs (Dendrobatidae). *J. Chem. Ecol.* 20:943–955.
- , W. L. PADGETT, R. L. SAUNDERS, AND J. F. COVER. 1997. Absence of tetrodotoxins in a captive-raised riparian frog, *Atelopus varius*. *Toxicon* 35(5):705–709.
- , S. I. SECUNDA, H. M. GARRAFFO, T. F. SPANDE, A. WISNIESKI, C. NISHIHARA, AND J. F. COVER, JR. 1992. Variability in alkaloid profiles in neotropical poison frogs (Dendrobatidae): genetic versus environmental determinants. *Toxicon* 30:887–898.
- , ET AL. 1992. Frog secretions and hunting magic in the upper Amazon: Identification of a peptide that interacts with an adenosine receptor. *Proc. Natl. Acad. Sci. USA* 89:10960–10963.
- DATHE, F., AND K. DEDEKIND. 1991. Erfahrungen bei der Haltung und Zucht von Venezuela-Baumsteigern, *Colostethus trinitatis* (Boulenger, 1889) im Tierpark Berlin [Experiences gained in the care and breeding of Venezuelan tree climbers *Colostethus trinitatis* (Boulenger, 1889) in the Tierpark Berlin]. *Amphibienforschung und Vivarium (Amphibian Research and Design)*. Schleusingen :22–24.
- DAWSON, J., F. PATEL, R. A. GRIFFITHS, AND R. P. YOUNG. 2016. Assessing the global zoo response to the amphibian crisis through 20year trends in captive collections. *Conserv. Biol.* 30(1):82–91.
- DE LA RIVA, I., L. TRUEB, AND W. E. DUELLMAN. 2012. A new species of *Telmatobius* (Anura: Telmatobiidae) from montane forests of southern Peru, with a review of osteological features of the genus. *South Am. J. Herpetol.* 7(2):91–109.
- DELLATOGNA, G. 2015. *Structural and Functional Characterization of the Panamanian Golden Frog Spermatazoa—Impact of Medium Osmolality and Cryopreservation on Motility and Cell Viability*. Ph.D. Thesis, University of Maryland.
- , G. L. TRUDEAU, B. GRATWICKE, M. EVANS, L. AUGUSTINE, HAN CHIA, E. J. BRONIKOWSKI, J. B. MURPHY, AND P. COMIZZOLI. 2017. Effects of hormonal stimulation on the concentration and quality of excreted spermatozoa in the critically endangered Panamanian golden frog (*Atelopus zeteki*). *Theriogenology* 91:27–35.
- DENSMORE, C. L., AND D. E. GREEN. 2007. Diseases of amphibians. *ILAR J.* 48(3):235–254.
- DE VOSJOLI, P., AND R. MAILLOUX. 1990. Breeding on thin ice: the husbandry and propagation of the Malagasy tomato frogs, *Dyscophus antongilii* and *D. insularis*. *In* M. J. Uricheck (ed.), *Proceedings of the 13<sup>th</sup> International Herpetological Symposium on Captive Propagation & Husbandry*, pp. 181–193. Western Connecticut State University, Danbury.
- DODD, C. K. JR., AND R. A. SEIGEL. 1991. Relocation, repatriation and translocation of amphibians and reptiles: Are they conservation strategies that work? *Herpetologica* 47:336–350.
- DRAKE, G. J., K. KOEPEL, AND M. BARROWS. 2010. Disinfectant (F10SC) nebulisation in the treatment of 'red leg' syndrome in amphibians. *Vet. Rec.* 166(19):593–594.
- DRISKELL, E. A., D. L. MILLER, S. L. SWIST, AND Z. S. GYIMESI. 2009. PCR detection of ranavirus in adult anurans from the Louisville Zoological Garden. *J. Zoo Wildl. Med.* 40(3):559–563.
- DUELLMAN, W. E., AND J. R. MENDELSON. 1995. Amphibians and reptiles from northern Departamento Loreto, Peru: taxonomy and biogeography. *Univ. Kansas Sci. Bull.* 55:329–376.
- , AND L. TRUEB. 1986. *Biology of Amphibians*. McGraw Hill, New York. 670 pp.
- DUGAS, M. B., J. YEAGER, AND C. L. RICHARDSZAWACKI. 2013. Carotenoid supplementation enhances reproductive success in captive strawberry poison frogs (*Oophaga pumilio*). *Zoo Biol.* 32(6):655–658.
- DUNCAN, A. E., M. M. GARNER, J. L. BARTHOLOMEW, T. A. REICHARD, AND R. W. NORDHAUSEN. 2004. Renal myxosporidiasis in Asian horned frogs (*Megophrys nasuta*). *J. Zoo Wildl. Med.* 35(3):381–386.
- EDMONDS, D., J. C. RAKOTOARISOA, R. DOLCH, J. PRAMUK, R. GAGLIARDO, F. ANDREONE, N. RABIBISOA, F. RABEMANANJARA, S. RABESHANAKA, AND E. ROB-SOMANITRANDRASANA. 2012. Building capacity to implement conservation breeding programs for frogs in Madagascar: results from year one of Mitsinjo's amphibian husbandry research and captive breeding facility. *Amphib. Rept. Conserv.* 5(3):57–69.
- , ———, S. RASOANANTENAINA, S. S. SAM, J. SOAMIARIMAMPIONONA, AND E. TSIMALOMANANA. 2016. Captive management and reproduction of the treefrog *Boophis pyrrhus* in Andasibe, Madagascar. *Herpetol. Rev.* 47:405–409.
- ELKAN, E. 1976. Pathology in the Amphibia. *Physiology of the Amphibia* 3:273–312.
- ELLISON, A. R., A. E. SAVAGE, G. V. DIRRENZO, P. LANGHAMMER, K. R. LIPS, AND K. R. ZAMUDIO. 2014. Fighting a losing battle: vigorous immune response countered by pathogen suppression of host defenses in the chytridiomycosis-susceptible frog *Atelopus zeteki*. *G3 Genes Genomes Genet.* 4:1275–1289.
- ESTRADA, A., B. GRATWICKE, A. BENEDETTI, G. DELLA TOGNA, D. GARRELLE, E. GRIFFITH, R. IBÁÑEZ, S. RYAN, AND P. S. MILLER. 2013. The golden frogs of Panama (*Atelopus zeteki*, *A. varius*): a conservation planning workshop 19–22 November 2013. IUCN/SCC Conservation Breeding Specialist Group. Apple Valley, Minnesota.
- EVANS, M. J., B. GRATWICKE, AND J. B. MURPHY. 2012. New Panama Amphibian Rescue and Conservation Project Exhibit at Smithsonian National Zoological Park. *Herpetol. Rev.* 43(2):208–209.
- FENOLIO, D. 1996. Captive reproduction of the orange-legged monkey frog (*Phyllomedusa hypocondrialis*), and development of a protocol for phyllomedusine frog reproduction in the laboratory. *Advances in Herpetoculture* 1:13–21.
- , A. CHARRIER, M. G. LEVY, M. O. FABRY, M. S. TIRADO, M. L. CRUMP, W. W. LAMAR, AND P. I. L. A. R. CALDERON. 2011. A review of the Chile mountains false toad, *Telmatobufo venustus* (Amphibia: Anura: Calyptocephalellidae), with comments on its conservation status. *Herpetol. Rev.* 42(4):514–519.
- FISCHER, J. v. 1883. Der australische Laubfrosch, *Pelotryas coeruleus* White = *Hyla cyanea*\* Daudin, in der Gefangenschaft [The Australian tree frog, *Pelotryas coeruleus* White = *Hyla cyanea*\* Daudin, in captivity]. *Zool. Gart., Frankfurt a. M.* 24:21–25.
- . 1883. Die Panther-Kröte in der Gefangenschaft (*Bufo pantherinus* Cichenot = *B. mauritanicus* Schlegel) [The panther toad (*Bufo pantherinus* Cichenot = *B. mauritanicus* Schlegel) in captivity]. *Zool. Gart., Frankfurt a. M.* 24:43–45.

- . 1884. Das Terrarium, seine Bepflanzung und Bevölkerung [The Terrarium, its Plantings and Population]. Mahlau & Waldschmidt, Frankfurt am Main. [reprint of this work published in 1989 by BINA Verlag für Biologie und Natur, Berlin]. 384 pp.
- FITES, J. S., J. P. RAMSEY, W. M. HOLDEN, S. P. COLLIER, D. M. SUTHERLAND, L. K. REINERT, A. S. GAYEK, T. S. DERMODY, T. M. AUNE, K. OSWALD-RICHTER, AND L. A. ROLLINS-SMITH. 2013. The invasive chytrid fungus of amphibians paralyzes lymphocyte responses *Science* 342:366–369.
- FLOWER, S. S. 1927. Loss of memory accompanying metamorphosis in amphibians. *Proc. Zool. Soc. London* 1927:155–156.
- . 1936. Further notes on the duration of life in animals. II. Amphibians. *Proc. Zool. Soc. London* 1936:369–394.
- FROST, D. R. 2016. Amphibian Species of the World: an Online Reference. Version 6.0 (7 Oct 2016). Electronic database accessible at <http://research.amnh.org/herpetology/amphibia/index.html>. American Museum of Natural History, New York.
- , J. R. MENDELSON III, AND J. PRAMUK. 2009. Further notes on the nomenclature of Middle American toads (Bufonidae). *Copeia* 2009(2):418.
- FURRER, S. C., AND G. CORREDOR. 2008. Conservation of threatened amphibians in Valle del Cauca, Colombia: a cooperative project between Cali Zoological Foundation, Colombia, and Zoo Zürich, Switzerland. *Inter. Zoo Yearbook* 42(1):158–164.
- FUJITANI, T., K. NISHIO, AND H. HASHIKAWA. 1998. Breeding the Amazonian poison frog, *Dendrobates ventrimaculatus*. *Animals and Zoos* 50:74–77. [in Japanese with English summary]
- GADOW, H. 1901. Amphibia and Reptiles. Macmillan & Co., England. [reprinted in 1968 by Wheldon & Wesley, Ltd., Codicote UK]. 668 pp.
- GAGLIARDO, R., E. GRIFFITH, R. HILL, H. ROSS, J. R. MENDELSON III, AND E. TIMPE. 2010. Observations on the captive reproduction of the horned marsupial frog *Gastrotheca cornuta* (Boulenger 1898). *Herpetol. Rev.* 41(1): 52–58.
- , P. CRUMP, E. GRIFFITH, J. MENDELSON, H. ROSS, AND K. ZIPPEL. 2008. The principles of rapid response for amphibian conservation, using the programmes in Panama as an example. *Int. Zoo Yearb.* 42(1):125–135.
- GARCIA, G., L. BOCK, S. EARLE, R. BERRIDGE, AND J. COPSEY. 2008. Captive breeding as a tool for the conservation of Malagasy amphibians: How ready are we to respond to the need? *In* F. Andreone (ed.), *A Conservation Strategy for the Amphibians of Madagascar*, pp. 321–342. Monografie XLV, Museo Regionale di Scienze Naturali, Torino, Italy.
- GARNER, M. M., D. COLLINS, AND J. O. JOSLIN. 1995. Diseases of Solomon Island leaf frogs (*Ceratobatrachus guentheri*) at the Woodland Park Zoo: a retrospective study of seventy-five necropsy cases. *Proc. Amer. Assoc. Zoo Vet.* :236–237.
- GARRETT, C. M. 2005. Herpetological research in zoos: A contemporary assessment. *Herpetol. Rev.* 36:103–106.
- GASCON, C., J. P. COLLINS, R. D. MOORE, D. R. CHURCH, J. E. MCKAY, AND J. R. MENDELSON III. 2007. Amphibian Conservation Action Plan. IUCN/SSC Amphibian Conservation Summit 2005..
- GEHRMANN, W. H. 1987. Ultraviolet irradiances of various lamps used in animal husbandry. *Zoo Biol.* 6:117–127.
- . 1994. Light requirements of captive amphibians and reptiles. *In* J. B. Murphy, K. Adler, and J. T. Collins (eds.), *Captive Management and Conservation of Amphibians and Reptiles*, pp. 53–59. Society for the Study of Amphibians and Reptiles. Contributions to Herpetology, volume 11, Ithaca, New York.
- GENOVA, M. I. 2011. Density and habitat preferences of Lake Titicaca frog (*Telmatobius culeus*) at north-west of Copacabana peninsula. Master's thesis. Ecology Resource Group, Wageningen University. 73 pp.
- GENTZ, E. J. 2007. Medicine and surgery of amphibians. *ILAR J.* 48(3):255–259.
- GEWALT, W. 1977. Einige Bemerkungen über Fang, Transport und Haltung des Goliathfrosches (*Conraua goliath* Boulenger) [Some remarks on the catching, transport and keeping of the giant frog (*Conraua goliath* Boulenger)]. *Zool. Gart. (N.F.)*, Jena 47:161–192.
- GIBSON, R. C., AND K. R. BULEY. 2004. Maternal care and obligatory oophagy in *Leptodactylus fallax*: a new reproductive mode in frogs. *Copeia* 2004:128–135.
- GILLESPIE, D., B. L. DRESSER, AND E. J. MARUSKA. 1988/1989. Sexing goliath frogs *Gigantorana goliath* by laparoscopy. *Proc. Amer. Assoc. Zoo Vet.* :62.
- GLIME, J. M., AND W. J. BOELEMA. 2013. Amphibians: anuran adaptations. Chapt. 14-1. *In* J. M. Glime (ed.), *Bryophyte Ecology*, Volume 14-1-1 2. Bryological Interaction. Ebook sponsored by Michigan Technological University and the International Association of Bryologists. Updated 6 July 2013 and available at <[www.bryoecol.mtu.edu](http://www.bryoecol.mtu.edu)>.
- GOLLMANN, B. 1995. Maintenance and breeding of the Australian frog *Neobatrachus sudelli* (Lamb, 1911) in captivity. *Bull. Br. Herpetol. Soc.* (1995):3–6.
- GRACZYK, T. K., M. R. CRANFIELD, E. J. BICKNESE, AND A. P. WISNIESKI. 1996. Progressive Ulcerative Dermatitis in a captive, wild-caught South American giant tree frog (*Phyllomedusa bicolor*) with microsporidial septicemia. *J. Zoo Wildl. Med.* 1996:522–527.
- GRATWICKE, B., M. J. EVANS, P. T. JENKINS, M. D. KUSRINI, R. D. MOORE, J. SEVIN, AND D. E. WILDT. 2010. Is the international frog legs trade a potential vector for deadly amphibian pathogens? *Front. Ecol. Environ.* 8(8):438–442.
- , T. E. LOVEJOY, AND D. E. WILDT. 2012. Will amphibians croak under the Endangered Species Act? *Bioscience* 62(2):197–202.
- , H. ROSS, A. BATISTA, G. CHAVES, A. J. CRAWFORD, L. ELIZONDO, A. ESTRADA, M. EVANS, D. GARELLE, J. GUERREL, A. HERTZ, M. HUGHEY, C. A. JARAMILLO, B. KLOCKE, M. MANDICA, D. MEDINA, C. L. RICHARDS-SAWACKI, M. J. RYAN, A. SOSA-BARTUANO, J. VOYLES, B. WALKER, D. C. WOODHAMS, AND R. IBÁÑEZ. 2016. Evaluating the probability of avoiding disease-related extinctions of Panamanian amphibians through captive breeding programs. *Anim. Conserv.* 19(4):324–336.
- GRIFFITHS, R. A., AND L. PAVAJEAU. 2008. Captive breeding, reintroduction, and the conservation of amphibians. *Conserv. Biol.* 22(4):852–861.
- GROW, D. T. 1980. Reptile reproduction and husbandry of the orange-striped poison dart frog, (*Phyllobates vittatus*), at the Sedgwick County Zoo, Wichita, Kansas. *In* R. A. Hahn (ser. ed.), 3<sup>rd</sup> International Herpetological Symposium on Captive Propagation and Husbandry, pp. 47–51. International Herpetological Symposium, Thurmont, Maryland.
- GUPTA, B. K. 1998. On reproduction and captive breeding of ranids. *Animal Keepers' Forum* 25(12):464–468.
- HADFIELD, C. A., L. A. CLAYTON, AND S. L. BARNETT. 2006. Nutritional support of amphibians. *J. Exotic Pet Med.* 15(4):255–263.
- , AND B. R. WHITAKER. 2005. Amphibian emergency medicine and care. *In* *Seminars in Avian and Exotic Pet Medicine* 14(2):79–89.
- HALL, B. K., AND M. H. WAKE (eds.). 1999. *The Origin and Evolution of Larval Forms*. Academic Press, San Diego, California. 426 pp.
- HARDING, G., R. A. GRIFFITHS, AND L. PAVAJEAU. 2016. Developments in amphibian captive breeding and reintroduction programs. *Conserv. Biol.* 30:340–349.
- HARRIS, R. N., R. M. BRUCKER, J. B. WALKER, M. H. BECKER, C. R. SCHWANTES, D. C. FLAHERTY, B. A. LAM, D. C. WOODHAMS, C. J. BRIGGS, V. T. VREDENBURG, AND K. P. MINIOLE. 2009. Skin microbes on frogs prevent morbidity and mortality caused by a lethal skin fungus. *ISME J.* 3(7):818–824.
- HARWELL, G., AND H. QUINN. 1982. The Houston toad—problems associated with the captive propagation of amphibians. *Proc. Amer. Assoc. Zoo Vet.*:1–2.
- HEATWOLE, H. (ed.). 1994. *Amphibian Biology*. 11 volumes. Surrey Beatty & Sons, Chipping Norton, NSW.
- HEICHLER, L., AND J. B. MURPHY. 2004. Johann Matthäus Bechstein: The father of herpetoculture. *Herpetol. Rev.* 35:8–13.
- HERNÁNDEZ DÍAZ, A. 2013. Crested toad reproduction at Africam Safari, Puebla, Mexico. *Aark Newsletter* 23:17.
- HERRMANN, H.-W. 2003. Conservation biology of goliath frogs. *Conservation Symposium*, September 2003, Center for the Reproduction of Endangered Species, San Diego, California.
- , AND T. EDWARDS. 2006. *Conraua goliath* (goliath frog). Skittering locomotion. *Herpetol. Rev.* 37(2):202–203.

- , AND P. A. HERRMANN. 2002. Herpetological conservation at the Cologne Zoo. *Herpetol. Rev.* 33(3):168–169.
- HEYER, W. R., M. A. DONNELLY, R. W. MCDIARMID, L. C. HAYEK, AND M. S. FOSTER (eds.). 1994. *Measuring and Monitoring Biological Diversity. Standard Methods for Amphibians*. Smithsonian Institution Press, Washington DC. 364 pp.
- , AND J. B. MURPHY. 2005. Declining Amphibian Populations Task Force. In M. Lannoo (ed.), *Amphibian Declines. The Conservation Status of United States Species*, pp. 17–21. University of California Press, Berkeley.
- HILER, B. I. 1985. An overview of the amphibian collection at the Steinhart Aquarium as an introduction to amphibian care. In R. L. Gray (ed.), *Captive Propagation and Husbandry of Reptiles and Amphibians*, pp. 145–152. Northern California Herpetological Society & Bay Area Amphibian and Reptile Society.
- HILL, R., ET AL. 2010. Observations on the captive reproduction of Gaige's rain frog *Pristimantis gaigeae* (Dunn 1931). *Herpetol. Rev.* 41(4):465–467.
- HINSCHKE, G. 1928. Kampfreaktionen bei einheimischen Anuren [Fight reactions of domestic frogs]. *Biol. Zentralbl.* 48:577–617.
- . 1939. Über die Entwicklund von Haltungs- und Bewegungsreaktionen [Concerning development of reactions to care and movement]. *W. Rous, Arch. Entwicklunsmech.* 139:724–731.
- . 1941. Domestikationsmerkmale bei Anuren [Characteristics of domestication in frogs]. *Zool. Anz.* 12:26.
- HOLYOAKE, A., B. WALDMAN, AND N. J. GEMMELL. 2001. Determining the species status of one of the world's rarest frogs: a conservation dilemma. *Anim. Conserv.* 4:29–35.
- HONEGGER, R. E. 1979. Marking amphibians and reptiles for future identification. *Inter. Zoo Yearb.* 19:14–22.
- , C. SCHNEIDER, AND E. ZIMMERMANN. 1985. Notizen zur Aufzucht von Schmuckhornfröschen *Ceratophrys ornata* (Bell, 1843) [Notes on the breeding of the ornate horned frog *Ceratophrys ornata* (Bell, 1843)]. *Salamandra* 21:70–80.
- HONEYMAN, V. L., K. G. MERHEN, I. K. BARKER, AND G. J. CRAWSHAW. 1992. *Bordetella* septicemia and chlamydiosis in eyelash leaf frogs (*Ceratotriton guentheri*). *Proc. Amer. Assoc. Zoo Vet.*:168.
- HOUSTON ZOO. 2016. Houston Zoo Website: Houston Toad <http://www.houstonzoo.org/saving-wildlife/texas-conservation/houston-toad/> (accessed 11 Sept 16).
- HUDSON, M. A., R. P. YOUNG, J. U. JACKSON, P. OROZCO-TERWENGEL, L. MARTIN, A. JAMES, M. SULTON, G. GARCIA, R. A. GRIFFITHS, R. THOMAS, AND C. MAGIN. 2016. Dynamics and genetics of a disease-driven species decline to near extinction: lessons for conservation. *Sci. Rep.* 6: 30772.
- , J. LOPEZ, L. MARTIN, C. FENTON, R. MCCREA, R. A. GRIFFITHS, S. L. ADAMS, G. GRAY, G. GARCIA, AND A. A. CUNNINGHAM. 2016. In-situ itraconazole treatment improves survival rate during an amphibian chytridiomycosis epidemic. *Biol. Conserv.* 195:37–45.
- IMAI, D. M., S. A. NADLER, D. BRENNER, T. A. DONOVAN, AND A. P. PESSIER. 2009. Rhabditid nematode-associated ophthalmitis and meningoencephalomyelitis in captive Asian horned frogs (*Megophrys montana*). *J. Vet. Diag. Invest.* 21(4):568–573.
- IVANYI, C. S. 1989. Captive reproduction of the black-eared frog *Leptodactylus melanonotus* at the Arizona-Sonora Desert Museum. In M. J. Uricheck (ed.), 13<sup>th</sup> International Herpetological Symposium on Captive Propagation and Husbandry, pp. 195–199. International Herpetological Symposium.
- JAMIESON, B. G. M. (ED.). 2003. *Reproductive Biology and Phylogeny of Anura*. Science Publishers, Enfield. New Hampshire. 452 pp.
- JOHNSON, R. 1984. Breeding the Bell's horned frog (*Ceratophrys ornata*): An alternative to hormonally induced reproduction. In R. A. Hahn (ser. ed.), 8<sup>th</sup> International Herpetological Symposium on Captive Propagation and Husbandry, pp. 22–32. International Herpetological Symposium, Thurmont, Maryland.
- JORDAN, T. 1969. Notes on keeping arboreal and terrestrial amphibians in captivity. *Inter. Zoo Yearb.* 9:14–16.
- KAHN, T. R., E. LA MARCA, S. LÖTTERS, J. L. BROWN, E. TWOMEY, AND A. AMÉZQUITA (EDS.) 2016. *Aposematic Poison Frogs (Dendrobatidae) of the Andean Countries: Bolivia, Colombia, Ecuador, Peru and Venezuela*. Conservation International Tropical Field Guide Series, Conservation International, Arlington, Virginia. 588 pp.
- KARAVLAN, S. A., AND M. D. VENESKY. 2016. Thermoregulatory behavior of *Anaxyrus americanus* in response to infection with *Batrachochytrium dendrobatidis*. *Copeia* 2016:746–751.
- KAUFFELD, C. F. 1942. Care of frog tadpoles. *Animaland* 9(3).
- KING, J. D., M. C. MUHLBAUER, AND A. JAMES. 2011. Radiographic diagnosis of metabolic bone disease in captive bred mountain chicken frogs (*Leptodactylus fallax*). *Zoo Biol.* 30(3):254–259.
- KLINGELHÖFFER, W. 1955–1959. *Terrarienkunde / Zweiter Teil (Terrarium Science)*. Alfred Kernen Verlag, 224 pp.
- KNEPPER, D. 1993. Production of the azure dart-poison frog *Dendrobates azureus* at the Chaffee Zoological Gardens at Fresno. In M. Bumgardner (ed.), *Captive Propagation and Husbandry of Reptiles and Amphibians*, pp. 1–5. Special Publication No. 7, Northern California Herpetological Society.
- KOESTLER, A. 1971. *The Case of the Midwife Toad*. Random House, New York. 187 pp.
- KONIG, C., AND A. SCHLUTER. 1991. Nachzucht der Balearen-Geburtshelferkröte *Alytes muletensis* (Sanchiz et Adrover 1979) im Rahmen eines Artenschutzprogrammes (Amphibia; Discoglossidae) [Breeding the Balearic midwife toad *Alytes muletensis* (Sanchiz et Adrover 1979) in the context of an endangered species program (Amphibia, Discoglossidae)]. *Jahresh. Ges. Naturkd. Württemb. [Annual Report of the Wuerttemberg Society for Natural History]* 146:193–205.
- KOUBA, A. J., C. K. VANCE, AND E. L. WILLIS. 2009. Artificial fertilization for amphibian conservation: current knowledge and future considerations. *Theriogenology* 71(1):214–227.
- KRAAIJEVELD-SMIT, F. J. L., R. A. GRIFFITHS, R. D. MOORE, AND T. J. C. BEEBEE. 2006. Captive breeding and the fitness of reintroduced species: a test of the responses to predators in a threatened amphibian. *J. Appl. Ecol.* 43(2):360–365.
- KRAJICK, K. 2006. The lost world of the Kihansi toad. *Science* 311:1230–1232.
- LA MARCA, E., K. R. LIPS, S. LÖTTERS, R. PUSCHENDORF, R. IBÁÑEZ, J. V. RUEDA ALMONACID, R. SCHULTE, ET AL. 2005. Catastrophic population declines and extinctions in Neotropical harlequin frogs (Bufonidae: *Atelopus*). *Biotropica* 37(2):190–201.
- LANGE, J. 1981. Beitrag zur Zucht von Smaragd-Baumsteigerfröschen (*Dendrobates auratus*) [Contribution concerning the breeding of emerald tree-climbing frogs (*Dendrobates auratus*)]. *Z. Köln. Zoo* 40(1):6–8.
- LANNOO, M. 2008. *Malformed Frogs. The Collapse of Ecosystems*. University of California Press, Berkeley, California. 270 pp.
- LEE, S., K. C. ZIPPEL, L. RAMOS, AND J. SEARLE. 2006. Captive breeding programme for the Kihansi spray toad *Nectophrynoides asperginis* at the Wildlife Conservation Society, Bronx, New York. *Inter. Zoo Yearb.* 40(1):241–53.
- LEUTSCHER, A. 1952. *Vivarium Life. A Manual on Amphibians, Reptiles and Cold-water Fish*. Cleaver-Hume Press Ltd, London. 252 pp.
- LOISEL, G. 1912. *Histoire des ménageries de l'antiquité à nos jours (History of Menageries from Antiquity to Present Times)*. O. Doin et fils, Paris.
- LÖTTERS, S., D. RÖDDER, J. KIELGAST, AND F. GLAW. 2011. Hotspots, conservation, and diseases: Madagascar's megadiverse amphibians and the potential impact of chytridiomycosis. In F. E. Zachose and J. C. Habel (eds.), *Biodiversity Hotspots*, pp. 255–274. Springer-Verlag Berlin Heidelberg.
- MAIN, D. C. 1998. An outbreak of mucormycosis in slender tree frogs (*Litoria adelensis*) and white-lipped tree frog (*Litoria infrafrenata*). *Aust. Vet. J.* 76(11):761.
- MALLINSON, J. J. C. 1998. Collaboration for conservation between the Jersey Wildlife Preservation Trust and countries where species are endangered. *Inter. Zoo Yearb.* 27:176–191.
- MARTIN, D. L. 1991. Captive husbandry as a technique to conserve a species of special concern, the Yosemite toad. In R. E. Staub (ed.),



- Captive Propagation and Husbandry of Reptiles and Amphibians, pp. 17–32. Northern California Herpetological Society.
- MARTINS, F., M. DO MAR OOM, R. REBELO, AND G. M. ROSA. 2013. Differential effects of dietary protein on early life history and morphological traits in natterjack toad (*Epidalea calamita*) tadpoles reared in captivity. *Zoo Biol.* 32(4):457–462.
- MARUSKA, E. J. 1986. Amphibians: review of zoo breeding programmes. *Inter. Zoo Yearb.* 24/25:56–65.
- MASLOW, J. N., R. WALLACE, M. MICHAELS, H. FOSKETT, E. A. MASLOW, AND J. A. KIEHLBAUCH. 2002. Outbreak of *Mycobacterium marinum* infection among captive snakes and bullfrogs. *Zoo Biol.* 21(3):233–241.
- MATTIOLI, E., C. GILL, AND F. ANDREONE. 2006. Economics of captive breeding applied to the conservation of selected amphibian and reptile species from Madagascar. *Natura-Società italiana di Scienze naturali e Museo civico di Storia Naturale di Milano* 95(2):67–80.
- MAYS, S. R., AND K. H. PETERSON. 1996. Aggregative behavior and sibling recognition in larvae of the Houston toad (*Bufo houstonensis*), pp. 33–38. *In* P. D. Strimple (ed.), *Advances in Herpetoculture*. Special Publication of the International Herpetological Symposium, Inc., No. 1. International Herpetological Symposium, Inc., Des Moines, Iowa.
- MCDIARMID, R. W., AND R. ALTIG (eds.). 1999. *Tadpoles: The Biology of Anuran Larvae*. University of Chicago Press, Chicago, Illinois. 444 pp.
- MCFADDEN, M., S. DUFFY, P. HARLOW, D. HOBROFT, C. WEBB, AND G. WARD-FEAR. 2008. A review of the green and golden bell frog *Litoria aurea* breeding program at Taronga Zoo. *Austral. Zool.* 34(3):291–296.
- , D. HUNTER, M. EVANS, B. SCHEELE, R. PIETSCH, AND P. HARLOW. 2016. Re-introduction of the northern Corroboree frog in the northern Brindabella Mountains, New South Wales, Australia. *Global Re-introduction Perspectives: 2016. Case-studies from around the globe*, IUCN p. 35.
- MCNAMARA, T. S., P. C. CHARLES, Y. KRESS, K. WEIDENHEIM, AND W. HOLMSTROM. 1999. Crystalline inclusions associated with vomeronasal organ pathology in red-eyed tree frogs (*Agalychnis callidryas*). *Proc. Amer. Assoc. Zoo Vet.*: 27–29.
- MCWILLIAMS, D. A. 2008. Nutrition recommendations for some captive amphibian species (Anura and Caudata). *The Canadian Association of Zoos and Aquariums Nutrition Advisory and Research Group*. 34 pp.
- MENDELSON III, J. R., J. M. SAVAGE, E. GRIFFITH, H. ROSS, B. KUBICKI, AND R. GAGLIARDO. 2008. Spectacular new gliding species of *Ecnomiohyla* (Anura: Hylidae) from central Panama. *J. Herpetol.* 42(4):750–759.
- MICHAELS, C. J., R. E. ANTWIS, AND R. F. PREZIOSI. 2015. Impacts of UVB provision and dietary calcium content on serum vitamin D<sub>3</sub>, growth rates, skeletal structure and coloration in captive oriental firebellied toads (*Bombina orientalis*). *J. Anim. Physiol. Anim. Nutrition* 99(2):391–403.
- , J. R. DOWNIE, AND R. CAMPBELL-PALMER. 2014. The importance of enrichment for advancing amphibian welfare and conservation goals. *Amphib. Rept. Conserv.* 8(1):7–23.
- , B. TAPLEY, L. HARDING, Z. BRYANT, S. GRANT, G. SUNTER, L. GILL, O. NYINGCHIA, AND T. DOHERTY-BONE. 2015. Breeding and rearing the Critically Endangered Lake Oku clawed frog (*Xenopus longipes* Loumont and Kobel 1991). *Amphib. Rept. Conserv.* 9(2):100–110.
- MILLER, D. L., S. RAJEEV, M. BROOKINS, J. COOK, L. WHITTINGTON, AND C. A. BALDWIN. 2008. Concurrent infection with ranavirus, *Batrachochytrium dendrobatidis*, and *Aeromonas* in a captive anuran colony. *J. Zoo Wildl. Med.* 39(3):445–449.
- MILLER, E. A., R. J. MONTALI, E. C. RAMSEY, AND B. A. RIDEOUT. 1992. Disseminated chromoblastomycosis in a colony of ornate-horned frogs (*Ceratophrys ornata*). *J. Zoo Wildl. Med.* 23:433–438.
- MILLER, G. L. (ed.). 2000. *Nature's Fading Chorus: Classic and Contemporary Writings on Amphibians*. Island Press, Washington DC. 249 pp.
- MILLER, T. J. 1983. Notes on a breeding of the red-eyed tree frog, *Agalychnis callidryas*, *In* P. J. Tolson (ed.), 7<sup>th</sup> International Herpetological Symposium on Captive Propagation and Husbandry, pp. 34–41. International Herpetological Symposium, Thurmont, Maryland.
- MULCAHY, D. G., AND J. R. MENDELSON. 2000. Phylogeography and speciation of the morphologically variable, widespread species *Bufo valliceps*, based on molecular evidence from mtDNA. *Mol. Phylog. Evol.* 17(2):173–189.
- , B. H. MORRILL, AND J. R. MENDELSON. 2006. Historical biogeography of lowland species of toads (*Bufo*) across the TransMexican Neovolcanic Belt and the Isthmus of Tehuantepec. *J. Biogeog.* 33(11):1889–1904.
- MURPHY, J. B. 1976. Pedal luring in the leptodactylid frog, *Ceratophrys calcarata* Boulenger. *Herpetologica* 32:339–341.
- . 2009a. History of early French herpetology. Part I: The Reptile Menagerie of the Museum of Natural History in Paris. *Herpetol. Rev.* 40:263–273.
- . 2009b. History of early French herpetology. Part II: Picture Gallery. *Herpetol. Rev.* 40:404–409.
- , AND D. CHISZAR. 1989. Herpetological master planning for the 1990's. *Inter. Zoo Yearb.* 28:1–7.
- , AND G. ILIFF. 2004. Count de Lacepède: Renaissance zoo man. *Herpetol. Rev.* 35:220–223.
- , AND K. MCCLOUD. 2010. Evolution of keeping captive amphibians and reptiles. *Herpetol. Rev.* 41:134–142.
- , AND ———. 2010. Reptile dealers and their price lists. *Herpetol. Rev.* 41:266–281.
- MUTHS, E., L. L. BAILEY, AND M. K. WATRY. 2014. Animal reintroductions: an innovative assessment of survival. *Biol. Conserv.* 172:200–208.
- MUTSCHMANN, F. 1998. Nachweis von *Chlamydia psittaci*- Infektionen bei Amphibien mittels eines spezifischen Immunofluoreszenztests [Evidence of *Chlamydia psittaci* infections in amphibians, obtained by means of a specific immunofluorescence test (IFT)]. *Berliner und Muenchener Tierärztliche Wochenschrift* [Berlin and Munich Veterinary Weekly] 111(5):187–189.
- NACE, G. W. 1977. Breeding amphibians in captivity. *Inter. Zoo Yearb.* 17:44–50.
- NARAYAN, E., K. CHRISTI, AND C. MORLEY. 2009. Captive propagation of the endangered native Fijian frog *Platymantis vitiana*: Implications for ex-situ conservation and management. *Pacific Conserv. Biol.* 15(1):47–55.
- NICHOLS, D. K. 2000. Amphibian respiratory diseases. *Vet. Clin. North America: Exotic Animal Practice* 3:551–554.
- . 2003. Tracking down the killer chytrid of amphibians. *Herpetol. Rev.* 34:101–104.
- , E. W. LAMIRANDE, A. P. PESSIER, AND J. E. LONGCORE. 2000. Experimental transmission and treatment of cutaneous chytridiomycosis in poison dart frogs (*Dendrobates auratus* and *Dendrobates tinctorius*). *Proc. Amer. Assoc. Zoo Vet.*:42–44.
- , ———, ———, AND ———. 2001. Experimental transmission of cutaneous chytridiomycosis in dendrobatid frogs. *J. Wildl. Dis.* 37:1–11.
- , A. P. PESSIER, AND J. E. LONGCORE. 1998. Cutaneous chytridiomycosis in amphibians: an emerging disease? *Proc. Amer. Assoc. Zoo Vet.*:269–271.
- , A. J. SMITH, AND C. H. GARDINER. 1996. Dermatitis of anurans caused by fungal-like protists. *Proc. Amer. Assoc. Zoo Vet.*:220–222.
- NIETZKE, G. 1969. *Die Terrarientiere; Bau, technische Einrichtung und Bepflanzung der Terrarien, Haltung, Fütterung und Pflege der Terrarientiere*. 2 volumes. E. Ulmer, Stuttgart.
- NOBLE, G. K. 1954. *The Biology of the Amphibia*. Dover Publications, New York. 577 pp.
- ODUM, A. 1984. Water quality, an often overlooked parameter for the amphibian enclosure. *In* R. A. Hahn (ser. ed.), 8<sup>th</sup> International Herpetological Symposium on Captive Propagation and Husbandry, pp. 33–58. International Herpetological Symposium, Thurmont, Maryland.
- , AND K. C. ZIPPEL. 2008. Amphibian water quality: approaches to an essential environmental parameter. *Inter. Zoo Yearb.* 42:40–52.

- , J. M. McLAIN, AND T. C. SHELEY. 1983. Hormonally induced breeding and rearing of White's tree frog, *Litoria caerulea* (Anura: Pelodyadidae). In P. J. Tolson (ed.), 7<sup>th</sup> International Herpetological Symposium on Captive Propagation and Husbandry, pp. 42–53. International Herpetological Symposium, Thurmont, Maryland.
- PAINE, F. L. 1984. The husbandry, management and reproduction of the Puerto Rican crested toad (*Bufo lemur*). In R. A. Hahn (ser. ed.), 8<sup>th</sup> International Herpetological Symposium on Captive Propagation and Husbandry, pp. 59–75. International Herpetological Symposium, Thurmont, Maryland.
- , J. D. MILLER, G. CRAWSHAW, B. JOHNSON, R. LACY, C. F. SMITH III, AND P. J. TOLSON. 1989. Status of the Puerto Rican crested toad *Peltothyre lemur*. Inter. Zoo Yearb. 28:53–58.
- , AND J. WEINHEIMER. 1984. A method for tube-feeding anurans developed for *Rhacophorus viridis*. Inter. Zoo Yearb. 23:204–205.
- PAWLEY, R. 1988. Blomberg toad, *Bufo blombergi*, reproduction at Brookfield Zoo: paucity to profusion. Bull. Chicago Herpetol. Soc. 23(4):53–54.
- PEELING, C. 2013. Exhibiting amphibians. Current Therapy in Reptile Medicine and Surgery Chapter 20:238–246.
- PESSIER, A. P. 2002. An overview of amphibian skin disease. In Seminars in Avian and Exotic Pet Medicine 11(3):162–174.
- . 2009. Edematous frogs, urinary tract disease, and disorders of fluid balance in amphibians. J. Exotic Pet Med. 18(1):4–13.
- . 2013. Short tongue syndrome. Current Therapy in Reptile Medicine and Surgery (2013):271.
- , E. J. BAITCHMAN, P. CRUMP, B. WILSON, E. GRIFFITH, AND H. ROSS. 2014. Causes of mortality in anuran amphibians from an *ex situ* survival assurance colony in Panama. Zoo Biol. 33(6):516–526.
- PHILLIPS, K. 1994. Tracking the Vanishing Frogs. An Ecological Mystery. Penguin Books, New York. 244 pp.
- POLASIK, J. S., M. A. MURPHY, T. ABBOTT, AND K. VINCENT. 2015. Factors limiting early life stage survival and growth during endangered Wyoming toad reintroductions. J. Wildl. Man. 80:540–552.
- POUGH, F. H. 1991. Recommendations for the care of amphibians and reptiles in academic institutions. National Academy Press, Washington, D.C. 33(4) Fall 1991. 21 pp.
- PRAMUK, J. B., AND R. GAGLIARDO. 2008. General amphibian husbandry chapter 1. Amphibian Husbandry Resource Guide (2008): 4. Amphibian Husbandry Resource Guide, Edition 1.1 A publication of AZA's Amphibian Taxon Advisory Group, 52 pp.
- PREECE, D. 1998. The captive management and breeding of poison-dart frogs, family Dendrobatidae at Jersey Wildlife Preservation Trust. Dodo, J. Jersey Wildl. Preserv. Trust 34:103–114.
- QUINN, H. 1980. Captive propagation of endangered Houston toads. Herpetol. Rev. 11(4):109.
- , AND G. A. MENGENDEN. 1984. Reproduction and growth of the Houston toad, *Bufo houstonensis* (Bufonidae). Southwest. Nat. 29:189–195.
- RABB, G. B. 1960. On the unique sound production of the Surinam toad, *Pipa pipa*. Copeia 1960:368–369.
- . 1969. Frogs and pipid frogs. Brookfield Bandarlog No. 37.
- . 1973. Evolutionary aspects of the reproductive behavior of frogs. In J. L. Vial (ed.), Evolutionary Biology of the Anurans, pp. 213–227. University of Missouri Press, Columbia, Missouri.
- , AND M. S. RABB. 1960. On the mating and egg-laying behavior of the Surinam toad, *Pipa pipa*. Copeia 1960:271–276.
- , AND ———. 1963. On the behavior and breeding biology of the African pipid frog *Hymenochirus boettgeri*. Z. Tierpsych. 20:215–240.
- , AND ———. 1963. Additional observations on breeding behavior of the Surinam toad, *Pipa pipa*. Copeia 1963:636–642.
- , AND R. SNEDIGAR. 1960. Observations on the breeding and development of the Surinam toad, *Pipa pipa*. Copeia 1960:40–44.
- RADCLIFFE, C. W., D. CHISZAR, K. ESTEP, J. B. MURPHY, AND H. M. SMITH. 1986. Observations on pedal luring in leptodactylid frogs. J. Herpetol. 20:300–306.
- RAPHAEL, B. L. 1993. Amphibians. Vet. Clinics North Amer. Small Anim. Pract. 23:1271–1286.
- REICHENBACH-KLINKE, H.-H. 1961. Krankheiten der Amphibien [Diseases of Amphibians]. Gustav Fischer Verlag, Stuttgart. 100 pp.
- ROCA, V., G. GARCIA, E. CARBONELL, C. SANCHEZ-ACEDO, AND E. DELCACHO. 1998. Parasites and conservation of *Alytes muletensis* (Sanchiz et Androver, 1977) (Anura: Discoglossidae). Rev. Esp. Herpetol. 12:91–95.
- RODRÍGUEZ, C. E., AND A. P. PESSIER. 2014. Pathologic changes associated with suspected hypovitaminosis A in amphibians under managed care. Zoo Biol. 33(6):508–515.
- ROTH, T. L., D. C. SZYMANSKI, AND E. D. KEYSER. 2010. Effects of age, weight, hormones, and hibernation on breeding success in boreal toads (*Bufo boreas boreas*). Theriogenology 73(4):501–511.
- RUNDQUIST, E. M. 1993. Captive amphibian culture: some observations and suggestions for future veterinary investigations. Proc. Amer. Assoc. Zoo Vet.:19–22.
- RYAN, M. J. (ed.). 2001. Anuran Communication. Smithsonian Institution Press, Washington DC. 262 pp.
- SANTISTEVAN, C., AND M. NEFF. 2015. FrogWatch & Listen. Zoogoer, National Zoological Park.
- SAVAGE, A. E., K. A. TERRELL, B. GRATWICKE, N. M. MATTHEUS, L. AUGUSTINE, AND R. C. FLEISCHER. 2016. Reduced immune function predicts disease susceptibility in frogs infected with a deadly fungal pathogen. Conserv. Physiol. 4(1): cow011.
- , AND K. R. ZAMUDIO. 2011. MHC Genotypes associate with resistance to a frog-killing fungus. Proc. Nat. Acad. Sci. 108(40):16705–16710.
- SCHAFFER, S. F. 1981. Rearing the Asiatic tree frog *Rhacophorus leucomystax* at the San Diego Zoo. In R. A. Hahn (ser. ed.), 5<sup>th</sup> International Herpetological Symposium on Captive Propagation and Husbandry, pp. 147–150. International Herpetological Symposium, Thurmont, Maryland.
- SCHALK, C. M., C. G. MONTAÑA, J. L. KLEMISH, AND E. R. WILD. 2014. On the diet of the frogs of the Ceratophryidae: Synopsis and new contributions. S. Am. J. Herpetol. 9(2):90–105.
- SCHHEEL, B. C., D. A. HUNTER, L. F. GROGAN, L. E. E. BERGER, J. E. KOLBY, M. S. McFADDEN, G. MARANTELLI, L. F. SKERRATT, AND D. A. DRISCOLL. 2014. Interventions for reducing extinction risk in chytridiomycosis-threatened amphibians. Conserv. Biol. 28(5):1195–1205.
- SCHHEELINGS, T. F. 2015. Fighting extinction: Zoo Victoria's commitment to endangered herpetofauna. J. Herpetol. Med. Surg. 25(3–4):100–106.
- SCHELD, S., R. G. BINA PERL, A. RAUHAUS, D. KARBE, K. VAN DER STRAETEN, J. S. HAUSWALDT, R. D. RANDRIANIANA, A. GAWOR, M. VENCES, AND T. ZIEGLER. 2013. Larval morphology and development of the Malagasy frog *Mantidactylus betsileanus*. Salamandra 49:186–200.
- SCHOMBERG, G. 1957. British Zoos. A Study of Animals in Captivity. Allan Wingate, London. 194 pp.
- SCLATER, P. L. 1895. Note on the breeding of the Surinam water-toad (*Pipa surinamensis*) in the Society's Reptile-House. Proc. Zool. Soc. London 1895:86–88.
- SEARLE, C. L., J. R. MENDELSON, L. E. GREEN, AND M. A. DUFFY. 2013. Daphnia predation on the amphibian chytrid fungus and its impacts on disease risk in tadpoles. Ecology and Evolution 3(12):4129–4138.
- SEGEV, O., F. ANDREONE, R. PALA, G. TESSA, AND M. VENCES. 2012. Reproductive phenology of the tomato frog, *Dyscophus antongli*, in an urban pond of Madagascar's east coast. Acta Herpetologica 7(2):331–340.
- SEMLITSCH, R. D. (ed.) 2003. Amphibian Conservation. Smithsonian Books, Washington DC. 324 pp.
- SHARBEL, T. F., AND D. M. GREEN. 1989. Easy to build riffle tanks for aquatic amphibians. Can. Assoc. Herpetol. Bull. 3(1):3–5.
- , AND ———. 1992. Captive maintenance of the primitive New Zealand frog, *Leiopelma hochstetteri*. Herpetol. Rev. 23(3):77–79.
- SHAW, E. 2014. Improving captive maintenance techniques for New Zealand native frogs (*Leiopelma* spp.). Ph.D. dissertation, University of Otago.
- SHAW, S. D., P. J. BISHOP, C. HARVEY, L. BERGER, L. F. SKERRATT, K. CALLON, M. WATSON, J. POTTER, R. JAKOB-HOFF, M. GOOLD, N. KUMZMANN, P. WEST,

- AND R. SPEARE. 2012. Fluorosis as a probable factor in metabolic bone disease in captive New Zealand native frogs (*Leiopelma* species). *J. Zoo Wildl. Med.* 43(3):549–565.
- , AND A. S. HOLZAPFEL. 2008. Mortality of New Zealand native frogs in captivity. Science & Technical Publ., Department of Conservation.
- SHEIL, C. A., J. R. MENDELSON III, AND H. R. DA SILVA. 2001. Phylogenetic relationships of the species of Neotropical horned frogs, genus *Hemiphractus* (Anura: Hylidae: Hemiphractinae), based on evidence from morphology. *Herpetologica* 57:203–214.
- SHIBUYA, Y. 1978. Breeding of the Surinam toad. *Animals and Zoos (Official Bulletin of Ueno Zoological Garden, Tokyo)* 30:4–5.
- SHIHHARA, S., AND M. SAMEJIMA. 1995. Breeding Ishikawa's frog in captivity. *J. Japan. Assoc. Zoos Aquar.* 36(4):101–105.
- SILVA DA, H. R., AND J. R. MENDELSON III. 1999. A new organ and sternal morphology in toads (Anura: Bufonidae): descriptions, taxonomic distribution, and evolution. *Herpetologica* 55:114–126.
- SIM, R. R., K. E. SULLIVAN, E. V. VALDES, G. J. FLEMING, AND S. P. TERRELL. 2010. A comparison of oral and topical vitamin A supplementation in African foam-nesting frogs (*Chiromantis xerampelina*). *J. Zoo Wildl. Med.* 41(3):456–460.
- SKERRATT, L.F., L. BERGER, N. CLEMAN, D. A. HUNTER, G. MARANTELLI, D. A. NEWELL, A. PHILIPS, M. MCFADDEN, H. B. HINES, B. C. SCHEELE, AND L. A. BRANNELLY. 2016. Priorities for management of chytridiomycosis in Australia: saving frogs from extinction. *Wildl. Res.* 43(2):105–120.
- SLAVENS, F. L. 1989. The Inventory of Live Reptiles and Amphibians in Captivity: a brief history. *Inter. Zoo Yearb.* 28:7–9.
- SMITH, C. E., AND E. L. PAINE. 1989. A system for rearing tadpoles at the Buffalo Zoological Gardens. *Inter. Zoo Yearb.* 28:58–59.
- SMITH, R. J., AND H. M. FISCHER. 1975. Breeding and rearing the Colombian giant toad *Bufo blombergi* at Los Angeles Zoo. *Inter. Zoo Yearb.* 15:87–89.
- SMITH, R. K., AND W. J. SUTHERLAND. 2014. Amphibian Conservation: Global Evidence for the Effects of Interventions. Pelagic Publishing, Exeter. 266 pp.
- SNIDER, A. T. AND J. K. BOWLER. 1992. Longevity of reptiles and amphibians in North American collections. Second edition. Society for the Study of Amphibians and Reptiles Herpetol. Circ. No. 21:1–40.
- SOAMIRIAMAMPIONONA, J., S. S. SAM, R. DOLCH, K. KLYMUS, F. RABEMANANJARA, E. ROBSOMANITRANDRASANA, J. C. RAKOTOARISOA, AND D. EDMONDS. 2015. Effects of three diets on development of *Mantidactylus betsileanus* larvae in captivity. *Alytes* 32:7–15.
- SOTO-AZAT, C., A. VALENZUELA-SÁNCHEZ, B. COLLEN, J. M. ROWCLIFFE, A. VELOSO, AND A. A. CUNNINGHAM. 2013. The population decline and extinction of Darwin's frogs. *PLoS ONE* 8(6): e66957.
- , ———, B. T. CLARKE, K. BUSSE, J. C. ORTIZ, C. BARRIENTOS, AND A. A. CUNNINGHAM. 2013. Is Chytridiomycosis driving Darwin's frogs to extinction? *PLoS One.* 8(11): e79862.
- SOUDER, W. 2000. A Plague of Frogs: The Horrifying True Story. Hyperion, New York. 299 pp.
- SPIITZEN-VAN DER SLUIJS, A., A. MARTEL, E. WOMBWELL, P. VAN ROOIJ, R. ZOLLINGER, T. WOELTJES, M. RENDLE, F. HAESEBROUCH, AND F. PASMANS. 2011. Clinically healthy amphibians in captive collections and at pet fairs: A reservoir of *Batrachochytrium dendrobatidis*. *Amphibia-Reptilia* 32(3):419–423.
- STANISZEWSKI, M. S. 1995. Amphibians in Captivity. T.F.H., Neptune City, New Jersey. 544 pp.
- STEBBINS, R. C., AND N. W. COHEN. 1995. A Natural History of Amphibians. Princeton University, Princeton, New Jersey. 316 pp.
- STETTER, M. D., AND R. A. COOK. 1994. Normal and pathological ultrasonographic anatomy of amphibians. *Proc. Amer. Assoc. Zoo Vet.* :76–78.
- , B. RAPHAEL, F. INDIVIGLIO, AND R. A. COOK. 1996. Isoflurane anesthesia in amphibians: comparison of five application methods. *Proc. Amer. Assoc. Zoo Vet.* :255–257.
- STOSKOPF, M. K., A. WISNIESKI, AND L. PIEPER. 1985. Iodine toxicity in poison arrow frogs. *Proc. Amer. Assoc. Zoo Vet.* :86–88.
- STUART, S., ET AL. 2008. Threatened Amphibians of the World. Lynx Edicions, Barcelona, Spain. IUCN, Gland, Switzerland and Conservation International, Arlington, Virginia. 758 pp.
- SUEDMEYER, W. K., D. S. GILLESPIE, AND L. PACE. 1997. Chromomycosis in a marine toad, *Bufo marinus*. *Bull. Assoc. Rept. Amphib. Vet.* 7(3):13–15.
- TAPLEY, B., K. S. BRADFIELD, C. MICHAELS, AND M. BUNGARD. 2015 Amphibians and conservation breeding programmes: do all threatened amphibians belong on the ark? *Biodiv. Conserv.* 24:2625–2646.
- , M. RENDLE, F. M. BAINES, M. GOETZ, K. S. BRADFIELD, D. ROOD, J. LOPEZ, G. GARCIA, AND A. ROUTH. 2015. Meeting ultraviolet B radiation requirements of amphibians in captivity: A case study with mountain chicken frogs (*Leptodactylus fallax*) and general recommendations for prerelease health screening. *Zoo Biol.* 34(1):46–52.
- TAYLOR, S. K., E. S. WILLIAMS, K. MILLS, A. BOERGER-FIELDS, E. T. THORNE, D. R. KWIAKOWSKI, S. L. ANDERSON, AND M. S. BURTON. 1994. The Wyoming toad (*Bufo hemiophrys baxteri*): a review of causes of mortality in the captive population. *Proc. Amer. Assoc. Zoo Vet.* :75.
- TEARE, J. A., R. S. WALLACE, AND M. BUSH. 1991. Pharmacology of gentamicin in the leopard frog (*Rana pipiens*). *Proc. Amer. Assoc. Zoo Vet.* :128–131.
- THOMPSON REUTERS. 2016. Web of Science. website: <https://login.webofknowledge.com/> Accessed 30 June 2016.
- TONGE, S., AND Q. BLOXAM. 1989. Breeding the Mallorcan midwife toad *Alytes muletensis* in captivity. *Inter. Zoo Yearb.* 28:45–53.
- TYLER, M. J. 1996. The Action Plan for Australian Frogs. Wildlife Australia, Canberra.
- UPTON, S. J., P. S. FREED, D. A. FREED, C. T. McALLISTER, AND S. R. GOLDBERG. 1992. Testicular myxosporidiosis in the flat-backed toad, *Bufo maculatus* (Amphibia; Bufonidae), from Cameroon, Africa. *J. Wildl. Dis.* 28:326–329.
- VAUGHAN, A., AND J. R. MENDELSON III. 2007. Taxonomy and ecology of the Central American toads of the genus *Crepidophryne* (Anura: Bufonidae). *Copeia* 2007:304–314.
- VERSCHOOREN, E., R. K. BROWN, F. VERCAMMEN, AND J. PEREBOOM. 2011. Ultraviolet B radiation (UV-B) and the growth and skeletal development of the Amazonian milk frog (*Trachycephalus resinifictrix*) from metamorphosis. *J. Physiol. Pathophysiol.* 2(3):34–42.
- VOGEL, Z. 1964. Reptiles and Amphibians. Their Care and Behaviour. The Viking Press, New York. 228 pp.
- VOGT, P. 1974. Breeding and rearing the Colombian giant toad *Bufo blombergi* at Krefeld Zoo. *Inter. Zoo Yearb.* 14:87–90.
- WAGNER, E. 1987. Breeding arrow poison frogs and looking for ways to reduce the labor. In R. Gowen (ed.), *Captive Propagation and Husbandry of Reptiles and Amphibians*, pp. 11–16. Special Publication No. 4, Northern California Herpetological Society.
- WELLS, K. D. 2007. The Ecology and Behavior of Amphibians. The University of Chicago Press, Chicago, Illinois. 1148 pp.
- WEYGOLDT, P. 1976a. Beobachtungen zur Fortpflanzungsbiologie der Wabenkröte *Pipa carvalhoi* Miranda Ribeiro (Observations concerning the reproductive biology of the Surinam toad *Pipa carvalhoi* Miranda Ribeiro). *Z. Köln. Zoo* 19(3):77–84.
- . 1976b. Notes on biology and ethology of *Pipa carvalhoi* Mir. Rib. 1937 (Anura, Pipidae). *Zeitschrift für Tierpsychologie* 40:80–99.
- WHITAKER, B. R., AND S. L. POYTON. 1993. Protozoans in dendrobatid frogs: identification, clinical assessment, and indications for treatment. *Proc. Amer. Assoc. Zoo Vet.* :13–15.
- WHITTAKER, K., AND V. VREDENBURG. 2014. An overview of chytridiomycosis. <http://www.amphibiaweb.org/chytrid/chytridiomycosis.html>
- WHITFIELD, S. M., K. R. LIPS, AND M. A. DONNELLY. 2016. Amphibian decline and conservation in Central America. *Copeia* 2016:351–379.
- WIESE, R. J., AND M. HUTCHINS. 1994. The role of zoos and aquariums in amphibian and reptilian conservation. In J. B. Murphy, K. Adler, and J. T. Collins (eds.), *Captive Management and Conservation of Amphibians and Reptiles*, pp. 37–45. Society for the Study of Amphibians and Reptiles. Contributions to Herpetology, volume 11, Ithaca, New York.

- WILDENHUES, M. J., M. F. BAGATUROV, A. SCHMITZ, D. A. T. TRAN, R. HENDRIX, AND T. ZIEGLER. 2011. Captive management and reproductive biology of Orlov's treefrog, *Rhacophorus orlovi* Ziegler & Köhler, 2001 (Amphibia: Anura: Rhacophoridae), including larval description, colour pattern variation and advertisement call. *Der Zoologische Garten* 80(6):287–303.
- WRIGHT, K. M. 1996. Amphibian husbandry and medicine. In D. R. Mader (ed.), *Reptile Medicine and Surgery*, pp. 436–459. W. B. Saunders Co., Philadelphia, Pennsylvania.
- , AND B. R. WHITAKER. 2001. *Amphibian Medicine and Captive Husbandry*. Krieger Publishing Co., Malabar, Florida. 499 pp.
- YOSHIMI, D. H., D. A. PAYNE, AND F. L. SLAVENS. 1996. Maintenance and captive breeding of the Solomon Island leaf frog (*Ceratobatrachus guentheri*), pp. 23–32. In P. D. Strimple (ed.), *Advances in Herpetoculture*. Special Publication of the International Herpetological Symposium, Inc., No. 1. Des Moines, Iowa.
- YOUNG, S., L. BERGER, AND R. SPEARE. 2007. Amphibian chytridiomycosis: strategies for captive management and conservation. *Inter. Zoo Yearb.* 41:85–95.
- ZIMMERMANN, E. 1983. *Breeding Terrarium Animals*. T.F.H. Publications, Neptune City, New Jersey. 384 pp.
- , AND H. ZIMMERMANN. 1994. Reproductive strategies, breeding, and conservation of tropical frogs: dart-poison frogs and Malagasy poison frogs. In J. B. Murphy, K. Adler, and J. T. Collins (eds.), *Captive Management and Conservation of Amphibians and Reptiles*, pp. 255–266. Society for the Study of Amphibians and Reptiles. Contributions to Herpetology, volume 11, Ithaca, New York.
- ZIMMERMANN, H. 1992. Nachzucht und Schutz von *Mantella crocea*, *Mantella viridis* und vom madagassisches Goldfröschen *Mantella aurantiaca* [Breeding and protection of *Mantella crocea*, *Mantella viridis* and of Madagascar gold frogs *Mantella aurantiaca*]. *Z. Köln. Zoo* 35(4):165–171.
- . 1994. Erhaltungszuchtprogramme für Anuren am Beispiel von *Dendrobates variabilis*, einem seltenen Vertreter der Pfeilgiftfrösche Südamerikas [Preservation breeding programs for frogs, using the example of *Dendrobates variabilis*, a rare representative of the poison dart frogs of South America]. *Z. Köln. Zoo* 37(4):143–151.
- , AND E. ZIMMERMANN. 1981. Sozialverhalten, Fortpflanzungsverhalten und Zucht der Färberfrösche *Dendrobates histrionicus* und *D. lehmanni* sowie einiger anderer Dendrobatiden [Social behavior, reproductive behavior and breeding of the poison dart frogs *Dendrobates histrionicus* and *Dendrobates lehmanni* as well as of several other dendrobatids]. *Z. Köln. Zoo* 24(3):83–99.
- , AND ———. 1987. Mindestanforderungen für eine artgerechte Haltung einiger tropischer Anurenarten [Minimum requirements for the species-appropriate care of some tropical frog species]. *Z. Köln. Zoo* 30(2):61–71.
- ZIPPEL, K. 2002. Conserving the Panamanian golden frog: Proyecto Rana Dorada. *Herpetol. Rev.* 33:11–12.
- . 2006. Further observations of oviposition in the Surinam toad (*Pipa pipa*), with comments on biology, misconceptions, and husbandry. *Herpetol. Rev.* 37(1):60–68.
- , K. JOHNSON, R. GAGLIARDO, R. GIBSON, M. MCFADDEN, R. BROWNE, C. MARTINEZ, AND E. TOWNSEND. 2011. The Amphibian Ark: a global community for ex situ conservation of amphibians. *Herpetol. Conserv. Biol.* 6(3):340–352.
- , AND A. SNIDER. 2001. The Detroit Zoo makes a bold statement for amphibians. *Communiqué March* 2001:5–6, 51.