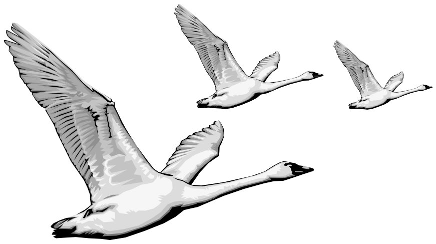

Animal Behavior Society **ABS Conservation Committee**

The Conservation Behaviorist, an electronic news-update, informs ABS members about the Conservation Committee's activities, research trends in behavior and conservation, and relevant scientific news in conservation research where behavior plays an important role.
www.animalbehavior.org/Committees/Conservation

The Conservation Behaviorist

Vol. 4 No. 1 - May 2006

Building a Case for Conservation Behavior

In this special issue of The Conservation Behaviorist (TCB) we include articles published since 2003 and new essays. The area of conservation behavior has grown significantly during the past decade and the Animal Behavior Society Conservation Committee has played an important role in this process. Besides TCB, the Committee has created the E. O. Wilson Conservation Award, three data bases available online (funding opportunities for behavioral research, publications in conservation behavior, mentors in conservation behavior), and has also sponsored scientific events at the Society's annual meetings. We are confident that our efforts benefit ABS, the conservation community, and the public at large.

The ABS Conservation Committee

Created in 1997, the Conservation Committee aims to encourage ABS members to participate in research programs addressing the interface between animal behavior and conservation science. By identifying and evaluating the areas in which behavioral research has contributed to conservation, as well as the fields that need development, the Committee seeks to generate discussion and promote studies in behavior and conservation.

Interact with the Conservation Committee

Send letters, announcements, comments and contributions to The Conservation Behaviorist *gpazymino@worcester.edu* Deadlines for articles are the 15th of the month preceding the next news update. The next deadline is **October 15th**. Contributions submitted by members of the Animal Behavior Society and judged by the Conservation Committee to be appropriate will be published in The Conservation Behaviorist. The publication of such material does not imply ABS or Conservation Committee endorsement of the opinions expressed by contributors.

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In this special issue

Behavioral Unknowns: An Emerging Challenge for Conservation

By Guillermo Paz-y-Miño C.*

In 1995, Norman Myers defined "Environmental Unknowns" as those problems we had not even identified as yet but for which we were all accountable[1]. Examples included climate change, mass extinctions, and ozone layer depletion. Society disregarded their existence until the early 1980s. These "surprise phenomena" have already disrupted ecological and evolutionary processes[2-7].

As data become available and environmental public awareness grows, new "unknowns" are emerging. One such "surprise" is the impact of global disruptions on the behavior of animals. Scarce scientific information has limited our capacity to anticipate and prevent negative effects caused by global environmental problems on the physiological and sensory mechanisms that control behavior, its development, function and evolution.

By participating in seed dispersal, pollination, predation, competition, and parasitism, animals shape communities and ecosystems. Behaviors, however, can be easily disturbed directly through physiology (metabolic and reproductive processes) [2,7] or indirectly through the ecosystem, by changes in the abundance of resources, predators, parasites, and competitors[2,5,6].

Large-scale patterns of climate variability, such as the ones generated by the North Atlantic Oscillation (NAO) or the El Niño-Southern Oscillation (ENSO), determine altitudinal, transcontinental and transoceanic migrations of animals[2,6,7]; NAO and ENSO influence recruitment synchrony between fish-predators and zooplankton, and facilitate species food-web assemblages in the sea and in land[2,5]. How are NAO and ENSO affecting animal dispersal and settlement, reproductive behavior and social organization, species interactions, foraging and feeding[8]? What will be the impact of global environmental problems on aspects of behavior that are still unknown to scientists, such as cognition, behavioral endocrinology and physiology, communication, behavioral diversity, or behavioral evolution[9]?

"Behavioral unknowns" are emerging at a time when ethological data are most needed for captive breeding of endangered species, reintroduction programs, and habitat restoration[8,10]. Yet, despite Myers' previous warnings, we have been taken by surprise. For too long, we have omitted behavior from the list of "things to be done" to keep our Planet running. Behaviorists have much to contribute to conservation.

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8. Paz-y-Miño C., G. 2003. Contribution of animal behavior research to conservation biology. Animal Behavior Society Newsletter 48: 1-2. Four main areas of behavioral research are addressed in most environmental-related studies (N=277): dispersal and settlement (includes home range, habitat selection), reproductive behavior and social organization (mating systems, mate choice, parental care, kinship, cooperation and helping), species interactions (predation, competition, pathogen-induced behavior, brood parasitism), and foraging (pollination) and feeding.
9. Source ref. 8. Cognition (includes perception, learning, decision making, information processing), behavioral endocrinology and physiology (hormonal and physiological traits and behavior), communication (information sharing, vocalization, signaling), behavioral diversity (genetic variability and behavior, population genetics and behavior), behavioral evolution (speciation, reproductive isolation, tradition/culture, and behavioral phylogenies).
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Ten Things a Behavioral Biologist Can do to Help Conservation

By Daniel T. Blumstein*

1. Study an endangered species. Much of endangered species management is a quest for knowledge about the behavior and ecology of rare species. Decisions are routinely made with remarkably limited data, and not always by those trained in the scientific method. By studying endangered species, you can contribute to this needed dataset. More importantly, as a scientist, you should bring needed rigor to your studies and conclusions.

2. Work in an endangered habitat. Even if you are not focusing on an endangered species, by working in an endangered habitat you will illustrate, by example, the value of the habitat, and you may be able to collect additional information that will be useful for endangered species management.

3. Work on a question of conservation concern. Wildlife managers have many behavioral questions they need answered. It is often possible to collect needed ecological data while asking a variety of theoretically interesting behavioral questions. Strive to combine studies with both a theoretical and an applied objective.

4. Study more than one species at a time. By studying several species simultaneously you will gain a much better understanding of how different species respond to the same ecological pressures. Whether they respond in the same way or differently will be good information for answering both conservation and behavioral questions. Managers and policy-makers often do not have the luxury of waiting for results. Studying more than once species at a time will generate more information more efficiently.

5. Capitalize on these 'unnatural' experiments. Most behavioral researchers try to eliminate human influences in their research. By adding a component of human disturbance (e.g., fragmented versus intact field sites or subjects regularly trapped and weighed versus trapped once annually), you will generate information that also may be of conservation interest as well as identifying how humans may be currently altering a species' 'evolutionary landscape'.

6. Apply Tinbergen's Four Questions to a conservation question. Applying our major conceptual framework can provide novel management questions and can help structure the scientific study of an endangered species. Share our conceptual framework with others! It works well for us and it can surely work well for mainstream conservation biologists.

7. Develop and test predictive models of animal behavior that apply to endangered and non-endangered species. Predictive models will be useful when managers are faced with managing an endangered species for which little information is known. While not a substitute for detailed study of the endangered species, predictive models may help highlight behaviors that influence demographic parameters, such as infanticide or reproductive suppression.

8. Talk with a wildlife manager. Wildlife and wildland managers may not be trained in animal behavior. By talking with them and understanding their objectives and needs, it may become obvious how and why knowledge of animal behavior may help them address those needs. It may also become obvious that behavior is not that important for a particular pressing conservation issue. Only by understanding the needs of the on-the-ground managers can we effectively integrate behavior into conservation biology.

9. Comment on a conservation plan. The US Fish and Wildlife Service, as well as many state, local, and international agencies, make conservation plans available for public comment. Most of these species survival or habitat conservation plans were not written by behavioral biologists. Lack of behavioral knowledge should not be seen as a short-coming as much as it should be seen as an opportunity for us to share our knowledge and intellectual toolkit with others. Most of these plans are now easily accessible on agency websites.

10. Teach conservation behavior. Conservation behavior can be integrated into traditional courses in behavior, ecology, and conservation biology. There are a number of excellent books and reviews that can form the subject of a seminar course. It is our fault if the next generation of conservation biologists does not think about behavior.

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Should Animal Behaviorists Teach Conservation?

By Richard Buchholz*

The neglect shown ethology in conservation-biology textbooks was an impetus for the formal development of conservation behavior. Now that scholarly texts are available for conservation behaviorists, it is time to address the absence of conservation in animal behavior textbooks and in our classes. First, I ask whether conservation belongs in the undergraduate animal behavior course. Next, I review the conservation content of a recent sample of ethology textbooks. Finally, I suggest ways in which conservation could be incorporated into both the lecture and laboratory work in animal behavior, behavioral ecology, comparative psychology and ethology.

Most animal behavior instructors do not teach conservation. Teaching behavioral methodology along with the proximate underpinnings and evolutionary patterns of behavior in a diversity of animal taxa easily fills a semester. What justifies squeezing in some conservation to an already crowded syllabus? From a purely pedagogical viewpoint, including examples from conservation makes sense. While it is not unusual to include examples of behavioral principles by describing published studies in behavior research journals, some students may have difficulty thinking of problems of behavioral theory as true "problems." Conservation problems appeal to an entirely different set of student motivations. Using a 'case study' approach to teaching is a popular and apparently effective way to motivate student interest in learning. Asking students to apply behavioral theory to actual conservation dilemmas can reinforce their learning. Pedagogy aside, students want their learning to be relevant to the "real world." Not all biology students will become surgeons, and most animal behavior students will not become college professors. Therefore, we need to broaden our students' perspectives on how they might employ their biological knowledge in an array of career possibilities. Applied animal behavior, and specifically conservation management, is a valid career option for aspiring animal behaviorists. Thus teaching conservation behavior enhances both student learning and student opportunities.

Is conservation already included in the textbooks used in most animal behavior courses? A quick search for the words "conservation" and "endangered species" in the subject indices of a variety of animal behavior texts that happen to be on my bookshelf is somewhat heartening (Table 1). Recent texts are more likely to mention conservation themes than older texts. However, with the exception of Bolhuis & Giradeau[2], none of the large, comprehensive texts have chapters on conservation behavior. The relatively small overview text by Scott[12] uses conservation case studies effectively. Table 1 shows that the advanced text of Krebs & Davies[9] is prescient in allocating an entire chapter to conservation behavior at about the same time that scholarly texts on etho-conservation were just starting to be published. In contrast, the stalwart texts probably used most often in today's animal behavior classes contain none or virtually no conservation content. Ironically, Alcock[1] dedicates the 8th edition of his popular animal behavior text to those trying to save biodiversity, but his book lacks mention of conservation themes (although the term "endangerment" is used). Other recent and influential textbooks by prominent members of the profession provide only token index reference to conservation. In the case of Drickamer et al.[4], the absence of conservation is puzzling given that the mammalogy textbook by some of the same authors[6] dedicates an entire chapter to conservation biology.

Table 1. Page allocation to conservation themes in some new and old animal behavior textbooks

Text author(s) or editor(s)	Conservation chapter	Conservation mentioned*	% of text pages involving conservation (total content pages in book)
Alcock 2005[1]	NO	0	0.0 (515)
Bolhuis & Giradeau 2005[2]	YES	5	7.0 (408)
Scott 2005[12]	NO	3	3.0 (196)
Dugatkin 2004[5]	NO	1	0.2 (596)
Drickamer et al. 2004[4]	NO	1	0.2 (349)
Goodenough et al. 2001[7]	NO	0	0.0 (477)
Slater 1999[13]	NO	0	0.0 (207)
Krebs & Davies 1997[9]	YES	0	6.0 (395)
Krebs & Davies 1993[8]	NO	0	0.0 (386)
McFarland 1985[11]	NO	0	0.0 (531)
Brown 1975[3]	NO	0	0.0 (676)
Tavolga 1969[14]	NO	0	0.0 (117)
Marler & Hamilton 1966[10]	NO	0	0.0 (740)

Not including individual mentions of conservation themes in conservation chapter

When animal behaviorists are asked to review new animal behavior texts or revisions to established texts, we need to be especially critical of the lack of conservation applications. In the meantime, we must begin to supplement our lecture material with conservation behavior. Behaviorists involved in conservation efforts are likely to already know of numerous examples of conservation problems suitable for the case study approach. Case studies can be posted at a central internet depository (e.g. ABS Conservation Committee website www.animalbehavior.org/Committees/Conservation). For instructors with little experience in conservation, back issues of The Conservation Behaviorist, the ABSCC website's example section, and various volumes in behavior conservation serve as suitable resources. Some instructors may prefer to incorporate conservation into behavioral topics peppered throughout their course, while others would separate conservation behavior out as its own topic, perhaps alongside other topics in applied animal behavior. One important objective of those active in conservation behavior efforts should be to make educational materials readily available to animal behavior instructors, for example, in the form of downloadable well-illustrated Power Point presentations along with an instructor's guide, possible exam questions, and a bibliography. We need to make it easy to incorporate conservation behavior teachings; this will minimize excuses not to do it. Lab exercises in conservation behavior will be harder to develop so that they are usable at a variety of universities. Integrating etho-conservation lab exercises on captive propagation of endangered species with a trip to a local zoological park or aquarium is one possibility. A lab exploring conservation behavior in wild habitats would be more difficult to achieve, despite its greater importance to protecting biodiversity. As with case studies and Power Point presentations, lab exercises in conservation could be collected at a curated internet depository.

Conservation case studies are likely to improve student understanding of both the theory and practice of ethology in all its guises. My review of themes in animal behavior textbooks suggests that improvement in conservation coverage is needed. Behaviorists concerned with the conservation of biodiversity have made great efforts to develop a theoretical and practical basis for the incorporation of behavioral considerations into the management of threatened and endangered animal populations. As we continue to apply our profession to saving animals from extinction, and their habitats from ruin, we must begin to ensure that future generation of behaviorists receive basic instruction in conservation behavior. In the future, some of these students (and perhaps their instructors) will build on our efforts to establish behavioral study in the toolbox of the conservation biologist, wildlife manager, and environmental policy maker, and reinforce biological conservation as an accepted mission of the animal behaviorist.

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Developing a Career in Conservation Behavior

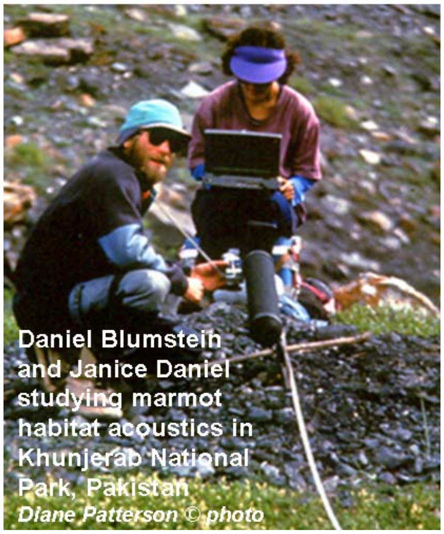
By Daniel T. Blumstein*

Many of the inquiries I receive from prospective graduate students are from people who have interest in conservation behavior. However, most have vague notions of what conservation behavior is. This is -in itself- an important reason to embrace new disciples and mentor them.

I define conservation behavior as the application of general principles of behavior to help conserve or manage wildlife populations. Others have different definitions. Such is the excitement associated with working in a growing field. Enthusiasts usually seek the hands-on opportunity to prevent the extinction of endangered species. This is an admirable goal. Others gravitate toward studying theoretical questions that may not turn into immediate conservation outcomes, but that will influence future decisions. From my perspective, there are several ways to contribute to conservation behavior. I do believe, however, that obtaining a broad and strong education is not only crucial for good conservation-decision making but also a smart career move. Here is my advice:

First, obtain an integrative education in Tinbergian behavior while also studying ecology (particularly population biology) and conservation science. Broadly studying behavior at multiple levels of analysis (i.e. mechanisms, ontogeny, function, evolution) should help with integration later on in your career. A working “vocabulary” of population biology is essential because it is the lingua franca for many wildlife biologists. After all, to save species, we have to know the status of their populations, predict how many individuals we’ll have in the future, and plan strategies to conserve and manage them. Population biology principles have proven to be essential in conservation plans.

Second, study some topic of behavioral interest and simultaneously work on a conservation problem. When I was a graduate student interested in studying marmots in a high-alpine national park in Pakistan, I was told by a wildlife conservation biologist that working with marmots would contribute nothing to conservation! I believed then, as I do now, that I could contribute to conservation with my research. While addressing questions about marmot communication and anti-predator behavior (nowadays essential topics in reintroduction and management plans), I also worked with the local community who sought help protecting the land and managing the park. I documented the biodiversity of this spectacular alpine ecosystem. I interacted with managers, non-governmental organizations, and government officials lobbying on the park’s behalf. Now, I realize in retrospect that my theoretically-interesting behavioral studies did, in fact, have conservation relevance, and that they prepared me intellectually for future work.


Daniel Blumstein and Janice Daniel studying marmot habitat acoustics in Khunjerab National Park, Pakistan
Diane Patterson © photo

Third, study some facet of behavior in an endangered species. But remember that everyone working with endangered species loses some aspect of control over the research. Sample sizes with endangered species are often distressingly small, and some research techniques might in fact harm animals. I believe it’s often preferable to first gain experience working with non-endangered species and then apply this knowledge to extinction-risk prone taxa. Moreover, working with endangered species usually involves interacting with other professionals, including veterinarians, managers, government officials, and other scientists whose decisions could influence your work, delaying it or even jeopardizing the completion of the research. I have learned through my own work that studying endangered species should be left for those that already have a degree under the belt. But of course there must be exceptions.

We live at an exciting time. Conservation behavior, as a new area of common work, is just emerging, and students today will be who make fundamental contributions tomorrow.

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The Conservation Behaviorist

Contribution of Animal Behavior Research to Conservation Biology

By Guillermo Paz-y-Miño C.*

Behavioral research encompasses the study of the physiological and sensory mechanisms that control behavior, the development or ontogeny of behavior, and the function and evolution of behavior. Conservation biologists have debated about these paradigms for decades, at times not realizing that their discussions have contributed directly or indirectly to the area of animal behavior and conservation.

To assess the contribution of behavioral paradigms in conservation studies, I identified and evaluated 277 articles (N=1631) published in Conservation Biology between 1987 and 2002 that were directly related to animal behavior and conservation. Four main areas of behavioral research were commonly addressed in these studies (Fig. 1): dispersal and settlement, reproductive behavior and social organization, species interactions, and foraging/feeding and pollination. These areas have helped biologists to understand and alleviate conservation problems such as extinction of endangered species and biodiversity loss, habitat destruction and ecosystem management and restoration (Fig. 2).

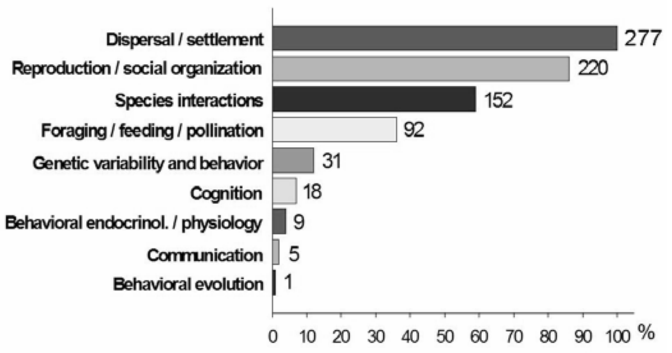

Figure 1. Areas of animal behavior most commonly discussed in conservation biology studies. Number of articles per category is indicated next to each bar. Percentages were calculated for each category in respect to the total number of articles in the survey.

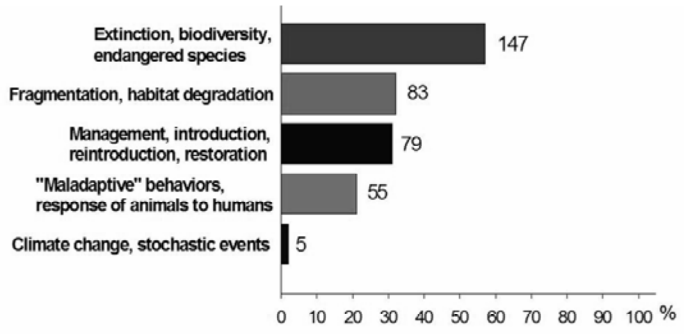

Figure 2. Conservation problems most commonly discussed in behavioral conservation studies. Values correspond to categories explained in Fig. 1.

Areas of behavioral research that still need development and that have not yet been applied to conservation in a significant manner include: cognition (perception, learning, decision making, information processing), genetic variability and behavior (biodiversity, behavioral diversity, population genetics and behavior), behavioral endocrinology and physiology (hormones and behavior, physiological traits and behavior), animal communication (information sharing, vocalization, signaling) or behavioral evolution (speciation and behavior, reproductive isolation, tradition = culture, phylogenies and behavior). The full impact of large-scale environmental problems (i.e. global warming, ozone depletion, pollution, mass extinctions) on animal behavior, particularly transcontinental and altitudinal migrations or population cycles, remains unknown.

The data indicate that, in the short-term, the experimental design for a most effective study in behavioral conservation should include (1) more than one endangered species that (2) interact and live in fragmented or degraded habitats, and that (3) need imminent management to prevent their extinction. This sinecological study in behavioral ecology should focus on (4) species interactions, particularly predator and anti-predator behaviors, territoriality, and competition for food, mates and nest sites; (5) reproductive behavior and social organization, including not only parental care and cooperation/helping, but also mating systems, mate choice, and kinship; (6) dispersal and settlement, particularly phylopatry or emigration, habitat selection, establishment and home range; and (7) foraging and feeding strategies. Because habitat fragmentation and degradation are the sources of most conservation problems worldwide, current studies in behavioral conservation may be most valuable when conceptualized and conducted under patch-dynamic theory (including patch size, edge effects, patch-matrix interactions, landscape composition, and connectivity), population viability principles applied to fragmented areas (i.e. effective population size, inbreeding depression, extinction), as well as species diversity (both biodiversity and behavioral diversity) and abundance.

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What Can Captive Breeding do for Conservation and What Can Behavior Research do for Captive Breeding?

By Ronald R. Swaisgood*

How can we justify confining animals in small enclosures, often far removed from many salient features of the animal's natural environment? This question speaks to concerns of animal welfare, and I see it as a challenge to behaviorists and managers to understand the behavioral needs of animals and develop captive environments that meet these needs. How can we justify the expenditure of money to maintain a few representatives of endangered species in captivity when the same funds could significantly enhance in situ conservation efforts? A reasonable answer must show that these expenses actually do not take away funds that otherwise could go to conservation of animals in their natural environments and that captive breeding programs contribute to in situ conservation. These questions are interrelated because minimal well-being is a prerequisite for reproduction[18] for conservation breeding.

Zoos are the preeminent domain of captive breeding programs, but not the only players. Governmental agencies and many Non-Governmental Organizations (NGO's) are increasingly involved in species recovery efforts that involve a stint in captivity. This underscores the sad truth that we are too often confronted with conservation triage, where we have to rescue populations that are no longer able to sustain themselves in the human-altered landscape in which they live (witness the plight of the California condor). But these last-ditch efforts are not the preferred method of rescuing disappearing populations. The International Union for the Conservation of Nature (IUCN) recommends that captive breeding programs for vulnerable populations be established before their existence becomes so precarious that further removals for captive breeding will exacerbate their decline in situ. In this view, viable captive populations are established as an insurance policy, providing a genetic reservoir for reintroduction should in situ efforts fail.

As habitat for wild populations becomes increasingly altered by human activities, conservationists are relying more on meta-population management, where many populations in small reserves (and breeding centers) are managed as a whole to preserve genetic diversity. As zoos and breeding centers move more to large, naturalistic enclosures and many wild populations are managed in smaller, fenced areas (e.g., rhino reserves in Africa), the captive-wild distinction becomes blurred. It is not the preferred model for conservation, but often the reality.

Studies of white rhino social organization, reproductive behavior, and endocrinology are underway in the Hluhluwe-Umfolozi Park in South Africa. One goal of this research is to use these data to evaluate reproductive problems that plague the captive population. Ronald R. Swaisgood © photo

What about the role of captive breeding in the conservation community? As a previous outsider to the zoo community—now nearly a 10-year veteran of zoo-based conservation—I can speak to issues that initially weighed heavily on my mind, but I have learned to appreciate from a new perspective. First, the money. I think it's fair to say that the typical zoogoer is not necessarily an avid conservationist. Money spent at the gate is likely not money taken out of the environmental charity tithes. This money is used to feed and house the zoo animals. And today zoos often skim off a few dollars earned from ticket, T-shirt and hamburger sales to support their own in situ conservation programs. Second, zoos have the unique opportunity to educate people that might not otherwise embrace conservation. Typically busy urbanite families that need a break and enjoy seeing animals easily (e.g., without the heat and the mosquitoes), the zoogoer may not be up to speed on the latest conservation issues. A zoo devoted to a conservation message can capitalize on this opportunity to educate the zoo-going citizen. A close-up experience with a wild animal can foster a bond that—with the proper educational experience—can grow into a conservation ethic. Some may just throw an extra buck in the conservation donation box, but some may develop into true conservationists, support environmentally sound policy, and make significant monetary contributions. This is a best-case scenario, and it is incumbent upon zoos to do everything in their power to ensure that this goal is realized, or risk becoming an obsolete holdover from the circus mentality of previous generations.

Take the case of the giant panda, global conservation icon[11]. Probably no other animal can claim so much conservation fund-raising in its name—for itself and for the ecosystem in which it resides. Sure, some monies have been misappropriated, but increasingly panda-generated funds are finding their way into valid conservation channels. The visionary U.S. Fish & Wildlife policy dictates that no zoo turns a profit from panda importation, that any money generated is put back into panda conservation in China, and that at least 80% of these funds go to in situ conservation. Long lines of T-shirt-buying zoogoers often wait for a brief view of a sleeping panda. This means that each of the four U.S institutions holding pandas sends a million dollars per year back to China, supporting reserve protection staff, capacity building, reforestation, conservation science, the establishment of new reserves, and the creation of corridors. Not just pandas, but an incredible diversity of life is protected in the more than 40 reserves that have been established in the panda's name. The panda has also generated a surreal level of public interest. Panda PR dominates the media with regularity, and—in addition to the warm fuzzy stories—often conveys a conservation message. One more step toward an educated citizenry. Surely, conservationists had the panda in mind when they came up with terms like "flagship species" and "umbrella species." The endearing character of the panda has made it a good will ambassador of almost unparalleled success. The coming decades will see what comes of this—will scientists and policy-makers make the most of this opportunity to conserve the panda and its co-inhabitants? And how can this form of self-promotion—perhaps on a smaller scale—be maximized for less charismatic species?

In principle -and often in practice- zoos can contribute to in situ conservation through education and fund-raising. But how can captive breeding programs contribute to conservation more directly and what role can behavior research play? (i) Perhaps most importantly, many aspects of biology and behavior can be studied in the captive environment that would be impossible to study in the wild. Lack of such scientific knowledge often hinders management of endangered populations both ex situ and in situ. (ii) Behavior research can help captive populations reach self-sustaining growth, reducing demand for removals of individuals from the wild and creating a genetic reservoir as a safeguard against extinction. Health, nutrition, and basic husbandry play crucial roles in captive breeding programs, but good behavioral management often means the difference between stagnant breeding and viable captive populations[10,12,19,24]. (iii) Behavior research programs are essential for both generating surplus animals for reintroduction into the wild and for preparing candidates for a drastically different set of challenges in nature[7,9,14]. For example, captive-bred black-footed ferrets faired better when released in the wild if they were raised in enriched environments that afforded behavioral opportunities that mimic those found in nature[14]. To put things in perspective, however, I need to point out that many reintroduction attempts fail[2] and some conservationists do not consider captive breeding and reintroductions to be worthwhile pursuits[15].

This brings us to what—specifically—animal behaviorists can do to promote these conservation-related activities. Below are a few research activities that conservation behaviorists can pursue to promote captive breeding.

Mimicking nature. Behaviorists can use the literature and/or conduct their own studies to learn about the species' behavioral ecology in nature. Two key pieces of information include its foraging strategy and social organization. This is a starting point for creating a biologically relevant captive environment for improved well-being and reproduction. However, it is not that simple a matter, for we can never mimic all the complexities inherent in the natural environment, so further evaluation is necessary to determine just what the animal requires for psychological health and sexual motivation.

Stress. Understanding animal stress-response systems has long played a role in captive breeding programs, but recent years have seen a surge of interest in understanding anthropogenic stressors that affect wild populations in shrinking habitat, now subjected to increasing levels of human disturbance. "Stress"—used here as a loose descriptive concept pertaining to a variety of physiological and behavioral responses that animals use to cope with environmental challenges to homeostasis—can frustrate captive breeding efforts through its suppressive effects on reproduction and immunocompetence. In my favorite example of how stress can affect captive breeding, Nadja Wielebnowski and colleagues used a controlled experiment to show how social stress can impair ovarian function in captive cheetahs[26]. Many other aspects of the captive environment, such as chronic proximity to predators, small or barren enclosures, and noise, can be related to stress[3], and only well-designed behavioral research will tease out potential stressors. Captive animals also present a valuable opportunity to develop stress-monitoring tools that can be used with wild populations.

Abnormal behavior, enrichment and ethological needs. "Enrichment" is any modification of the captive environment to promote psychological well-being, and runs the gamut from appropriate conspecific companions, to adding environmental complexity such as climbing structures and novel objects, to encouraging animals to work for food rather than quickly consuming a bowl of processed food. "Ethological needs" refers to one model of motivation that posits that animals are motivated not just to obtain important biological resources (e.g., food), but also to perform the appetitive behaviors typically used to locate, capture, extract or process the resource[8]. If the captive environment does not provide opportunities to perform these behaviors, animal well-being will suffer, as often manifest in the performance of abnormal behaviors. Other motivational theories that may explain poor well-being in captivity include the need for control over the environment, behavioral contingency, and information gathering needs[17]. A major class of abnormal behavior seen in captive animals is stereotypies, which are highly repetitive behaviors, invariant in form, that have no obvious goal or function, such as pacing[13]. Behaviorists can design studies that test these motivational theories and help develop more effective enrichment programs to reduce stereotypies, enhance a more natural diversity of behavior, and promote well-being[22]. Enrichment studies not only contribute to animal well-being, but promote reproduction by reducing stress and improving behavioral competence[4].

Social environment. Another critical link in the chain leading to successful reproduction is the social environment. In general, the rule of thumb is to mimic the group composition prevalent in the wild, but recent studies have shown the social system of many species to be highly flexible, depending on the distribution of resources, population density, and so forth. By capitalizing on this flexibility, some experimentation in captivity may yield the best composition for captive environments.

Reproductive behavior. A “bread-and-butter” research activity in captive breeding programs is to study the female estrous cycle to illuminate the temporal pattern of behavior leading up to ovulation[25]. This is essential information in relatively asocial species where male and female are held separately: without it, managers will not know when to allow pairs access for mating. In addition, by establishing species’ norms, deviations in individuals can help pinpoint the cause of reproductive failure. It also provides important clues regarding the overall reproductive strategy of the species.

Studies of reproductive behavior and communication are helping researchers tease out the components governing sexual motivation in giant pandas. New scientific understandings of panda behavior have played a crucial role in recent successes at the Wolong breeding center, where the numbers have increased from 25 to nearly 80 in recent years. Ronald R. Swaisgood © photo

Communication. A subset of reproductive behavior, but also used in competitive and other social contexts, communication plays an important role in bringing the sexes together for reproduction. For example, my own work with giant pandas has shown that sexual motivation is enhanced by providing appropriate opportunities for olfactory communication, and olfactory management has figured prominently in recent growth of the captive population[20,21]. Behavioral research targeting judicious use of animal signaling behavior stands to increase successes in captive breeding programs.

Manipulating reproductive skew. When a few individuals—typically males—attain higher reproductive success than others, they obtain greater genetic representation in the population at the expense of others. As a result, the effective population size decreases and the population may suffer from the effects of reduced genetic diversity. In a previous issue of The Conservation Behaviorist (Vol. 1, No. 2) Allison Alberts described how her research team dealt with this problem in a small wild population of Cuban rock iguanas[1]. They captured and temporarily removed the dominant males that out-competed the other males for mates, allowing the subordinate males a chance to make a genetic contribution to the population. If many females prefer to mate with a few males, mate choice can also lead to reproductive skew. Recent studies have shown that it is possible to manipulate female choice by “faking” olfactory cues related to competitive ability, capitalizing on female preference for the most competitive males[5,6,16]. Such management tools need to be used with caution, since free female choice may produce more viable offspring, but when populations are very small, intervention to preserve remaining genetic diversity is warranted[23].

Parental care and development. Good management for captive breeding does not end with the birth of offspring, but also includes fostering good parental skills so that the offspring survive and reproduce. Some species or individuals can be very sensitive to the environment during the period of offspring dependency, and may abandon or kill offspring if disturbed. Behavioral research can identify the proper environmental variables to encourage parental behavior. Studies of caregiving systems can elucidate species norms for comparison with individuals that show abnormal responses to newborns, and suggest ways of encouraging reluctant mothers. For example, we used such studies to develop techniques to train female pandas to accept and rear cubs that were initially abandoned[27]. And finally, normal behavioral development requires that we pay attention to all of the behavioral concepts discussed above throughout the animal’s lifetime.

Reintroduction. Once the combination of these behavioral and other management strategies lead to a self-sustaining viable population it is possible to consider reintroducing captive-born animals to the wild, if the other criteria for reintroduction as a conservation tool are met[9]. Much of the behavioral research required to obtain reproduction will also be critical for reintroduction, which depends on the development of behaviorally competent individuals. More behavioral research to select the best candidates and prepare them for the very different challenges that await them in nature will be essential also. Behaviorists will again play a crucial role in post-release monitoring to determine the behavioral deficiencies that limit the success of reintroductions. There may be no other conservation action where the skills of behavioral researchers are more essential than reintroduction.

These behavioral research strategies are just a few starters important for behavioral management in captive breeding programs. In actual practice, the ways that behavior research can contribute to conservation breeding are as diverse as the imaginations of researchers tackling the challenge of managing animals outside the natural context in which they evolved.

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Behavioral Deficiencies and the Reintroduction of Animals into the Wild

By M. Elsbeth McPhee* & Emily Silverman**

When captive-bred animals are released to re-establish or supplement a wild stock, reintroduced populations show behavioral deficiencies. Absence of anti-predator behavior, difficulty recognizing and finding food, and inadequate social skills, compromise the success of reintroductions. How many animals should be released to compensate for mortality caused by behavioral deficiencies? In this article, the authors discuss a method to estimate a "release ratio," a figure that considers the effects of behavioral deficiencies and can help us estimate the number of animals needed for successful reintroductions.

As wildlife populations continue to decline, the number of captive breeding and reintroduction programs aimed at conserving endangered species increases. The efficacy of these programs, however, still generates debate. In a number of recent reintroductions –e.g. golden lion tamarins, black- and white-ruffed lemurs, thick-billed parrots, and African wild dogs– behavioral deficiencies (e.g. absence of anti-predator behavior, difficulty in recognizing and finding food, and inadequate social interactions) have caused numerous fatalities.

Selective pressures in a captive environment differ from those in the wild. Over time, captivity causes the variability and average expression of population traits to change. Some animals do not survive reintroductions because their behaviors, and the morphological traits directly associated with the performance of behaviors, are functional in captivity but not in the wild. Unless individuals with behavioral traits similar to wild animals can be released, an increased number of captive-bred animals will need to be reintroduced to compensate for the mortalities caused by behavioral deficiencies, and thus meet the targeted wild-population size (the minimum number of survivors required for the population to persist).

Consider the following case study. Captivity affects the natural behavior of old-field mice (*Peromyscus polionotus*). When exposed to an owl silhouette in the laboratory (a simulated predator), captive-bred animals take more time than their wild-born counterparts to seek protection inside a burrow. We have documented that the time it takes a mouse to enter a burrow after seeing the owl silhouette and the variability associated with response time is greater for mice from populations that have been in captivity for several generations. If we want to release captive-bred mice to successfully restore a population in the wild, we must assume that some of the released animals will probably die due to lack of appropriate anti-predator responses. How many animals should we release to compensate for the expected increase in mortality? For years, the answer to this question has remained elusive. We have recently developed a mathematical method to estimate a "release ratio," a value that tells us the number of individuals we should release after taking into consideration potential mortality caused by behavioral deficiencies. Our calculations indicate that the release of 120 captive-bred mice is equivalent to releasing 100 wild-like animals (see supplement).

Each case imposes unique challenges. More data are needed to develop a quantitative approach to reintroduction planning. Our release ratio is an important step toward ensuring that the optimal number of animals is released, thus increasing the probability of success of reintroduction programs.

Supplement: Release Ratios

To calculate the release ratio, R, we need to define the traits of interest and specify their distributions. Then, we must determine the range of trait values associated with high survival rates in a wild environment; this is the target-trait range. The release ratio is calculated as R = Pw / Pr, where Pw is the proportion of the wild population that falls within the target-trait range, and Pr is the proportion of the captive-bred released population that falls within that same range.

In the case of the old-field mouse, there is a significant increase in the mean and variance of time that it takes a mouse to enter a burrow after seeing a simulated predator as generations in captivity increase. These data appear to be exponentially distributed: the sample mean and standard deviation are close in value (wild mean = 9.6 sec, wild standard deviation = 8.4 sec, release mean = 15.1 sec, release standard *deviation = 14.6 sec), and the null hypothesis of an exponential distribution cannot be rejected for either. In this case, we calculate R to ensure a sufficient number of individuals at the lower tail (i.e. the "fast" end) of the trait distribution. Thus, we define the target-trait range as zero to one standard deviation above the wild mean. In other words, the target-trait range includes all animals that take between 0 and 18.1 sec to get into the burrow. Using calculations developed for exponentially distributed data, we found that, for time to burrow, the release ratio for one standard deviation above the mean is 1.2 (for 0 and 2 standard deviations, R = 1.3 and 1.1, respectively). Therefore, if we plan a reintroduction of old-field mice and our goal is to have the same number of released animals in the target-trait range as expected from the release of 100 wild individuals, we should release 120 captive-bred mice to compensate for morality caused by behavioral deficiencies.*

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Family Support Increases the Success of Translocated Prairie Dogs

By Debra M. Shier*

Translocation has become a widely used conservation tool but remains only marginally successful. High mortality is often attributed to predation, but for highly social species, founder group composition may also play a critical role in post-release survival. Here I show that maintaining family groups significantly increases translocation success in terms of both survival and reproductive success in the highly social black-tailed prairie dog. More broadly, these results demonstrate the importance of behavior for conservation and suggest that other species that depend on social interactions for survival and reproduction may also benefit substantially from the maintenance of social groups during translocations.

Prairie dog numbers have declined as much as 98% in North America. All species in the genus (*Cynomys*) are rare, threatened or endangered, thus knowledge of their behavior is directly applicable to conservation efforts. Prairie dogs are considered keystone species that influence environmental heterogeneity, nutrient cycling, biodiversity and, therefore, play an integral role in grassland ecosystems[1]. Black-tailed prairie dog colonies provide food or habitat for other 140 species, some threatened or endangered (e.g. black-footed ferrets[2], burrowing owls, ferruginous hawks, and tiger salamanders)[3]. Until 2004, the U.S. Fish and Wildlife Service had designated the black-tailed prairie dog as a candidate species for listing under the Endangered Species Act[4,5]. That designation stimulated conservation efforts in the species' original range by private organizations and eleven states. Current conservation methods include translocations to supplement small populations or to restore extinct ones.

Prairie dog translocation methodology has been far from effective. Survival rates following translocations seldom exceed 40% and frequently are much lower[6]. Current methods are not sensitive to the importance of social factors; prairie dogs are trapped and translocated without regard to family membership and before newly emergent young are likely to have developed appropriate survival skills. The obvious alternative of keeping family groups together during translocation is not trivial because it requires exhaustive trapping of individual families.

I conducted an experiment to determine whether preserving family groups during translocation could increase the probability that prairie dogs would survive and reproduce following release. During the summers of 2001 and 2002, I translocated 973 prairie dogs into 10 new sites on the Vermejo Park Ranch in Northeastern New Mexico. The experiment included two treatment groups: family-translocated (moved in intact family groups) and non-family-translocated (moved without consideration of family membership). I determined family membership in April and May by observing behavioral interactions and sleeping patterns of ear-tagged dye-marked individuals at three large source colonies. Family members were transferred to artificial burrow systems at five sites. Non-family members from three source colonies were transferred into artificial burrow systems at five other sites (5 individuals per burrow). One year following release, I estimated survival by re-trapping all tagged/marked prairie dogs that remained at the translocation sites. Reproductive success was estimated from the pup/female ratio (number of emergent juveniles/the number of adult females), litter size (for females that weaned a litter), and the percentage of females that weaned a litter.

Family translocation produced dramatic differences in survival and reproductive success[7]. Prairie dogs translocated with their families intact were 5 times more likely to survive one year after release than non-family-translocated prairie dogs. While both adult males and females in the family-translocated treatment survived at higher rates than non-family-translocated animals, the effect was more pronounced for adult females. This sex difference is consistent with the natural history of the species. Females remain with their families their entire lives, while most males disperse after the first year.

Many species return to sites previously inhabited by prairie dogs following reestablishment of colonies via translocation. Swift fox (left), burrowing owl (right). Debra M. Shier © photo

Translocation Success

Family-translocated females also showed higher reproductive success one year after release than non-family translocated females. In particular, yearling females translocated with their family members were much more likely to wean a litter than yearling females translocated without family members.

Prairie dogs translocated with family members. Debra M. Shier © photo

Effects of Predation

Predation is a major cause of death following release in translocated prairie dogs[6]. Not surprisingly, as predation pressure increase, survival decreased for both groups of prairie dogs. Interestingly, predation pressure and survival were both higher on family-translocated than on non-family-tranlsocated colonies; suggesting that family-translocation significantly reduces the success of predators on newly established prairie dog colonies.

It is well documented that this highly social species is adapted for living in large groups and dependent on family members for predator detection and deterrence[3]. Larger groups and the presence of relatives are both associated with higher numbers of alarm-calling individuals, and prairie dogs spend less time scanning for predators when more adult family members are present above ground[3,8]. The ability of prairie dogs to directly deter predators is also dependent on family membership. Prairie dogs are known to attack small predators (e.g. weasels) as a group when they encounter them in their family's home territory but not in other families' territories[3]. If the presence of relatives does provide antipredator benefits to translocated prairie dogs, then individuals moved with larger families should experience higher survival. They do. For family-translocated prairie dogs, survival increased with family size.

Rattlesnake predation event. Debra M. Shier © photo

Prairie dog pups in alert postures. Debra M. Shier © photo

Timing of Release

Release timing may also affect post-release survival. Results of this study indicate that survival increased steadily during the summer months such that late summer translocations had the highest survival regardless of predation pressure and translocation method. This pattern was more pronounced in juveniles than adults.

One reason time of release may have such a large effect on survival for juveniles is that more time above-ground prior to translocation may allow juveniles to grow and improve in physical condition and/or it may allow juveniles more time to develop and hone their survival skills. Results show that both age from emergence and weight were good predictors of survival for family-translocated juveniles. Thus pups likely benefit from the extra time to both learn and grow.

Post-Release Behavior

What about behavior? Immediately following release, family-translocated and non-family-translocated animals behaved differently. These behavioral differences remained pronounced two weeks after release and persisted for at least one year. The proportion of individuals that were vigilant on a colony was higher for non-family-translocated than for family-translocated colonies; while family-translocated animals spent more time foraging and digging burrows. This is consistent with what we know about prairie dogs in the wild. Individuals spend more time scanning for predators when fewer adult family members are above ground[3]. These data indicate that family-translocated individuals spend less time vigilant than non-family-translocated animals, and that this allows them to forage more, improve in physical condition, and get in their burrows more quickly.

Settlement Decisions

Data from this study demonstrate that family membership significantly increases post-release survival and reproductive success. But, the question of how family membership affects survival remains. Are family-translocated individuals simply less stressed because they were released with family members and therefore more likely to survive on their own? Or does family composition allow individuals to benefit directly from well established social relationships? Evidence thus far suggests the latter. Individuals from larger families show higher survival than those from smaller ones. And, fewer animals released with family members were vigilant during approaches by humans two weeks and one year post release. However, the true test of the benefits of long-term family membership should be revealed by settlement decisions. If individuals released with family members also settle with them, they will benefit from well established social relationships. Therefore, I examined settlement patterns of family-translocated prairie dogs to determine if they were in fact settling with family members. Family-translocated prairie dogs were more likely than expected by chance to settle with family members not from their same release cage than non-family members. However, individuals were not more likely to settle with family members from their same release cage than to settle with family members released in adjacent release cages. This suggests that prairie dogs use long-term familiarity rather than short term association to determine settlement decisions and provides further support to the importance of maintaining family membership prior to translocation.

Black-tailed prairie dog mother and pup. Debra M. Shier © photo

Population Viability

Beyond survival and reproductive success, the ultimate goal of translocation is population viability. Thus, when releases are not successful in establishing sustainable populations, supplementation is often conducted. In this study, two of the three non-family-translocated colonies released in 2001 had less than 7% survival by the following spring. Therefore, additional animals were added to these colonies after the first year. In spite of supplementation, non-family-translocated colonies continued to decline in size relative to family-translocated colonies through the summer of the second year. These data indicate that differences between colonies established using different translocation methods become even more pronounced by the second year post-release and that supplementation does not offset these differences.

Concluding Remarks

These results have important implications for conservation and animal behavior. The data clearly demonstrate that for highly social prairie dogs, founder groups composed of intact family units are more successful in terms of post-release survival, reproductive success and population viability. More broadly, these results suggest that any species which depends on social interactions for survival and reproduction may benefit substantially from the maintenance of social groups during translocations (e.g. wolves, elephants, primates). Thus, translocation methodology should be restructured to incorporate the target species behavior.

The most obvious implication of these results is that social relationships have survival value. Most studies on group living have focused on the costs and benefits of group composition, specifically, group size, not the relationships between individuals in a group. My research shows that relationships are important for individual survival. These findings have implications for dispersal. To date, most studies on dispersal have focused on the individual as the unit of dispersal, but little attention has been directed to the mechanisms that underlie dispersal in social groups[9]. My results suggest that animals that disperse in groups would benefit from reduced predation and extended opportunities for learning survival skills. Still, other mechanisms may confer advantages of group dispersal to individuals (e.g. information pooling among dispersers[10] and increased competitive ability[9]). Evidence presented here highlights the importance of social factors in the development of appropriate survival skills, a topic that is rich with opportunities for future research.

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Animal Cognition and Its Role in Conservation Behavior

By Guillermo Paz-y-Miño C.*

Animal cognition includes perception, learning, memory, decision making, and other processes in which animals obtain information about the environment through their senses, retain and act on it[1,2]. Here I discuss case-studies that have used animal-cognition principles in conservation. My goal is to draw attention to the value of these studies - conducted mostly by non-behaviorists, remark on the cognitive concepts intrinsic to each case, and encourage discussion and research in the interface animal cognition-conservation behavior.

Animal cognition (=cognitive ethology[3]) has contributed to conservation in four main areas: i) training animals to avoid predators, ii) eliminating inter-specific sexual and social imprinting, iii) identifying inappropriate conservation strategies, and iv) identifying and minimizing the negative effects of maladaptive behaviors.

Training animals to avoid predators

Animals that have been isolated from predators, either throughout their lifetime or over evolutionary time, may no longer express effective anti-predator behavior[4]. Mortality due to predation is the principal cause of failure in animal reintroduction and translocation programs: It is easier to teach animals to cope with predators if they have experienced ontogenetic isolation than if they have undergone evolutionary isolation from predators[4]. In the absence of predators, anti-predator behavior may degenerate or be lost. For example, a significant threat to released California Condors (*Gymnogyps californianus*) is nest predation by Common Ravens (*Corvus corax*). Wild and/or released condors lack defenses against ravens, possibly because ravens have become abundant during recent times and condors have had limited evolutionary exposure to raven predators[5].

Learning theory principles can be used to predict which anti-predator responses can be enhanced or recovered by training animals prior to their reintroduction into the wild or translocation into new habitats[4]. Training techniques involve conditioning procedures in which animals learn that model predators are predictors of aversive events. Researchers have documented how terrestrial predator recognition and defense behaviors are more developed and easier to restore in the Pukeko (*Porphyrio porphyrio*), an Australian and New Zealand bird that evolved in the presence of terrestrial marsupial predators, than in the Takahe (*Porphyrio mantelli*), a large flightless gallinule that evolved in the absence of predators until the end of the nineteenth century, when European settlers introduced the stoat (*Mustela erminea*) to New Zealand[6].

Animals on islands are extraordinarily tame relative to animals on continents and, when exotic predators arrive, they trigger a shift in selective forces on the insular fauna. Feral cats (*Felis catus*) in the Galapagos Islands, for example, are responsible for increased wariness (loss of "unusual tame behavior") in the lava lizards (*Tropidurus* spp.) as a result of predation pressure[7]. Survival of lizards in islands inhabited by cats is attributable to fast development of predator avoidance strategies (i.e., associative learning, aversive events) supported by selection toward phenotypes with effective fleeing responses.

Eliminating inter-specific sexual and social imprinting

Puppet rearing, a technique aimed to reduce sexual and filial imprinting on human caretakers, has been used in bird species. Maladaptive imprinting is most likely to occur during early stages in an animal's behavioral development. Studies indicate that rearing common ravens (*Corvus corax*) with a puppet does not affect social behaviors prior to release, dispersal from the release area, or interaction with wild birds after release. Ravens raised with a puppet, however, are more fearful of caretakers and more vigilant prior to release than ravens reared without a puppet and in full view of humans. These effects on behavior have translated to changes in survival after release of captive-reared young[8]. Likewise, aversive conditioning of puppet-reared California Condors in later releases has reduced initial tendencies to approach humans and human structures (i.e. collisions with electric wires and towers) [5, but see 9].

Enhancing social learning and social facilitation

Animals that live in stable social groups have substantial cognitive abilities and usually interact with conspecifics and the environment in complex manners. Orangutans (*Pongo pygmaeus*), for example, have extensive parental care and prolonged infant and juvenile periods in which animals are extremely dependent; their appropriate social and sexual responses are learned within the context of the social group[10]. The ability to find and prepare food is generally acquired through a combination of observational and experimental learning. Most non-human primates reared in captivity exhibit behavioral abnormalities (e.g. repetitive behaviors, rocking, self-abuse) not observed in wild populations, particularly those who have been reared or housed in social isolation. Lack of stimulation and social interaction can result in developmental retardation[10].

Some reintroduction programs have taken these premises into consideration. For example, female and male wild-born orphan chimpanzees (*Pan troglodytes troglodytes*) have been successfully released into the Conkouati Reserve, Republic of Congo, by identifying behavioral traits that the animals required prior to translocation from diverse localities into the release area, e.g. the release of mostly adolescent females mimicked the natural pattern of movement between communities. The complexity of chimpanzee social behavior also required that the released animals have the full species-specific repertoire (e.g. greetings, grooming, and agonistic behaviors needed to establish and reaffirm relationships) and show no abnormal or inappropriate patterns of behavior[11].

Identifying inappropriate conservation strategies

Mate choice, sexual selection, and dominance associated with mate acquisition depend on cognitive processes such as perception, learning, memory and decision making. For example, rhino dehorning, a controversial practice designed to remove the incentive for poachers to kill the hornless animals, may have had mate choice implications in both the one-horned rhinoceros (*Rhinoceros unicornis*) and the white rhinoceros (*Ceratotherium simmum*), two sexually dimorphic species with males having larger horns than females[12]. Horn size is likely a consequence of sexual selection and it is positively associated with dominance in males. Because dehorning generates unnatural horn size asymmetries that affect combat outcomes between males, dehorning may have had fitness consequences due to female assessment (perception) of male quality. [Note: dehorning was discontinued as a conservation practice due to high neonate mortality; females use horns in neonate defense[12]].

Identifying and minimizing the negative effects of maladaptive behaviors

Some behaviors become maladaptive when selective pressures change, usually because of human intervention, and animals are no longer able to assess (perception) the change or respond appropriately to it (e.g. traffic collisions or collisions with overhead wires, ingestion of anthropogenic debris, disorientation caused by artificial lights). If a species can survive long enough and the behavior has heritable variation, these maladaptive traits can disappear through natural selection[13], and the species may persist with modified cognitive capabilities of adaptive value in the new environment [for specific examples, see supplement].

To minimize the negative effect of these maladaptive responses, various techniques have been applied or suggested; all take into consideration animal perception, learning, information processing, and decision making: construction of under road passages for terrestrial vertebrates, establishment of buffer zones to reduce contact between animals and people (i.e. vehicles, motorized tour boats, tourists), and intermittently lighted signals triggered by passing animals[14,18].

Concluding remarks

Animal cognition has indeed played an important role in animal rehabilitation and captive breeding for reintroductions. Some of the paradigms currently explored by cognitive ethologists could further influence conservation efforts in significant ways, for example, phenotypic plasticity in learning and animal adaptability to changing environments (i.e. animals learn to assess new landscapes, new prey, new predators), visual and vocal communication (i.e., signaling, dialect formation in increasingly isolated metapopulations), spatial orientation and navigation (memory in food-storing birds), foraging and search-image formation in constantly evolving prey or habitat (e.g. virtual behavioral ecology), hierarchy learning, social learning and social facilitation[1,2,24-27].

Animals have numerous cognitive capabilities: they have evolved mechanisms to discriminate, recognize, and evaluate habitats, resources and individuals; animals track the position, social behavior and foraging success of conspecifics, group them by age, sex, reproductive status, genetic relatedness and dominance rank, as well as infer relationships among individuals in a socio-sexual context. The extent to which these capabilities are being influenced or disrupted by current habitat fragmentation and degradation or even larger-scale environmental problems (i.e. global warming, ozone depletion, pollution) deserves closer analysis. Animal cognition, therefore, could help us identify, understand and restore some of these disruptions.

Supplement: Examples of maladaptive behaviors

*Mortality due to traffic collisions in Florida Scrub-Jays (*Aphelocoma coerulescens*) is particularly high in immigrant (naïve) birds that colonize and establish territories in habitats along roads[19]. Excessive tameness and curiosity shown by released California Condors toward humans and urbanized areas have contributed to mortality due to collisions with overhead wires[5]. Traffic collisions are responsible for increased mortality in at least ten species of European ungulates[16]. Simple human traffic has induced diurnal animals and their predators to become nocturnal in Sumatran rain forests, where poachers are active during daylight[20]. Road construction in Central Amazonian Brazil affects movement patterns of understory birds in mixed-species flocks; the birds are unable to adapt to the formation of abrupt edges inside their territories and avoid crossing the roads to visit areas where foraging was frequent before the clearing[21]. Foraging behavior (time spent with prey at kill sites) and survival of Amur tigers (*Panthera tigris altica*) have been affected by road construction and human disturbance on and near the Sikhote-Alin State Biosphere, Zapovednik, Russia. Tigers disturbed at kills spent less time at kill sites and consumed less meat from each kill than undisturbed tigers do. Adult and cub mortality is greatest in areas with primary roads[22]. Ingestion of anthropogenic debris by terrestrial and aquatic species has been documented extensively. California Condors exhibit high mortality caused by lead poisoning resulting from ingestion of bullet fragments in carcasses[5]. Reduced nutrient gain from diets diluted by consumption of debris is a common problem among post-hatchling and juvenile loggerhead sea turtles[23].*

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The Role of Studying Behavior in the Conservation of Chimpanzees and Gorillas

By Elizabeth V. Lonsdorf*

Chimpanzees and gorillas are among our closest living relatives, sharing most of our genetic code and many similarities in anatomy, physiology and behavior. These apes have the capacity to make and use tools, have strong family bonds and some even have population-specific behaviors similar to human cultures. But populations of chimpanzees and gorillas are in dramatic decline due to hunting for bushmeat, loss of habitat, and the varied risks of small, isolated populations. Recognizing and understanding the complexities of these threats is the first step in conserving the world's wild ape populations. Mitigating these risks takes a deeper understanding of ape behavior. In this article, I provide examples of how the study of gorilla and chimpanzee behaviors intersects with and should be considered critical to conservation efforts.

Some common natural history characteristics shared by chimpanzees and gorillas make their conservation particularly challenging. Conservation is ultimately a numbers game, i.e. you need viable numbers of animals or the population will go extinct. However, basic ape natural history characteristics make chimpanzees and gorillas particularly vulnerable to population declines. Both have incredibly complex social dynamics within breeding groups and are relatively slow to reproduce. Gorilla societies are polygynous, with a dominant silverback male and several breeding females comprising the core social structure[1,2]. However, in mountain gorillas, an increasing number of multiple male groups have been observed in recent years[3]. Both males and females may disperse from their natal groups when they reach sexual maturity[1,2]. Chimpanzees live in 'communities'[4] or 'unit-groups'[5] that range in size from 20-150 individuals. These communities are multi-male, promiscuous and have a male dominance hierarchy in which males form the stable core of the community and defend a group home range[6]. Chimpanzee society is termed "fission-fusion" as members of a community can join or leave traveling parties at any time[6,7]. An individual's presence in a party is determined by a combination of factors which may include food availability, sexual state of females, and social relationships with other individuals. Males remain in their natal groups, while females typically leave their natal group when they reach sexual maturity[8,9]. In addition to having complex societies, gorillas and chimpanzees are both relatively slow to reproduce in the wild. Average age of first reproduction in gorilla females is 10 years with a single offspring typically born every 3 to 4 years[10]. Chimpanzees have their first offspring at 13 years of age, on average, with a 3 to 5 years interbirth interval[6,9]. Single offspring are the most common pregnancy results, although some sets of twins have been reported[6,9]. The natural history and behavioral characteristics detailed above have important consequences for conservation.

The bushmeat trade and ape behavior

One of the primary threats to African ape populations is hunting by humans for bushmeat. Indigenous forest people historically hunted apes for meat, but at sustainable levels that did not threaten the survival of ape populations. Now, the combined effects of expanding human populations and the perception of bushmeat as a delicacy by city-dwellers, both in Africa and abroad, have resulted in catastrophic losses of ape populations[11]. The logging industry compounds the problem by opening roads into pristine forests and setting up camps for thousands of employees[12]. These people are often told they must feed themselves and end up hunting for food in the forests, both to eat and to sell. In addition, the roads built by logging companies allow poachers access to formerly inaccessible forests[12]. Together, the commercialization of bushmeat and the practices of the logging industry result in the opening of pristine forests and an increase in harvesting of forest animals, including apes.

Female chimpanzees produce their first offspring, on average, at 13 years of age and usually have a single offspring every 3 to 5 years. E. V. Lonsdorf © photo

An understanding of ape behavior helps us to more fully understand the effects of the bushmeat trade. As described above, apes are known to have very long periods of infant dependence. The mother-offspring bond is quite strong in apes and youngsters may not survive being orphaned even after they are weaned[6]. If an adult female is shot for bushmeat, her offspring are likely to be casualties as well. In practice, mothers may be shot for bushmeat and their infants sold live into the pet trade where their chances for survival are small. Due to the complex social behaviors of apes, the death of a particularly important individual can lead to great behavioral destabilization and reorganization of the social structure of the group. For example, removal of male silverback gorilla and his subsequent accession by a new male may result in infanticide by the new silverback[13,14]. To summarize, in species that have long periods of offspring dependence, close mother-offspring bonds, and complex societies, removal of individuals via hunting can have trickle-down effects that reduce the breeding output, and therefore, population viability of an entire ape group. Rigorous and long-term behavioral studies are a key element in identifying these secondary impacts.

Habitat destruction and ape behavior

The African forests where apes live are becoming smaller and more fragmented due to the intense pressure of human land needs for farming, logging or other utilization practices[12,15]. When forests become small and fragmented and carrying capacities are changed, resident animal populations are inevitably affected. Basic population biology analyses tell us that smaller and more isolated populations are at higher risk of decline due to random catastrophes such as forest fires, civil unrest and/or disease outbreaks. Apes' slow reproductive rates mean that they are less able to rebound from these catastrophic events which can drive small populations to extinction.

Deaths of silverback male gorillas may result in secondary fatalities due to infanticide. Photo courtesy of Lincoln Park Zoo ©

The complex social behavior of apes compounds the primary habitat destruction problems of reduced carrying capacity and low resilience[16]. Both gorillas and chimpanzees are territorial but chimpanzees lie at the extreme end of the spectrum in that male chimpanzees will defend their territory to the death in some cases[6,17]. As a result, it is likely that as forests become smaller and chimpanzee density increases, so does the probability for lethal territorial interactions. Furthermore, if a chimpanzee community experiences a reduced number of males due to a random catastrophe, that community becomes vulnerable to attack by a neighboring community with a stronger core of males[17,18], resulting in fatalities secondary to the initial catastrophe. These complexities of territorial behavior also make it difficult to reintroduce chimpanzees into areas where wild chimpanzees reside. One such reintroduction has been attempted and is reporting positive results, but extreme caution needs to be taken to ensure that the behavioral ramifications of reintroduction are considered and planned for[19]. The territorial nature of chimpanzees was not fully understood until many years of detailed behavioral observations were collected across multiple sites[17], providing another example of the value of behavioral studies for conservation.

Disease risk analysis and ape behavior

Many gorilla and chimpanzee study sites have reportedly been affected by epidemic disease and most of these outbreaks are suspected to be the result of close contact with humans[20-23]. A 2003 outbreak of the Ebola virus is thought to have killed a significant number of gorillas and chimpanzees in western equatorial Africa[21]. Because of these emerging disease risks, more ape behaviorists are becoming involved in trying to understand the disease threats to their populations and potential ways to reduce such threats.

In an upcoming *American Journal of Primatology Special Topics Issue* on Disease Risk Analysis, Lonsdorf and colleagues[24] detail how long-term behavioral data collection can contribute to improving the risk analysis process. I provide a brief summary of that work here: Risk analysis is a blend of 1) identifying a hazard (risk), 2) assessing the probability that a particular risk will occur, 3) identifying actions or policies to reduce risk, and 4) communicating the risks and managing it. Applied to great ape study sites, this process can be used to evaluate risks such as disease transmission between apes and humans, as well as the risk of differing management options (e.g. the use of drop toilets versus compost toilets). The methods used to collect behavioral data on apes (lengthy, detailed follows on individually identified animals) provide information on spatial ranging patterns and social interactions which, in turn, provide a solid foundation for the risk assessment process. These data are the critical resource for understanding the contact structure of the community and how individual differences in behavior may affect health. Coupled with a long-term data collection effort, researchers can analyze the impacts of "risky" behavior, such as spending time near human settlements, on survival and reproduction. Only with long-term and detailed behavioral data can we fully understand what factors are likely to impact population viability for animals as complex as apes.

Concluding remarks

Because many ape populations are relatively small, they require proactive management to prevent populations from going extinct. However, as I have detailed above, management actions are likely to be much more successful when the complexity of gorilla and chimpanzee behaviors are taken into account. For example, it may not be enough to simply protect pieces of habitat for chimpanzees if their natural territorial behavior renders that strategy ineffective. Likewise, it may not be enough to provide income alternatives to bushmeat via ecotourism because that may increase the risks of disease transmission. Behavioral research is an important component in assessing conservation strategies for apes and should be considered a key aspect of the type of multi-disciplinary approach that is necessary to address the challenging and complex issues facing chimpanzees and gorillas today.

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The Role of Reproductive Behavior in the Conservation of Fishes: Examples from the Great Plains Riverine Fishes

By Mark L. Wildhaber*

Recovery efforts for threatened and endangered fish species are hampered by lack of knowledge on their reproductive ecology. Habitat requirements and environmental stimuli necessary for reproduction are unknown and vary widely among species. For Great Plains riverine fishes, this is often complicated by the high turbidity of the system where the species occur, which precludes direct visual observation of behavior. Innovative methods for collecting behavioral data are required to better understand the conditions necessary for successful reproduction. To this goal, I will discuss four fish species on which I have worked in collaboration with university and agency researchers, graduate students, state and federal resource managers, and private landowners.

The species are: Topeka shiner (*Notropis topeka* -Gilbert 1884), a headwater and low-order stream species, Neosho madtom (*Noturus placidus* Taylor 1969), a middle-size river species, and pallid (*Scaphirhynchus albus* Forbes and Richardson 1905) and shovelnose sturgeon (*S. platorynchus* Rafinesque 1828), large river species. These species demonstrate the variety of physical requirements necessary for successful reproduction in Great Plains riverine fishes. The recovery plans for these fishes indicate that information on behavior and habitat requirements for spawning is lacking[1,2,3].

Topeka Shiner

The Topeka shiner was listed as an endangered species in 1999[3]. It is a small, stout minnow (<75 mm total length -TL) characteristic of small, low order (headwater) prairie streams. Topeka shiners occur in pool and run areas of streams, seldom being found in riffles. They are pelagic, occurring in mid-water and surface areas, and are primarily considered schooling fish[4]. Clean gravel, cobble and sand are the predominant substrates within Topeka shiner streams. Kerns[5] found that this species primarily feeds on insects while Hatch[6] found it to be omnivorous (flowering-plant seeds are common in the diet). Topeka shiners are broadcast spawners (i.e. eggs are released over open substrate) in pool habitats, over green sunfish (*Lepomis cyanellus*) and orangespotted sunfish (*L. humilis*) nests, with males establishing small territories on the edges of these nests[4,5].

Topeka shiner (*Notropis topeka*). Konrad Schmidt © photo

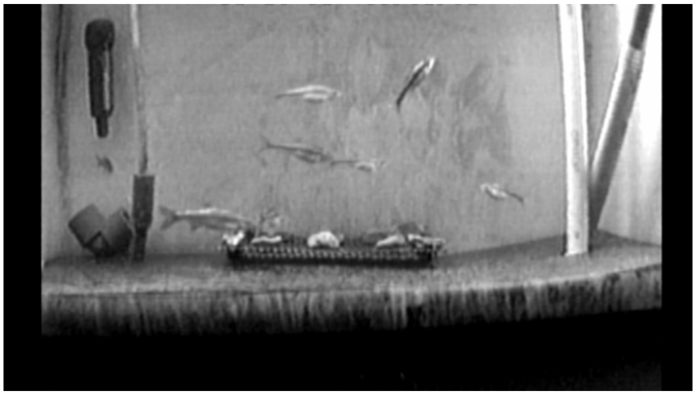
The Topeka shiner is affected by habitat destruction, degradation, modification, and fragmentation resulting from siltation, reduced water quality, tributary impoundment, stream channelization, in-stream gravel mining, changes in stream hydrology, and introduced predaceous fishes[3]. The historic distribution of Topeka shiners included low order tributary streams throughout the central prairie regions of the United States. Topeka shiner occurrences have declined by 80 percent (50 percent within the last 40 years); isolated and fragmented populations now exist in less than 10 percent of its original range.

Limited reproductive success is considered a potential cause for the decline of the species[3]. My research focuses on the effects of temperature and photoperiod on reproductive development and behavior, as well as substrate particle size preference.

Approach

The small size of adult Topeka shiners makes laboratory studies a relatively easy task. Under controlled conditions, adults are exposed to various combinations of photoperiod, temperature, and substrate to determine which combination is most effective at stimulating reproduction. For these studies, adult fish came from hatchery ponds run by state and federal resource managers.

The experiments included individually controlled and monitored experimental chambers and simulated winter conditions to assess stimulation of reproductive development. Six females and one male were placed in a tank under specific temperature and photoperiod combinations. Each tank was monitored with video cameras to minimize experimenter's disturbance and to record counting and spawning behaviors, defined as presence and successful hatching of eggs.



Topeka shiner experiment tank. Christopher S. Witte © photo

Information gained

Preliminary results suggest that the combination of photoperiod and temperature are important factors influencing reproduction. Longer photoperiods and temperatures between 22-28° C enhance reproductive development, while 31° C hinder the process. The next step in this research will be to determine substrate preferences under photoperiod and temperature combinations in which spawning behavior and success are highest.

This research should provide the U.S. Fish and Wildlife Service (USFWS) with information on the spawning requirements of the Topeka shiner; it will also help to identify suitable habitats for reintroductions and plan large-scale production for reintroductions, which ultimately will contribute to recover the species [3].

Neosho Madtom

The Neosho madtom was listed as threatened in 1991[1]. It is a small (<75 mm TL) ictalurid fish endemic to the mainstems of the Neosho and Cottonwood rivers in Kansas and Oklahoma and the Spring River in Kansas and Missouri[7-9]. This species occupies portions of riffles with mean flows of 79 cm/sec, mean depths of 0.23 m, and unconsolidated pebble and gravel (2-64 mm in diameter)[10]. Neosho madtoms feed at night on larval insects found among the gravel[8]. High abundance of this species has been documented in riffles in late summer and early fall, after young-of-year (YOY) are estimated to have recruited to the population[7,10,11]. Previous research suggests that the Neosho madtoms have an annual lifecycle with recruitment of YOY into adult collection gear about the time the adults begin to disappear from collections[11].

Neosho madtom (**Noturus placidus*****). Janice L. Bryan © photo***

Once distributed throughout the Spring-Neosho (Grand) River system, this species is now restricted to portions of the Neosho and Cottonwood Rivers in Kansas and Oklahoma, with one remnant population in the Spring River in Kansas. Much of Neosho madtom's historic habitat has been inundated by impoundments[1]. Additional habitats have been degraded by in-stream gravel mining, feedlot operations, and lead-zinc mining[12]. Reservoir operations have affected reproduction and survival[13].

Similar methods to those described for Topeka shiner (above)[14,15,17,19] have been used to examine the effects of photoperiod, temperature, and water flow on the reproductive behavior of Neosho madtom. In this specific study, the main goal was to determine the temperature range, light period within which spawning occurs, and if excessive water flow limits spawning.

Approach

The small size of the Neosho madtom allowed for laboratory work under controlled conditions. Adults were exposed to various combinations of photoperiod, temperature, and water flow to determine the most effective at stimulating reproduction. Since production of offspring in the laboratory has been limited, for these studies individuals had to be obtained from the wild.

The collection of data employed time-lapsed videography for monitoring behavior, individual controlled and monitored experimental chambers, and simulated winter conditions to stimulate reproductive development. One female and one male were placed in a tank under a specific combination of temperature, photoperiod, and flow, and supplied with a gravel substrate and a PVC nesting objects. Each tank was monitored with video cameras to minimize human disturbance and to document courting, spawning, and rearing behaviors[14,19]. The nest building habits of Neosho madtoms facilitated the collection of up-close spawning behaviors using an additional camera placed inside each nest[20]. In initial studies, sex was determined through secondary sexual characteristics and internal examination upon completion of the study. In later studies designed to document changes in reproductive state under varying temperature and photoperiod, a medical ultrasound unit was used to confirm sex and to estimate fecundity of the same individuals over several annual cycles. Presence and successful hatching of eggs indicated successful spawning.

Information gained

The studies demonstrated that Neosho madtoms' proportion of time spent performing cavity enhancement was higher, cavities were deeper, and gravel size in cavities was smaller for fish given a longer photoperiod[14]. Courtship behaviors were observed in male-female pairs held in longer photoperiods, but not in shorter photoperiods. Under flowing water conditions, there was a decreased average frequency, proportion of time, and event duration of male nest building behavior[19]. Water flow decreased the overall frequency of occurrence of reproductive behavior sequences. Spawning was observed between 21 to 28° C, with most occurring at 25° C. Temperature and photoperiod influenced the reproductive cycle and increased river flows during spawning could have affected reproductive success negatively.

Knowledge of how photoperiod, temperature, and water flow affect Neosho madtom reproductive success will provide information to the USFWS and the U.S. Army Corps of Engineers on how flow regulation in concert with natural photothermal changes can be used to improve species recovery plans.

Neosho madtom experiment tank. Janice L. Bryan © photo

Ultrasound use on Neosho madtom. Mark L. Wildhaber © photo

Neosho madtom spawning event, Janice L. Bryan © photo

Pallid and Shovelnose Sturgeon

The pallid sturgeon was listed as endangered by USFWS in 1990[2]. Although the shovelnose sturgeon is not listed by the USFWS, as either threatened or endangered, it has been listed as vulnerable by the World Conservation Commission[21]. The pallid is a mid-sized sturgeon reaching up to 30 kg in weight, the shovelnose is smaller (<3 kg)[4]; both are native to the Missouri and Mississippi Rivers[22,23]. The shovelnose sturgeon feeds primarily on invertebrates, while the larger pallid sturgeon starts out feeding on invertebrates but shifts later to a fish diet[24-26]. Pallid sturgeons are adapted to large, turbid, riverine environments and do not frequent tributaries or clear-water riverine habitats, used by shovelnose sturgeon[27]. Spawning habitat preferences of pallid and shovelnose sturgeon are not known; both species are assumed to spawn in current over coarse substrate[27,28]. Like most sturgeon species, pallid and shovelnose sturgeon are suspected to be broadcast spawners where the eggs become adhesive soon after release and attach to the substrate until hatch[29]. Biologists speculate that spawning runs are dependent on river flow[28,30,31]. Spawning behavior, habitat, and environmental cues necessary to elicit spawning have not been documented. Morphological, physiological and genetic similarities indicate that pallid and shovelnose sturgeon are closely related[22,32-34]. Therefore, research on the shovelnose sturgeon may be also applicable to the conservation of the pallid sturgeon.

_Pallid sturgeon (_Scaphirhynchus albus_). Steven Krentz © photo_

_Shovelnose sturgeon (_Scaphirhynchus platorynchus_). Aaron J. DeLonay © photo_

As with many sturgeon species, habitat alteration and destruction are limiting factors for pallid and shovelnose sturgeon[35,36]. The shovelnose sturgeon may also be threatened by commercial over-harvest for the caviar industry, which has eliminated it from part of its range[2]. The USFWS recovery plan for the pallid sturgeon lists rehabilitation of habitat as necessary for reproduction and recruitment[2]. The shovelnose sturgeon is more common and widespread than the pallid sturgeon[28]. Past distribution of the species includes the Mississippi, Missouri, Ohio, and Rio Grande Rivers and their tributaries. There has been a 30% reduction in the shovelnose sturgeon range, with an additional 30% reduction in population predicted for the next 10 years (three generations)[21]. If the shovelnose and pallid sturgeon are to be conserved and recovered, their limited reproduction will be the primary obstacle to overcome[2].

The goal of this research is to determine the ecological requirements for successful reproduction of pallid and shovelnose sturgeon in the Missouri River. The specific objectives are to: (1) determine the direction, magnitude, and habitat used during spawning migrations, (2) understand the reproductive physiology prior to and after successful and unsuccessful spawning, and (3) evaluate the effect that a semi-natural increase in flow has on the reproductive status, movements, and habitat use.

Approach

The approach of this study is interdisciplinary and integrates physiology, behavior, habitat use, and physical habitat assessment to document sturgeon spawning and assess the effects of environmental variables on spawning success. In the field, as many as 100 sturgeon were collected and assessed for reproductive state, fecundity of females, and gonadosomatic index using ultrasonic and endoscopic methods[37]. Blood samples were taken for hormone analyses. Female sturgeon that were ready to spawn were tagged both with ultrasonic telemetry tags (for relocating fish) and data storage tags (DSTs) that continuously monitor depth and temperature from within the fish's body cavity. This study took place in two different (ca. 640 km each) segments of the 1280 km Lower Missouri River. One of the river segments is highly influenced by controlled flows while the other has more natural flows, which allowed a comparison of the effects of natural and artificial flows on reproductive behavior.

The tagged fish were located repeatedly throughout the spawning season. Using mapping equipment, a 3 km stretch of the river centered on a fish location was mapped for depth, velocity, and substrate to provide not only fish habitat use but also local habitat availability. Continuous temperature loggers were placed in the Missouri River and tributaries where fish were collected. Gravel and rock deposits were located within the thalweg of the Missouri River, from the mouth at St. Louis to Sioux City, Iowa (during low water conditions). After spawning season, the fish were recaptured to assess spawning success and retrieve the DST tags.

Fish movement and habitat use data, along with the physical habitat data, were analyzed using a combination of discrete-choice and utilization distribution model[38]. Multivariate statistical analyses were conducted to determine predictor and explanatory variables (both environmental and physiological) indicative of spawning success.

Information gained

The majority of shovelnose sturgeon recaptured did spawn successfully, suggesting that the methodology did not compromise spawning behavior. Furthermore, data indicate that shovelnose sturgeon may travel over 640 km from point of tagging during their spawning migration.

The measurements of water conditions and habitat characteristics will be important in qualitative and quantitative description of habitat used during pre-spawn and spawning periods. Fish internal temperature (from DSTs), compared with the temperature measured by the continuous temperature loggers, will indicate whether fish are selecting seasonal habitats based on thermal preferences and the role of temperature as a spawning cue. This comparison will also indicate whether fish ascended river tributaries. The discrete-choice and utilization distribution modeling will contribute to determine if fish are selecting one habitat over another among those available on a local level, particularly during spawning.

Blood chemistry data will be used to assess spawning or failure to spawn. A combined analysis of the hormone data with environmental data may point to potential spawning cues. Tracking reproductively mature fish will provide data on the timing and magnitude of spawning movements, and the potential spawning habitats. Environmental and physical habitat data, obtained together with tracking gravid and post-spawn females, will be critical to understand where and under what conditions sturgeon spawn. Results will be used to quantify existing spawning habitat and develop management strategies to create suitable and sufficient spawning habitat. This information will be critical to design adequate habitat alterations and experimental flow manipulations intended to promote reproduction. Telemetry locations of implanted fish and the associated habitat and water quality measurements will be incorporated into a GIS format and made available to the U.S. Army Corps of Engineers (USACE), the USFWS and others for use in the redirection of sturgeon assessment and monitoring efforts.

The USACE, USFWS, numerous Tribes, state agencies, and stakeholders are involved in efforts to define operational changes that will minimize jeopardy and contribute to survival of the pallid sturgeon. Management actions to alter the flow regime or morphology of the Missouri River and provide benefits to the pallid sturgeon need to be designed with a comprehensive and detailed understanding of how sturgeon might respond.

Final Comment

It is important to realize the crucial role that behavior can play in the conservation of Great Plains fishes. I hope this article provides an overview of the exciting approaches that are being used in the conservation of native fishes. This research could inspire similar conservation projects on other fish species where analogous questions and logistical problems arise.

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Kidnapping the Don Juans of Guantánamo

By Allison C. Alberts*

Temporary removal of dominant males and careful manipulation of a population's social structure could help conservation behaviorists reduce the effects of inbreeding. The technique may be most effective for small genetically-compromised endangered species that show strong polygyny, with a few dominant males monopolizing territories and females. After the "Don Juans" are removed from their home ranges, new males take over their roles and females have access to a more diverse set of mates[1].

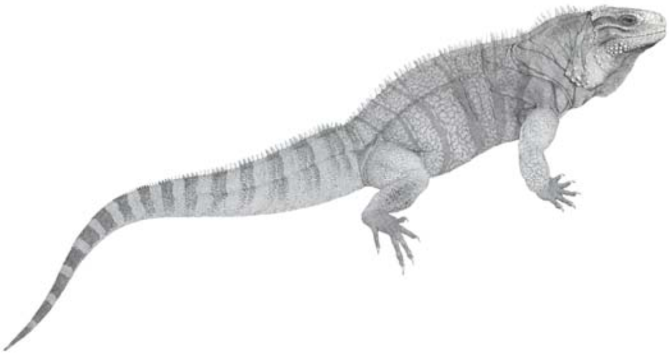
West Indian rock iguanas (genus *Cyclura*) are among the most endangered lizards in the world, with five of the eight species considered critically endangered by IUCN. Introduced mongooses, feral cats and dogs, and free-ranging hoofstock have decimated once teeming populations of iguanas by predating young and degrading native vegetation. Rock iguanas, as herbivores, play a crucial role in Caribbean dry forest ecology: they promote foliage growth through cropping, provide nutrients to developing seedlings, and disperse seeds into new habitats.

In the mid-1990s, we spent a year documenting hormones and behavior in a group of iguanas inhabiting the U.S. Naval Base at Guantánamo Bay. Our behavioral observations revealed that 80% of adult males engaged in aggressive interactions with other males. We classified males winning more than 50% of encounters as high-ranking, and those winning less than 50% of encounters as low-ranking. The remaining 20% of males never participated in agonistic interactions (non-ranking).

High-ranking males exhibited higher testosterone levels and were significantly larger in body length, weight, head size, and scent gland diameter than low-ranking males. High-ranking males vigorously defended small but well-defined home ranges that overlapped the ranges of various females. Non-ranking males occupied peripheral home ranges with very limited access to females and tended to avoid movement to escape the notice of more aggressive individuals. Low-ranking males did not defend territories, instead they moved extensively throughout the study area while suffering constant chases by high-ranking males. Analysis of mean distances between pairs of individuals indicated that each of the resident females on the site was closer to a high-ranking male than to a low- or non-ranking male. Headbob displays, chases, and mouth gaping, behaviors usually performed in the context of territorial defense, were exhibited by high-ranking males significantly more often than by low-ranking males. There was also a trend for courtship to be performed more often by high-ranking males than by other males. Although it is impossible to be certain in the absence of genetic studies, our results suggested that high-ranking males, through their more robust body morphology and behavioral dominance, had better access to mates than low and non-ranking males.

We conducted an experiment to determine whether temporary alteration of local social structure could increase the probability that sexually mature but genetically under-represented male iguanas could improve chances to mate. During the 1994 breeding season, we temporarily removed the five highest-ranked males from the study site. Removal of these "Don Juans" produced immediate and dramatic changes in male social structure. Within a few days, the five largest previously low-ranking males began to win more than half of their encounters and could be classified as high-ranking. All of the previously non-ranking males began to move throughout the study site and fight extensively with other males, behaving like low-ranking individuals. The newly dominant males showed increased rates of headbob display and chases associated with territorial defense, as well as testosterone levels typical of high-ranking males during the breeding season. Active courtship of females was seen in both the newly dominant males as well as the low ranking males. Once the previously dominant males were removed from the site, the five males that achieved high-ranking status in their absence defended territories that were strikingly spatially similar to those vacated by the removed individuals.

At the close of the breeding season, we returned the Don Juans to the study site. Our behavioral observations and home range mapping for five weeks following the release of the dominant males indicated no long-term disruption of behavior or social relationships.



West Indian rock iguana

The Conservation Behaviorist

These findings suggest that temporary alteration of local social structure may represent a potential management tool for small or otherwise genetically-compromised populations by enhancing the chances that a greater percentage of males will have opportunity to mate. This strategy, however, may not be equally appropriate for all species of rock iguanas, and to be fully effective will need to be combined with other measures, such as predator control, that directly counter the factors responsible for population decline. Temporary removal of dominant males is likely to be most effective for species that show strong dominance polygyny, in populations for which inbreeding has become a serious threat to genetic integrity. Because of the possibility that high variance in male reproductive success is naturally maintained through genetic or age-dependent balanced polymorphism, it is important that this strategy only be considered as an emergency interim measure until the effective population size is large enough to insure genetic viability.

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Conservation Behavior in Borneo's Logged Forests

By Jason Munshi-South*

Most of Borneo's wildlife is not found within pristine protected jurisdictions, but instead exists within production forests. These vast logged areas can play a significant role in conservation but until recently have not been a priority for researchers. Understanding foraging and breeding behaviors in logged forests will help explain why species either persist or go extinct after habitat degradation. I am studying the evolution of monogamy in the Large Treeshrew,* Tupaia tana*, in both primary and logged forests in Sabah, Malaysia (NE Borneo). I am examining body condition, reproduction, territoriality, and extra-pair paternity among treeshrews in the two habitats.

Protected areas are vital to wildlife conservation, especially for species that require large, contiguous areas of undisturbed habitat. However, political, economic, and demographic pressures limit the amount of pristine habitat that can be protected from human disturbance. Take the case of Borneo, the world's third largest island and a significant reservoir of biodiversity, as well as a leading supplier of tropical timber[1]. Of the three nations that comprise Borneo, only the tiny sultanate of Brunei protects a significant percentage of the area under their control (20%). Overall, only 6% of Borneo enjoys legal protection[2] and protected areas in Indonesian Borneo continue to be severely degraded[3] Despite this lack of protection, much of Borneo remains forested, including nearly 60% of the Malaysian state of Sabah[4].

Even though most of Sabah's remaining forests have been selectively logged, they still contain most of the vertebrate species found in primary forests. These vast logged areas should play a significant role in conservation efforts, but until recently they have not been a priority for researchers. Controversy has sometimes surrounded conservation in logged areas, due to fears that research showing the ability of species to persist or even thrive after logging may be used as an excuse for further degradation. These fears have not materialized, and the conservation community now widely recognizes the need to develop conservation schemes that balance timber production and wildlife preservation[5]. Furthermore, the limited success of expensive translocation and captive breeding programs makes conservation of endangered species within logged forests an attractive alternative[6].

Most studies conducted in Sabah have found that vertebrate species occur in selectively logged forests, but what are the long-term prospects for these populations? Detailed demographic and behavioral studies are needed to identify and predict when populations are at risk of extinction. Logged forests also present the additional benefit of "unnatural experiments," allowing comparisons of the behavior of individuals in contrasting environments. Animal behaviorists can contribute to knowledge and conservation of vertebrates in logged forests in many ways, two of which have already been applied in Borneo:

Foraging Behavior: Selective logging reduces the abundance of some food sources while increasing others. Surrogate measures of behavioral plasticity, such as dietary flexibility, may be powerful predictors of persistence of many taxonomic groups in disturbed habitats. Mousedeer in Sabah fare more poorly in logged forests than other frugivorous ungulates or primates, most likely because of an inability to shift to a browsing foraging strategy[7]. Additionally, carnivorous civet species decline more drastically after logging than frugivore-omnivore species[8]. Maintaining body condition in altered habitats depends not only on individuals adapting to altered food availability, but also shifting the amount of energy devoted to foraging. Primate species in peninsular Malaysia spend less time foraging and more time resting after logging, presumably to conserve energy when faced with a reduction in preferred, high-calorie food sources[9]. In contrast, omnivorous sun bears and Malay civets show no differences in activity levels or home range sizes in logged vs. primary forests[10,11]. Optimal foraging models represent another potential behavioral predictor of extinction due to logging.

Breeding Behavior: Species that are capable of exhibiting a broader diversity of social or mating behavior in different habitats may be better equipped to persist in logged forests. For example, monogamous and weakly polygynous mammals in West Africa were found to be more prone to extinction than species with males that maintain large harems[12]. Monogamous species or populations may suffer disproportionately from Allee effects due to changes in abundance of breeding females brought on by demographic stochasticity. Sex ratio distortion may also change patterns of sexual interactions in logged forests. Nearly 60% of Sabah's orangutans live in logged forests[13], where local populations periodically experience overcrowding as orangutans move away from logging activities in adjacent areas. These populations can quickly become male-biased because females are much less likely to move away from logging areas than males[14]. Although behavioral studies have not been completed, this male crowding may increase the incidences of male harassment, forced copulation, and infanticide within the population. These behaviors could have long-term negative impacts on orangutan population growth in logged forests.

The examples above were specifically designed to examine vertebrate responses to logging, but behaviorists can contribute to the conservation of wildlife in logged forests in a number of ways (below). Baseline behavioral data from unlogged habitats is often not available. Working on a species affected by logging in other areas, whether endangered or not, can provide useful information. Studying behavior in multiple populations in different habitats can help conservation biologists predict when populations are likely to decline after habitat disturbance. Comparing the behavior of individuals in populations in logged and primary forests can also help untangle the ecological factors influencing the evolution of behavior. In this article, I discuss how my own research takes advantage of the "unnatural experiment" provided by logging to examine the evolution of monogamy in Bornean treeshrews.

Logging and Monogamy in the Large Treeshrew

In Autumn 2000, I was a new graduate student at the University of Maryland looking for a suitable dissertation project. I wanted to study the ecological basis of mating behavior and had the vague notion that I wanted to work on mammals in a tropical ecosystem. My first proposal, a field study of reproductive skew in the Dhole, a social canid found in India and Southeast Asia, fell through due to logistical problems. A few months later I read an article about treeshrews in Natural History magazine that was promoting a new book, Tupai: A Field Study of Bornean Treeshrews, by Dr. Louise Emmons. After ordering the book and reading it in a single night, I scheduled an appointment with Emmons (serendipitously she was just a subway ride away) to talk about treeshrew mating behavior. After that conversation I set about convincing my advisors and funding agencies that studying treeshrews in Borneo was worth pursuing.

After eight months writing grant proposals, coordinating research permits, and lining up local collaborators, I arrived at the Danum Valley Field Centre in Northeast Borneo. Initially aiming to study mating behavior in two species in multiple habitats, I quickly realized the folly of attempting to work on more than one species in more than one place. During the first field season I limited my observations to the Large Treeshrew (*Tupaia tana*) because it is the most abundant in primary rainforest and potentially most interesting; I postponed work in different habitats for a year. My field work, conducted from August to December in 2002-4, addressed the questions: Why did social monogamy evolve in treeshrews? Are treeshrews genetically monogamous? Do treeshrews exhibit different territorial or mating behavior in logged forests vs. primary forests?

Treeshrews as model species to study behavior in logged forests

Treeshrews (Mammalia, Scandentia) are small, diurnal mammals found throughout the Indomalayan region, but more species occur on Borneo than the rest of the Asian continent combined. Treeshrews received much interest from biologists when they were classified as primitive primates, but research has declined since they were grouped in their own order. The IUCN lists one Bornean treeshrew as endangered and all species are protected by CITES Appendix 2 regulations. This latter classification is due mainly to a lack of information on the conservation status of most taxa. Two previous assessments of treeshrews in logged forests suggest that all species are present after logging but at lower abundance and in different proportions[15,16].

Preliminary studies indicate that unlike 95% of mammals, all treeshrew species exhibit monogamous mating behavior. Mammalian males typically provide little parental care, so they can usually maximize their fitness by attempting to mate with the largest number of females. Molecular markers have revealed that even putatively monogamous mammals breed polygynously in certain ecological situations, prompting behaviorists to distinguish social monogamy (living in an exclusive male-female pair) from genetic monogamy (actually breeding with one partner). Emmons[15] recorded a pattern of territorial behavior consistent with social monogamy in six treeshrew species: a single adult male-female pair living on a joint territory that each defends against same-sex conspecifics. However, the Large Treeshrew deviates slightly from this pattern in that territorial boundaries often overlap with neighboring territories.

Four main explanations for the evolution of social monogamy in mammals have been proposed[17], all of which may be influenced by the ecological changes brought by logging. The first two involve protection provided by the male for his mate and/or offspring. If the male provides extra vigilance against predators or infanticidal males, then it may benefit the female to limit her reproductive opportunities to that one male. Thirdly, if the male provides extra food on the territory that he defends, then she may also benefit by limiting herself to that territory. Fourthly, treeshrews may be monogamous simply because females are too spread out. Female treeshrews defend very large territories for their body size, and thus males may find it difficult to defend more than one female territory.

Male treeshrews are unlikely to provide much benefit against infanticide; the unique absentee maternal care system of treeshrews makes it improbable that other males will know the location of the natal nest. Females leave their pups in a tree cavity and only visit them once every 48 hours for a vigorous period of suckling. Because male and female treeshrews seem to be equally vigilant against heterospecific predators, males might not be especially important for predator detection. Similarly, males and females defend territories of the same size, so males probably cannot offer additional food to females or offspring. The question remains: are females too spread out for males to defend more than one female (fourth hypothesis, above)?

Social monogamy in the Large Treeshrew

To address this specific question, I monitored a *T. tana* population in a ¼ square kilometer of primary rainforest over three years. Most of the adults at the site could be captured during each field season, along with several of their offspring. Each adult was sedated, weighed, measured, checked for reproductive status, permanently marked with a microchip under the skin, and fitted with a radio collar. After releasing the animals with their radio collars, my field assistants and I tracked every animal for three days, from just before dawn until sunset. These data on each animal's territory and daily movements allowed me to examine the spatial relationships between males and females within the population.

Large Treeshrews at Danum generally conformed to the pattern of social monogamy found in other studies of tupaiids. However, I recorded two males in 2004 defending territories that encompassed more than one female territory, even though their territories were not larger than other males. These results suggest that overdispersion of females may not be an adequate explanation of social monogamy in treeshrews. Currently I am working on a model based on daily movements and treeshrew reproductive biology to explain why most males do not defend more than one female or rove around the forest looking for additional mates rather than defending a territory.

It is still unclear whether socially monogamous treeshrew pairs actually breed with each other. I sampled a small amount of tissue from the ear of all treeshrew captured during the study with the purpose of using microsatellites to determine the parentage of each offspring within the population. The lab work has not been completed, but I suspect that, like many supposedly monogamous mammals, treeshrews are not as monogamous as they seem.

The fate of treeshrews in logged forests

The final aspect of my research concerns the fate of treeshrews in logged forests. I am examining three aspects of treeshrew breeding biology in these degraded habitats: body condition, territory sizes, and extra-pair paternity.

Overall fleshy fruit production is often lower in logged forests than in primary forests. Fruit trees destroyed by logging may be replaced by pioneer species such as Macaranga sp. that produce fruits of little value to terrestrial vertebrates. If fruit production is hindered by logging, then I predicted that treeshrews would exhibit worse body condition in logged forests. Lower fruit and/or invertebrate density in logged forest may also force *T. tana* to defend larger territories in logged forests to meet the energetic requirements for reproduction. If female territories are smaller in primary vs. logged forest (lower female dispersion) then the rate of encountering receptive females should also be higher for males in primary forest. To examine these predictions, I trapped and radio tracked treeshrews during 2003-4 in a logged area about an hour's drive from the primary forest site. If the 'female overdispersion' hypothesis explains monogamy in treeshrews, then larger female territories in logged forest should result in social monogamy and a low rate of extra-pair paternity. Alternatively, smaller female territories in logged forest should result in social polygyny (as observed for two males in primary forest) and a higher rate of extra-pair paternity.

The work in logged forest has been plagued with difficulties from the beginning. The capture rate was low during 2003, possibly because of the large amount of fruit falling from the trees during trapping. Radio tracking and other data were obtained from only a few adults. Additionally, this logged site is right in the center of the range of Sabah's elephant population. These elephants frequently feed on the grasses and shrubs that grow in disturbed areas and use logging roads as shortcuts between foraging sites, resulting in many more elephants at the logged site than in the primary forest. My small mammal traps and fruitfall nets were repeatedly destroyed by marauding proboscideans.

Promising findings

Results are emerging despite these difficulties. Treeshrews in logged forest were larger and in better condition than animals in primary forest. Additionally, a much higher percentage of juveniles were captured in logged forest than in primary forest, suggesting that the ecological conditions in logged forest may be quite favorable for the Large Treeshrew and an endangered Borneo endemic that I have also trapped in large numbers, the Large-footed Treeshrew (*Tupaia longipes*). In 2003 the elephants did not destroy all of the fruit nets and thus allowed me to measure much higher fruit production in logged vs. primary forest. Higher fruit production after logging may offset the effects of lower invertebrate diversity and abundance, allowing treeshrews to increase their reproductive output. It is currently unknown whether increased fruiting is only a short-term response to logging. Treeshrews in logged forest did not defend significantly smaller or larger territories, but all males were socially monogamous. The DNA work still needs to be completed before we determine if the increased body size and reproductive output of treeshrews in logged forests results in a greater incidence of extra-pair paternity in logged vs. primary forest.

Future behavioral research in logged areas will benefit from a comparative, model-building approach and should seek to examine multiple species and habitats simultaneously. Unfortunately, animal behaviorists, especially those working in the tropics, often work by themselves and lack the funding for large numbers of trained field assistants. Collaborative efforts using standardized protocols for collection of behavioral data, along with studies of the changes in forest structure and dynamics, are needed to move this vital area of research forward.

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