What Use Do Fauna Inventories Serve?

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In Search of Protocols for Environmental Study

The different techniques presently used for inventorying fauna provide the most direct means of accessing in part the components of animal diversity in a biome or locality, in a determined space and time. However, it is essential to understand that the components of this diversity will never be completely sampled. After all, the essence of sampling is to obtain a part that adequately represents the totality of the object of study. The result of any sampling represents the sum of technique(s) used, as well as the ability of the conductor, whose goal is to detect organisms in a given sample space. From a temporal aspect this is expressed as much in terms of hours spent in the field as in knowledge of the historical composition of the fauna which, naturally, is going to vary between localities. This "snapshot" of a specific locality contains the most important implications which will be discussed in this essay.

Detecting and describing the fauna of a specific region, and interpreting the data obtained in the field are not easy tasks, even among only slightly diversified groups. Elaboration of a list of any taxonomy of vertebrates or invertebrates is not trivial and involves, besides use of specific and efficient techniques to sample a specific group, a reasonable knowledge of systematics, taxonomy, ecology and natural history in general. The education of a researcher capable of dealing with Brazilian megadiversity (for numbers and a critical vision of each group, consult *Megadiversidade*, n.1, Conservação Internacional, 2005) requires more time than is allotted to undergraduate biology courses. Supplementary education is necessary at the graduate level. In addition, the high rate of discovery of new species, even in groups considered to be well-known, such as primates and birds, requires researchers to constantly keep themselves updated so that there will be no errors in identifying and defining the distribution of the uncommitted taxa. Researchers are continually adopting new concepts of species that better reflect our diversity (Aleixo, 2007; Silveira & Olmos, 2007) and that, consequently, refine our understanding about the taxa that occur in a specific space. Consequently, they are dedicated to elaborating inventories of fauna.

This touches upon one of the first problems to be discussed, which is who, in fact, has the ability and competence to elaborate these lists. Presently, professionals from different areas of study have been venturing to create inventories of fauna for companies that elaborate studies of environmental impact with the most varied results. Although they are often connected to the natural sciences, occasionally we may be surprised to read reports in which the inventories were conducted by professionals from other areas, such as engineering or even from the human sciences, all in search of a slice of the profitable market enjoyed by environmental consultants. Qualification and competence are distinct terms and are frequently misused and confused. By definition, the biologist is the only professional who has received all the necessary and basic knowledge during his studies as an undergraduate to recognize and deal with biodiversity. This is not to say that the same biologist is competent enough to correctly conduct inventories of any given group. This competence is acquired by means of supplementary education, which can result from courses and internships taken during the undergraduate period or even from a relevant graduate level course, *stricto sensu,* in the area of specialization. It is essential that properly qualified and competent professionals be employed for conducting an inventory of fauna, in order that the lists produced can generate useful knowledge for guiding very basic political decisions about how to deal with environmental impact, although this is frequently ignored.

Thus, the first point to be considered in the elaboration of fauna lists is not the elaboration of the list *per se*, but the selection of properly qualified, capable and competent human resources. However, the current situation is still far from ideal. A significant number of the hundreds of environmental consulting companies are more notable for selecting consultants on the basis of cost rather than for academic credentials and experience in conducting inventories of fauna which generate quality data that can correctly substantiate the decisions of the licensing agencies.

Fauna lists are essential components in the analysis of solicitations for undertakings that cause a myriad of impacts on the environment, many of them of major weight and irreversible. As such, whoever makes a "snapshot," and how the specific locality to be potentially impacted has been "photographed," are themes of greatest importance and responsibility. And it is precisely at this very important point of the process that we always perceive a series of failings. As stated previously, the results of an inventory of fauna, expressed in its primary data, will gauge the analysis to be done by environmental agencies. Failures in the collection of this data, or data that has been obtained in an incomplete or incongruent manner, can lead to disastrous consequences for the species in question, standards and processes (see the article by Trajano in this issue), and for the environment.

Brazilian environmental legislation is considered one of the most advanced of the planet, although effective implementation of some points is the basis of controversy. Even so, some of the sectors that most degrade the environment have for years attempted to propose important changes according to the interests of the moment (see, for example, the recent proposals in relation to the rainforest code - as in the article by Varjabedian in this issue) under the guise of "modernizing" or "updating." This legal guideline gives general directions but still fails in more specific questions, being, for example, overly generic in relation to inventories of fauna. This leaves a window open so that the inventories can often be conducted in a less than scientific way, setting aside various important aspects that could amplify the utility of these lists.

In both formal and informal analyses of various reports by environmental consultants in recent years, we have seen these works lacking an efficient experimental design. There have been problems in the choice of methodology, caring too little about documentation of the presence of species, as well as not spending enough time sampling in the field and in museums. What then would constitute a good inventory of fauna? This apparently simple question hides further proposals that necessarily need to be adapted to the size and impact of the undertaking. The definition of methods and sampling period is generally furnished by the environmental agency responsible for the licensing. However, as has been observed many times, the analysts themselves suggest inadequate methodologies, scarcely efficient or based on their own preconceptions and idiosyncrasies. A good example of this is the denial of licenses to collect specific groups of animals or restriction of the use of firearms, an essential tool for sampling in tree tops. This last tool, for example, if not used, necessarily leads to under-sampling an important portion of the diversity of vertebrate whose identification is difficult in the field. The different methodologies available and their established use for fauna inventories can and should be adapted for each situation. A degraded pasture is less complex and should be sampled in a manner distinct from a fragment of primary forest, where the diversity and the number of interactions among its components are exponentially greater. Thus, a more adequate and more efficient method of sampling the diversity should be defined and considered as a function of the location to be directly impacted, and of its boundaries which would eventually suffer from indirect impact.

Although different methods can and should be adapted to the reality of each locality to be inventoried, we believe that some general principles need to be observed. The selection of trained professionals competent enough to conduct the undertakings is unfortunately left to the determination of companies with direct interest in the approval of specific projects. This creates a potential for conflict of interest. It is important that the environmental agencies be concerned with the experimental design to be applied. This is a factor too often neglected and is, paradoxically, one of the most important because an inventory of fauna is very useful in permitting the environmental analyst to arrive at more precise conclusions. However, despite the essential importance of a good experimental design, one observes in many cases an absence of any experimental design that makes sense. It is frequent that a list of fauna is presented, having been obtained without transects replicated or without control areas. The list may lack indices of abundance for a given species, averages, and other aspects fundamental in a species inventory. In the majority of cases, not even a simple curve indicating the accumulation of species (also known as a collector's curve) is included. This prevents knowing whether the time spend obtaining the sample was sufficient enough to deem the area reasonably well known. Such a conclusion could be verified by observing the tendency of the curve in the graphic. Surprisingly or not, these inventories, with conceptual failures from their creation, are those on which decisions are made to either suppress or extensively impact a specific location.

Evidently this is a point that has called the attention of various researchers, and only very recently have licensing agencies begun to notice the importance of a good experimental design and demand an excellent product. For this there is a recent initiative developed by Magnusson et al. (2005), known as RAPELD, that consists basically of a combination of rapid inventories (RAP) and long term ecological research (PELD, in Portuguese). This method, which combines inventories of rapid and efficient diversity with obtaining data that can be used in studies of long duration, was developed to be used in Amazonia at a relatively low cost. The method still presents various operational problems and is difficult to apply to other areas that are not homogeneous, areas that are grand in scale, and especially areas that belong to the public domain (in other words, in Amazonia). It is subject to many improvements, yet it is a step toward having data obtained in a standardized and uniform manner, allowing the impacts to be better evaluated by means of monitoring programs (see the following). RAPELD with all of its problems of applicability, holds value in opening the dialogue so that experimental designs aimed at supporting studies in environmental impact will be discussed in the academic community. Also, it is hoped that they would be applied to the undertaking of ventures that potentially impact various kinds of environments present in Brazil, the history and dynamic of which are distinct from that observed in Amazonia.

Besides experimental design, another important aspect to be taken into account is the methodology to be used. This necessarily needs to be efficient, feasible and capable of generating data which responds appropriately to the given problem. It does not help to have an impeccable experimental design that requires a methodology that is impossible to implement, or that answers various important questions from a theoretical point of view, but that basically does not answer whether a specific undertaking is or is not environmentally feasible. Another important factor to be considered is the use of different methodologies whose sum aggregates the greater number of species in a minimal period of time. To provide an example, in inventories of birds it is common to use methods that rely on observation (with or without the aid of binoculars), and on identification of birds by means of their vocalizations, often without any concern for documenting the record, resulting in a process that is hardly scientific. Although these are two established methods, both of them efficient and at the lowest cost, since they only depend on a biologist willing to wake up early and go on the road, their results can vary a great deal. Needless to say that methods using only active search, based essentially on personal experience, are already, *per se*, surrounded by bias and have enormous potential for influencing the final results. A bird only needn't sing the day and time that the researcher is present (something very common while not in the reproductive season) or, not move very much so as not to attract the researcher's attention, for that species to not be counted. The chance of detection is even slimmer in the event that transects are not used repeatedly on different days. Thus, the use of complementary inventory methods, such as mist-nets (passive method) and firearms, assemble a greater number of species, frequently in a shorter period of time. The use of these methods unequivocally documents the presence of a specific species in an area, and the practice of scientific collection, duly authorized and conducted within the norms specified in legislation, does not affect the natural population in any important way. What's more, a collected example brings a range of important data not only for the inventory in question, but also for basic knowledge about systematics, taxonomy, biogeography and natural history (for a discussion about the subject, see Remsen, 1995, and Piacentini et al., in press), contribute in a decisive manner to the conservation of the species *in situ* and *ex situ*. The complementary nature of these methodologies should be seriously regarded and one method or another should not be chosen to accommodate the researcher. Methods must be considered as a means to obtain quality data for enabling well-founded decision-making.

Another aspect either ignored or incorrectly administered relates to the season in which studies are conducted and the time spent sampling each selected area. Generally, many inventories are conducted during only one period of the year, in a few days, mostly considering the needs of the contractor rather than the need to obtain reliable data. The behavior of a significant portion of Brazilian animal diversity relies on seasonal variations. This factor should be adequately considered in the inventories. Various areas in Brazil serve as rest stops for migratory species, by definition highly seasonal. Inventories carried out in only one period of the year can omit these species, which depend on rest areas for survival and to accumulate fat for the return to their reproduction locations. The defined period of sampling in the field must be sufficient enough so that a specific group of fauna would be well-sampled. This definition should depend on the environmental agencies, and not the contrary.

Inventories, as has been stated, are among the pillars upon which the decision-making processes is based in relation to undertakings that will impact the environment. Unauthorized undertakings are rare, yet nevertheless cause an impact. Overlooked are synergistic effects from small impacts, which add up over time (see the article by Trajano in this issue). Thus, another important consequence of these inventories is the monitoring programs. Monitoring programs should be conducted over a long period of time, preferably three years or more, so that it can be verified whether the specific impact has changed animal communities in an important way. Inventories are not monitoring programs. But, if done in a standardized manner, with intelligible and organized data gathering, they become essential points of departure for successful monitoring programs. Presently the monitoring program is the most powerful tool for evaluating the impact on natural populations, and the existence and continuity of it should be incentivized, the cost being incorporated into the undertaking.

We emphasize here the importance of well conducted inventories, suggesting a much deeper discussion about general protocols and standardization of methods that takes into account the particularities of each group. The majority of inventories conducted today are not comparable and rarely are they able to address broader questions, especially those related to the synergy caused by various impacts in nearby areas that might only be noticed later. Differences in methods and the absence of scientifically tested and feasible general protocols can simplify complex realities, leading to misleading decision-making that might only be noticed when it is no longer possible to remedy or mitigate specific impacts, the consequences of which are unpredictable and quite costly to society.

Luís Fábio Silveira

Case Studies

1 Seasonal and Infra-Annual Variations in Sampling Land Animals by Use of Camera Traps

Beatriz de Mello Beisiegel

Species of mammals are very diverse in size and habit. While some make use of areas as little as a few hectares (for example, the long-furred woolly mouse opossum *Micoureus demerarae* [Moraes Junior & Chiarello, 2005, p.89]), others have immense home ranges of hundreds or thousands of hectares, or square kilometers, with either highly variable or irregular seasons of usage, or whose regularity can only be determined after long periods of study (see, for example, the white-lipped peccary *Tayassu pecari* [Fragoso, 1998, p.462, 463, 466]; coatis *Nasua narica* [Hass, 2002, p.938] and *Nasua nasua* [Beisiegel & Mantovani, 2006, p.82-3]; jaguars *Panthera onca* [Cavalcanti & Gese, 2009, p.938, 942]). Many species also present cycles of population variation, which are well understood among small European mammals (see examples in Begon et al., 2007, p.432-7), and are studied also in small Brazilian mammals (for example, Oliveira et al., 2007, p.30-2). For medium and large Brazilian mammals, however, nothing is known about the existence of such cycles. Although significant variations occur among terrestrial mammal populations in well-studied tropical forests like Barro Colorado Island in Panama, it is only known that they occur in response to environmental variations (Leigh Junior, 1996, p.437).

This article will demonstrate temporal variability in the detection of terrestrial mammals, and consequently the necessity for long term studies with large sampling efforts, in order to allow for a description of the mammalian fauna in any given area. The results used here are from long-term monitoring of a community of mammals conducted in a large area of the Atlantic Rainforest, Carlos Botelho State Park (PECB), SP, through continuous sampling by use of camera traps, begun in May, 2006.

Seven to 12 camera traps were used (Tigrinus conventional model). The results presented refer to the period from the beginning of the study to July, 2009; a total period of 1,165 days, totaling 5,715 camera trap-days at 78 points over 39 months. The species photographed could be identified with certainty in 1,215 photos. Photos of the same species in the same location within a period of 10 minutes were considered a single photographic capture. The data were analyzed to determine seasonal and annual variation in the rates of photographic captures (number of captures divided by sample effort in each season or year) and the total and monthly frequency of captures. In the final year of sampling, a camera trap was permanently placed at a location on the road not previously sampled during the other years, which caused a great increase in the rate of capture of some species this particular year, especially for the ocelot *Leopardus pardalis*. Furthermore analyses of annual variation for the rates of capture were done separately for open environments (roads and fire breaks) and closed areas (forest interior).

Twenty eight species of native mammals (Table 1.1) and two exotic species, the hare *Lepus europaeus* and the domestic dog *Canis familiaris*, were identified. Species with less than ten captures were considered to be rarely recorded and only data relative to species with ten or more captures in the period were analyzed.

The thirteen rarely captured species included naturally rare mammals such as the water opossum *Chironectes minimus* and the bush dog *Speothos venaticus*, as well as others that could have been little captured due to their populations having been affected by hunting, by the abundance of top predators (for example, the collared peccary *Pecari tajacu*, nine-banded armadillo *Dasypus novemcinctus*, naked-tail armadillo *Cabassous tatouay*, Azara's agouti *Dasyprocta azarae*), or by competition with species from the same guild (for example, gray brocket deer *Mazama gouazoubira*, oncilla *Leopardus tigrinus*, jaguarundi *Puma yagouaroundi*, Azara's agouti *Dasyprocta azarae*). The small capture rates for some species could also be due to little sample efforts on the environments most used by the species (which perhaps is applied to the oncilla, the gray brocket deer, the white-eared opossum *Didelphis albiventris* and the lesser grison *Galictis cuja*). Eight of these thirteen species offer special interest for conservation because they are categorized as threatened either in São Paulo state or in Brazil, and five of them were captured only after the beginning of the second year of sampling.

Seasonal variation in the availability of food resources occurs even in tropical forests without a pronounced dry season (Morellato et al., 2000, p.817-20) and is an essential determinant in the life history of mammals, influencing reproductive periods, patterns of space used, and rates of birth and mortality (for example, Oliveira et al., 2007, p.30-2; Beisiegel & Mantovani, 2006, p.81). All of the native species with more than 10 captures, with the exception of the giant anteater *Myrmecophaga tridactyla*, presented apparent seasonal variation in the frequency of photographic captures (Figure 1.1), and for nine of them this variation was significant. The reduction of food resources during the drier period could explain the increase in capture rates of *Cerdocyon thous*, *Leopardus pardalis* and *Puma concolor* during autumn and winter, since these species need to increase their daily movements and/or the size of their home range areas during this period (B. M. Beisiegel, unpublished data). The mating period of *Panthera onca* in PECB, which seems to be in the spring, can influence the increase in capture rate of the species during this period. However, part of the seasonal variations observed cannot be explained yet.

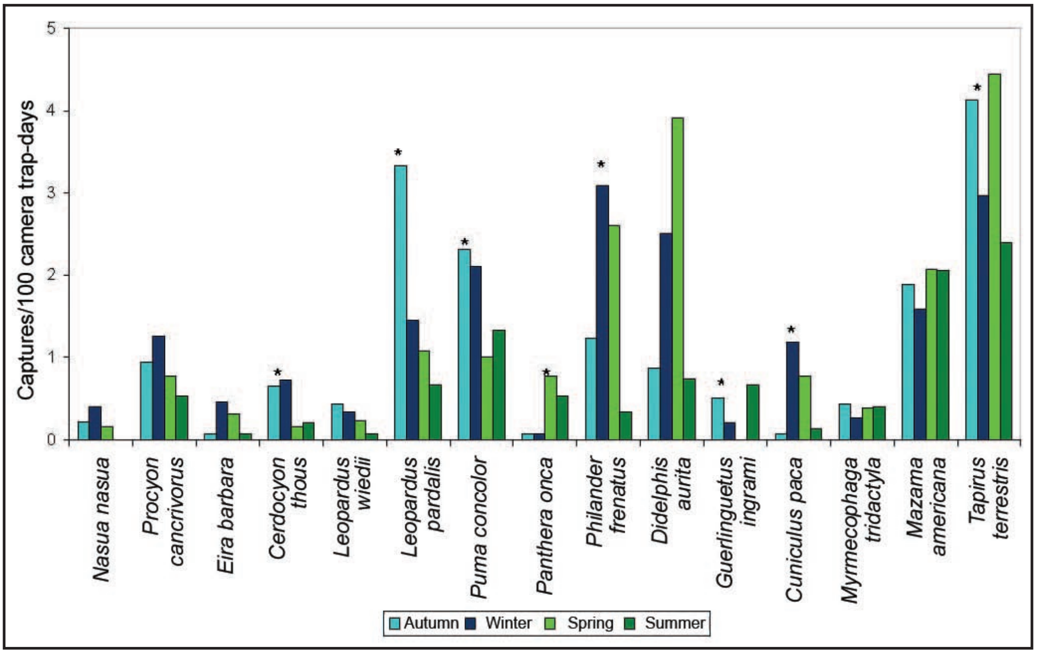
Besides the seasonal variation, all of the species presented different capture rates over the years. For three species (*Puma concolor*, *Didelphis aurita* and *Tapirus terrestris*), this infra-annual variation was as significant in the forest interior as in open areas. Another three species (*Guerlinguetus ingrami*, *Procyon cancrivorus* and *Philander frenatus*) presented significant infra-annual variation only in the forest interior (Figure 1.2), and *Cerdocyon thous*, *Mazama americana* and *Leopardus pardalis* presented infra-annual variation in the rate of captures on roads and at fire breaks (Figure 1.3). Three species (raccoons *Procyon cancrivorus*, squirrels *Guerlinguetus ingrami* and coatis *Nasua nasua*) were not registered for twelve or more months, and a fourth species (the jaguar *Panthera onca*) was photographically captured almost monthly, followed by a near disappearance that was interrupted by a single capture (Figure 1.4). All of these variations were accompanied by corresponding variations in other recordings of these species in the field – tracks or visual contacts. The understanding of these long-term fluctuations is much more complex than that of seasonal variations and, until now, we do not have sufficient data to explain these variations in the PECB. Changes in population density of sampled species, associated with large home range areas traveled over long periods of time that could surpass a year, besides interactions with populations of predators and prey, might explain some of the variations found.

Table 1.1 – Mammals identified by photographic captures during 39 months of monitoring in Carlos Botelho State Park, SP (modified from Beisiegel, 2009). The species are ranked by time necessary for the capture of each one after the beginning of monitoring. The categories of threat represent classifications on the official lists of São Paulo (2008) and Brazil (MMA, 2003). The captures represent the number of photographic captures up to July, 2009.

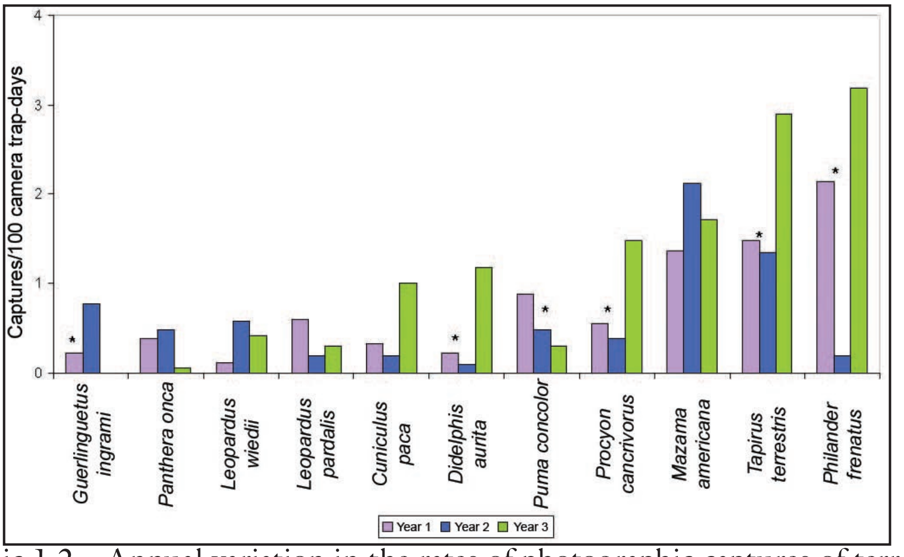
Species	Common name	Category of threat (SP-BR)	Days after beginning of sampling	Captures
Mazama americana	Red brocket deer	VU-lc	3	108
Leopardus pardalis	Ocelot	VU-VU	4	92
Metachirus nudicaudatus	Brown four-eyed opossum	NT-lc	5	7
Philander frenatus	Southeastern four-eyed opossum	lc-lc	11	103
Guerlinguetus ingrami	Squirrel	lc-lc	19	20
Procyon cancrivorus	Crab-eating raccoon	lc-lc	23	50
Panthera onca	Jaguar	CR-VU	30	20
Tapirus terrestris	Lowland tapir	VU-lc	30	196
Cerdocyon thous	Crab-eating fox	lc-lc	31	21
Eira barbara	Tayra	lc-lc	62	13
Chironectes minimus	Water opossum	NT-lc	72	3
Leopardus wiedii	Margay	EN-VU	73	15
Puma concolor	Puma	VU-VU	77	97
Nasua nasua	Coati	lc-lc	114	11

Cuniculus paca	Paca	NT-lc	131	31
Dasypus novemcinctus	Nine-banded armadillo	lc-lc	134	2
Dasyprocta azarae	Azara's agouti	lc-lc	184	2
Didelphis aurita	Black-eared opossum	lc-lc	192	112
Mazama gouazoubira	Gray brocket deer	lc-lc	195	1
Myrmecophaga tridactyla	Giant anteater	VU-VU	220	21
Pecari tajacu	Collared peccary	NT-lc	288	7
Puma yagouaroundi	Jaguarundi	lc-lc	308	4
Cabassous tatouay	Naked-tail armadillo	DD-lc	345	1
Galictis cuja	Lesser grison	DD-lc	451	2
Monodelphis scalops	Long-nosed short-tailed opossum	NT-lc	645	1
Didelphis albiventris	White-eared opossum	lc-lc	779	1
Leopardus tigrinus	Oncilla	VU-VU	837	6
Speothos venaticus	Bush dog	DD-VU	891	2

Abbreviations: lc = least concern (or not threatened); NT = near threatened; VU = vulnerable; EN = endangered; CR = critically endangered; DD = data deficient. The lines emphasized in yellow and green represent, respectively, captured species after the second and third years of sampling.

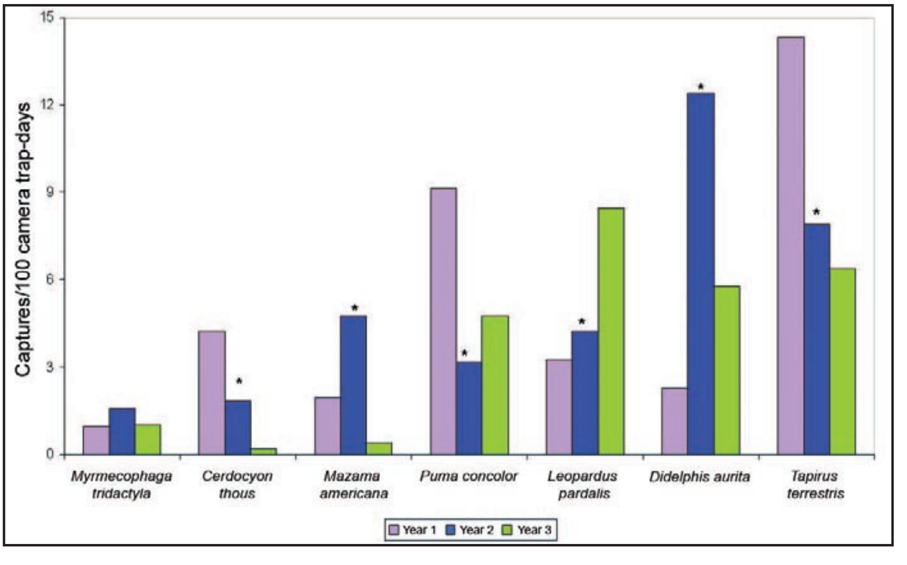


Graphic 1.1 – Seasonal variation in the rates of photographic captures of terrestrial mammals over 39 months in Carlos Botelho State Park (SP). The species marked with * are those for which there is significant variation in the X^2 test of adherence.

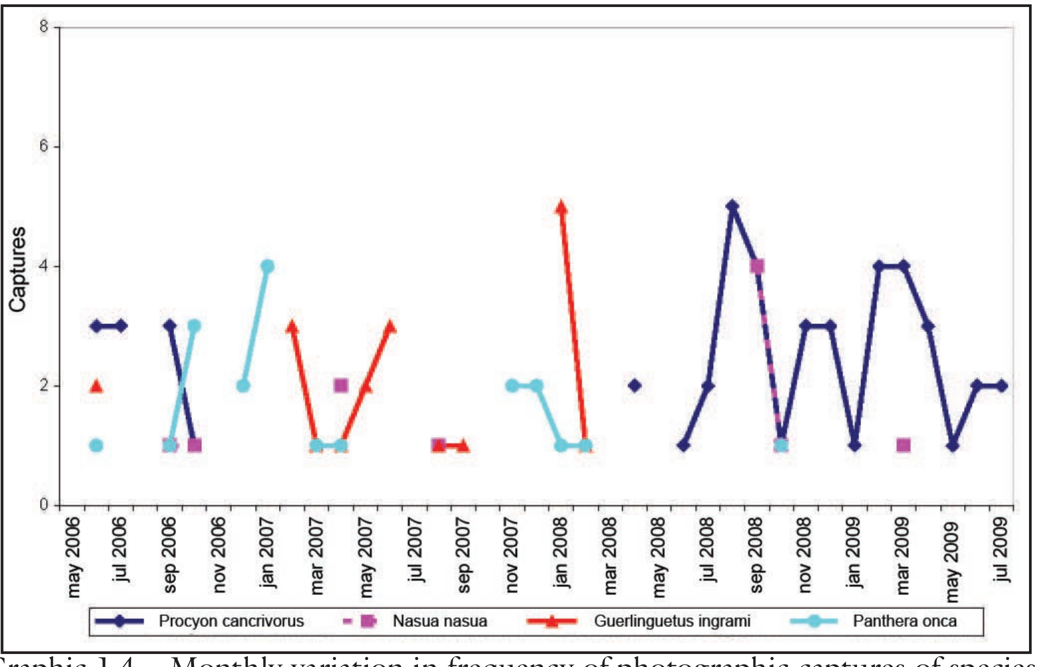


Graphic 1.2 – Annual variation in the rates of photographic captures of terrestrial mammals inside the forest over 36 months in Carlos Botelho State Park (SP). The species marked with * are those for which there was significant variation in the X^2 test of adherence. Year 1: June 2006 to May 2007; year 2: June 2007 to May 2008; year 3: June 2008 to May 2009.

Graphic 1.3 – Annual variation in the rates of photographic captures of terrestrial



mammals on roads over 36 months in the Carlos Botelho State Park (SP). The species marked with * are those for which there was significant variation in the X^2 test of adherence. Year 1: June 2006 to May 2007; year 2: June 2007 to May 2008; year 3: June 2008 to May 2009.



Graphic 1.4 – Monthly variation in frequency of photographic captures of species with large discontinuity in photographic recording in Carlos Botelho State Park (SP) over a period of 39 months.

Only four species with10 or more captures (*Nasua nasua*, *Eira barbara*, *Leopardus wiedii* and *Myrmecophaga tridactyla*) presented no seasonal or infra-annual variation in the frequency of captures. However, the first three species presented low capture frequencies and the giant anteater *Myrmecophaga tridactyla* was recorded for the first time in PECB only at the end of the first year of camera trap sampling.

The results presented above point to the existence of long-term variations in populations or to the use of vast space by terrestrial mammals in Atlantic Forest areas. This indicates the necessity for long periods of sampling to describe the mammalian fauna of these areas.

The extent to which this necessity is not covered by present Studies of Environmental Impact (EIA-RIMAs) could be suggested by comparing sample efforts, results obtained by camera traps of good quality in an EIA-RIMA, the dimension of environmental impact to be caused, and the geographic proximity and similarity of its environmental conditions with the PECB.

This EIA was elaborated for licensing to expand the Limeira Mine in the municipality of Ribeirão Grande, SP (Ribeirão Grande Cement Company, 2003). This mine is located in the Buffer Zone of the Ecological Station of Xitué. This site, together with Intervales State Park, Petar and PECB, comprises the continuous forest of Paranapiacaba, one of the largest remnants of the Atlantic Forest.

This EIA-RIMA was associated with a team of many good professionals

Photos Courtesy of Author

Jaguar *(Panthera onca)*

Raccoon *(Procyon cancrivorus)*

for the diagnostics of fauna, and was carefully elaborated. However, the sampling effort for the diagnostic of mammals by camera trap totaled approximately 23 camera trap-days over six months. A similar effort, in PECB, would be sufficient for capturing only the first (7 camera traps x 3 days = 21 camera trap-days) of the 28 species sampled during this study; in other words, 3.57% of the total of sampled species. A sampling effort of six months, or approximately 180 days, such as that conducted by the EIA of the Ribeirão Grande Cement Company, even if it were conducted with seven to ten camera traps, would have recorded only the first 16 species presented in Table 1.1. Therefore it would have failed to detect species of extreme importance for conservation such as the giant anteater *Myrmecophaga tridactyla*, collared peccary *Pecari tajacu* and the bush dog *Speothos venaticus.* A study conducted throughout this period would detect only part of the seasonal variation and none of the infra-annual variation in rates of capture of mammals, leading to completely wrong results, and would either over- or under-estimate the abundance of the species sampled.

Together with camera trap sampling, the other sampling methods employed by the Ribeirão Grande Cement Company EIA, totaling nearly 267 hours of field work distributed over 28 days in a half year, recorded 28 species of mammals for the area (Ribeirão Grande Cement Company, 2003, v.5, Annex 11, Part 5). A comparison similar to that conducted by the camera trap sampling effort could be applied to the many methodologies used in the EIA, reinforcing the conclusion that this number of species ought to represent only a small portion of the richness of mammalian fauna of the area. The fact that this EIA has been cautiously elaborated by comparison to many others, and was meant for the licensing of an activity with enormous potential impact on one of the most important areas of conservation of the Atlantic Forest, points to the total insufficiency of present environmental legislation with respect to the rigidity necessary in characterizing the fauna of the areas that will be affected by environmental impacts.

2 Considerations about Methods and Criteria Employed in Environmental Studies on Herpetofauna

Felipe Franco Curcio, Paula Hanna Valdujo, Marianna Dixo e Vanessa Kruth Verdade

The term herpetofauna refers to the species of reptiles and amphibians in a specific area. Concerning faunistic surveys, these two groups are sampled together, since the sampling methods broadly overlap. These methods are in turn varied, and their combined application is important to ensure satisfactory results of the inventories.

The first objective of an environmental impact study consists of identifying the largest possible number of the species occurring in the area of the undertaking in question. Herpetofauna richness can vary greatly due to the geographic location, extension and landscape diversity of the area. Considering that there are 849 species of amphibians and 708 species of reptiles in Brazil, distributed heterogeneously over six biomes of the territory, the task of identifying species is difficult. In addition, we know that this diversity is underestimated, since the taxonomy of neo-tropical reptiles and amphibians is still in development, demonstrating that there are still more to be discovered.

Once identified, the species should be characterized by geographic distribution, natural history, and the status of conservation. This information may be located in the literature and in zoological collections. Many reptile and amphibians species are unknown in terms of their natural history, and in environmental studies this information is frequently due only to the personal experience of herpetologists. A strong indication of the lack of information about the natural history of the species is the fact that 30% of Brazilian amphibians evaluated by IUCN in the last revision of globally threatened species had been classified as deficient in data.

Another important objective of environment studies involves determining the manner in which the species are distributed in the area of the undertaking, aiming to identify the extent of impacts over populations that will be exposed to them. This point is particularly important in the case of herpetofauna, since the majority of species thrive specifically in certain types of environments. These environments are generally distributed in a mosaic by areas of interest and many species present low mobility.

An essential point in the evaluation of impact consists of evaluating whether the species that will be affected by a specific undertaking are also represented in non-impacted areas. Occurrence of species in other areas does not exclude the possibility of permanent damage to a specific population. For example, even if a specific species of tortoise is widely distributed along a river, it could depend on specific sites for reproduction, and interruption of the flow or flooding of these sites could bring about local extinction of the species.

Finally, measures for mitigation and compensation of impacts should be explored, taking into account the natural history characteristics of the species, such as their reproduction sites, importance of the area impacted and the populations affected by the regional dynamic of the populations and communities. The possible loss of connectivity between populations and between different environments used by the species should be considered, as well as ways to minimize their effects.

Methods of Study

Survey of Secondary Data

The first step in any environmental study should be the elaboration of a list of species with potential occurrence in the study area. This first step is realized by means of bibliographic review and, especially by searching regional herpetological collections, as well as through comprehension of the wider geographic area.

Choice of Capture Methods

Adequate sampling of herpetofauna depends on simultaneous application of complementary methods, with the intent of adequately covering the great diversity of habits of the species involved. Therefore, many methods can be employed in the survey, depending on factors such as the objective of the study, the locale/biome where the study would be conducted, the time available for field work and the availability of resources.

The principal methods employed in sampling reptiles and amphibians can be divided into two major groups: i) active searching, in which the herpetologist actively looks for the animals; and ii) passive sampling, in which the animals are recorded by means of traps or instruments installed in the field.

Active Searching

Methods based on active searching are the most general, recording a great variety of species, but always require the presence of a herpetologist. Among the existing methods for active searching, the one most employed is encounter by visual search. Herpetologists search among trunks and stones, comb the foliage and search the most varied potential habitats, such as bromeliads, hollow trees and termite mounds. This method allows recording of species with various habits (that is: arboreal, aquatic, terrestrial and fossorial ditch dwelling). It is a sufficiently versatile and general process for detection and capture of vertebrates in the field (Crump Jr., 1994), taking place during the day or night. Many rare or cryptic species that are only recorded with difficulty by passive sampling methods are eventually recorded by active search. The search should be conducted randomly in the environment or employed in specifically marked areas, such as transects or parcels. The effort employed for the method should be counted by units of time (man-hours, for example) or by units of search area (parcels in m2, transects in km, for example).

Another method of active search widely employed is to search in reproductive sites, in which the herpetologist locates and walks around the perimeter, the margins and/or inside of swamps, streams, ponds and puddles in the study area during twilight and nighttime hours. In making the rounds, the species encountered visually or by vocalization should be recorded. This method, in spite of concentrating principally on species of amphibians, is efficient for sampling alligators, snakes and tortoises.

Sampling on Roads

The sampling method on roads (Fitch, 1987) is efficient for all groups, but especially for detection of serpents. It consists of going along roads at a slow speed looking for specimens that are immobile or moving along. Specimens killed by being run over are frequently recorded by this method. The results can be included with casual or systematic notes, recording the distance traveled and the types of environment sampled. The efficiency of the method depends on the ability of the herpetologist to spot specimens - even small ones - and capture them.

Advantages and Disadvantages

In general, the costs of active sampling methods are low and very efficient for sampling the great number of species of herpetofauna. However, results depend on the experience of each herpetologist involved in the work. Trained professionals can find a greater number of species and individuals animals than novices. In the same way, the identification of vocalizations in the field depends on facility in discerning sounds, as well as on the experience of each individual. It also should be emphasized that few localities can be simultaneously sampled by this method, since the number of field herpetologists is limited.

Passive Sampling

Among the most frequently used traps for herpetofauna sampling are those of interception and fall. This method consists of using buckets buried in the ground, connected by means of a fence made of canvas and stakes, which keep the structure upright. The fencing intercepts the animals, directing them to the traps (for more details, consult Gibbons & Semlistsch, 1981; Corn, 1994, Echin & Martins, 2000). Despite covering a more restricted range of species compared to active search, especially when sampling animals with terrestrial and/or fossorial habits, small or medium size, fall traps are responsible for recordings that rarely occur in active searches. This is true for species of cecilia serpents among amphibians, and two-headed-snakes (amphisbaena) among reptiles. Many species new to science are being discovered by use of this method.

Besides reptiles and amphibians, rodents and marsupials are also frequently captured in fall traps. Because of this the characteristics and disposition of the traps may be discussed among consultants of herpetofauna and mastofauna, looking to contribute to the sampling of the two groups.

While they are still little used, funnel traps appear to be efficient in the capture of serpents, the recording of which are mostly fortuitous. This method can be employed in locations where it is not possible to install buckets (for example, on rocky soil or flowering rocks), or in partnership with fall traps as a complement to the sampling (Hudson, et al. 2006).

A method still little popularized but highly efficient for recording amphibians in reproductive sites consists of the installation of recorders programmed to record sound at regular intervals of time (*data logger*; Jansen, 2009). Various recorders can be installed in diverse areas simultaneously and represent a significant gain in sampling during a reproductive period. This method is sufficiently reliable for qualitative comparison between areas. It can also be used to detect variation in the abundance of species, not in absolute values, but in classes of abundance.

Advantages and Disadvantages

Passive sampling allows various areas to be sampled simultaneously and the effort can be standardized. However, the costs and effort to implement these methods are greater than those for active search. More detailed compilations about capture methods of reptiles and amphibians are supplied by Caleffo (2002) and Franco & Salomão (2002).

Complementarity

Among the principal methods of sampling herpetofauna, how can the most adequate be selected in a specific environmental study? Herpetofauna encompasses a great diversity of species, with different forms of life, sizes and habits. Structurally, within this species there exists a range from small frogs of less than a centimeter, to snakes, lizards, alligators and large tortoises. Therefore, for an adequate sample that takes in all of these groups, an application that combines complementary methods should be used. Some important aspects of this complementary approach will be discussed below.

Distribution of Sampling Points

Independent of the method used, the sampling points should be distributed after consideration of all existing environmental variations in the area that will suffer impact. This is to ensure that the greatest portion of the local wealth would be sampled. The selection of the most adequate methods depends on the environment to be sampled.

There are various ways to systematize the distribution of the sampling points. These include: the selection of points placed at regular intervals (for example, every 1 km); random points distributed throughout the area of influence of the undertaking; and points selected on the basis of their environmental characteristics. All of them represent advantages and disadvantages for each objective to be reached. In the case of studies aimed at analyzing impacts, the areas should be deliberately selected so that it would be possible to consider the majority of existing abundance subject to potential impact. For the selection of these points, the following should be considered: the characteristics of the undertaking; the landscape; previous knowledge of the specialist regarding the characteristics of the species' natural history; and the potential of each type of environment. In spite of deliberated distribution of the points presenting some statistical disadvantages, it seems to be the most adequate alternative that complies with the objective of detecting the greatest number of species in a given area.

Besides sampling the area that would be directly affected, the sampling of points in the indirect area of influence of undertakings is also important. Data taken in these areas can reveal the impact on a regional scale, especially for the species that are distributed in patches determined by type of habitat. For example, in order to possibly understand impacts created by the suppression of a lake where various species of frogs reproduce, it is necessary to know if there are other populations of these same species that reproduce on nearby sites which will not be affected.

In many cases, it is not possible to use all the sampling methods in all types of environments. For example, fall traps cannot be installed in amphibian reproductive sites due to submersion of the soil. In this case, use of active search methods in all the reproductive sites would yield comparable results, at least qualitatively. However, it needs to be emphasized that it is always necessary to rigorously employ the same methods when comparing values of abundance of species in different locations.

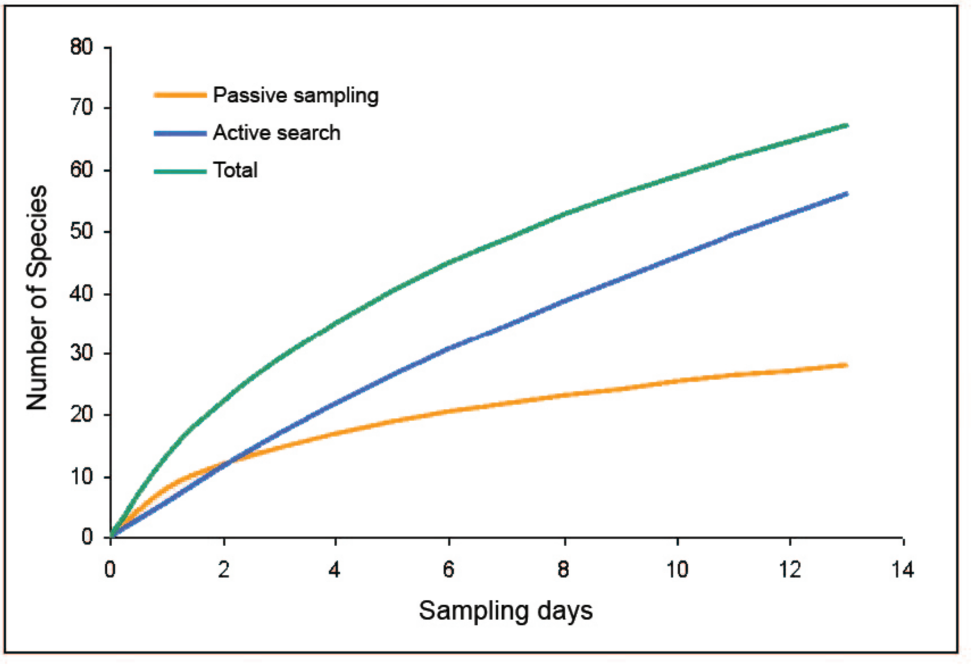
Sampling Effort

The ideal sampling effort varies according to the size of the area and its heterogeneity, since very extensive and/or very heterogeneous areas demand a great number of sample units. The best way to evaluate the effort is by means of *rarefaction curves,* also known as *accumulation of species curves* (Graphic 2.1). An area is considered well-sampled after the curve labeled "time of sampling for number of X species" reaches its point of inflection. This occurs when the number of species with few recordings diminishes, and the number of species with various recordings increases. It is important that a curve be constructed for each method of sampling, separately considering reptiles and amphibians as well as the two groups combined, since some methods are more limited than others in relation to potentially detectable species. Apparently in Graphic 2.1, the curve that represents the accumulation of species by means of passive sampling is stabilized, giving the idea that a good part of the species has been detected. However, not all of the species are recorded by this method, which can be seen in the curves referring to the active search method and then all methods combined.

Owing to the majority of species presenting strong changes in activity throughout the year, especially amphibians, a sampling conducted during a period in which few species are

active can result in a stabilized accumulation of species curve. Meanwhile, this stabilization yields a much lower value to the real abundance of the region being studied, which mean that the curves should be interpreted with caution, always considering the particularities of the region, the species being studied, and the period during which the sampling was done.

Some studies present a wealth estimator, jointly with the rarefaction curve, which is calculated on the basis of the shape of the curve and the number of species captured only once or twice. There are various estimators, many of them calculated by the free software EstimateS 8.0 (Colwell, 1994-2005).



Graphic 2.1 – Random accumulation of species curve (1000 times) with a herpetofauna base sampled over 13 days in the Cerrado of Central Brazil.

Seasonality

All species of reptiles and amphibians present some level of seasonality in their activity. These variations can be a reflection of the reproductive period, of the variation in resources, or from the climate characteristics of each region. Amphibians are especially sensitive to variation in temperature and rainfall conditions, concentrating their major period of activity in the rainiest months of the year, when there is greater availability of sites for reproduction. Because of this, conducting of sampling at different periods of the year should significantly enrich the results obtained. One very promising strategy consists in taking a sampling at the peak of the rainy season in order to guarantee good representation of amphibians, and another at the end of the rainy season and beginning of the dry season, when the temperature and frequency of sunny days can be more favorable to sampling of lizards. Another important period for conducting sampling is in the spawning or birth period of tortoise offspring, especially in the case of environmental studies for the installation of hydroelectric plants. Samplings at the height of the dry season, especially in open biomes (meadows and scrublands), provide an extremely low return due to the fact that the great majority of species is inactive, making their detection difficult. Seasonality in the activity of reptiles, and especially amphibians, is a recognized fact, having been demonstrated in various scientific articles and environmental studies. Thus, it is essential that seasonality be optimally incorporated into the sample design, in the best possible manner taking advantage of the resources and time invested in the study.

Specifics of the Biomes

Taking into account the specifics of each biome while planning the study of herpetofauna is essential, since the selection of sampling methods in themselves can vary greatly, just as is the case with the effort and seasonality. For example, it doesn't make sense to sample scrubland areas during the peak of the dry season, a time when animals will not be active and the success in recording a representative sample of the real diversity is improbable. In this case, it is more advantageous and productive to program a much longer, single sampling during the rainy season than to invest in two field campaigns (one in the dry and the other in the rainy season).

Some methods should be adapted depending on the sampling location. Differently from when they are used in forest areas where there is shade and humidity, interception and fall traps in open areas can kill animals from exposure to the sun during the hottest hours of the day. In these cases there are measures to be adopted that permit use of the traps without danger, such as creating shaded areas and including a reservoir of water in the buckets, besides reviewing the traps during the first hours of the day when temperatures are lower. The quantity of buckets to be installed in these circumstances will depend on the number of people available to review them in time.

Daily active search in transects, for example, is a very efficient method in Amazonia. However, doing the search in corral area transects is not pertinent, since lizards are active and, at the slightest sign of movement, quickly escape without the possibility of adequate identification.

These examples show that the specialist must consider all of the questions discussed here while shaping the best way to sample herpetofauna in an environmental study, always considering the complementary nature of methods to optimize the sampling. The contractor and environmental agencies should be conscious of this and open a dialogue to discuss the issue during the planning of the project.

Identification and Complementation

Different from other zoological groups, the majority of reptiles and amphibians cannot be securely identified only by means of field recording. Thus, it is essential to first compare representative samples of local morphological variation with data from the literature, and then reinforce the identification by consulting material from zoological collections. This will ensure precise conclusions.

Because of this, the consultant should count on access to the archives of the most representative Brazilian herpetofauna, as well as archives in regional collections. An inventory of herpetofauna based only on field observations can be subject to errors that cannot be corrected in the future.

The importance of consulting zoological collections goes beyond supporting the identification of species from the inventory cross-sections. In general, collections can contain species from the same sampled area or from nearby areas that have not been recorded in the survey. They serve as a means of complementing the list of species.

Legally, the material originating from the surveys should be deposited in the collections of an institution agreed upon by the contractor and consultant. Issue of the collector license relies in part on a manifestation from the curator of the collection chosen for the deposit, declaring that his institution has the conditions to receive and incorporate into the collection the biological material from the survey in question. In this way the material collected will be also available to the scientific community, and consultants and scientific institutions can go on to act as partners, conscious of the relevant roles they are performing.

Raw data from a faunal survey in large part is concentrated on the list of recorded species. Because of this, refinement of identifications provides quality diagnosis in environmental impact studies. This reliable information should be evident not only in the simple list of species, but also in the content of the report which comments on the recordings.

The complexity of the identification process therefore depends on the biological group in question, and it is common to find identifications limited to the level of taxa on many lists (for example, *Bothrops* sp.). These imprecise identifications should be analyzed with caution in the reports. Many times decisive identification is not possible, not for lack of technical criteria, but because of dealing with species whose taxonomy is confused and controversial. In these cases, the consultant should justify the imprecision and discuss its relevance to the environmental problem it touches upon. If, however, groups of relatively well resolved taxonomy are only identified at the genus level without further consideration of them, there is a lack of taxonomic rigor, which testifies against the quality of work.

Finally, it is important to emphasize that judicious identification is a slow process. A common lament among herpetofauna consultants resides in the fact that, soon after returning from field activities, the time for identifying the material and presenting the final report to the contractor is extremely short. The consultant, who understands the nuances of these proceedings, is compelled to project and expose to the contractor the process and time necessary for the work of identification. In light of this fact, the importance of adequate planning for an environmental impact study cannot be understated. If the planning takes into account the urgency of the entrepreneur, it should also clearly ponder the consultant's work conditions, thus avoiding the sacrifice of quality.

Necessity of the Collection

Collection of animals for scientific purposes is a debatable subject which divides public opinion, the scientific community, and environmental agencies. For the general public, it is not easy to justify that knowledge of diversity depends on the collection of animals, which are removed from their habitats, sacrificed and preserved for study. In the same way, the subject is also discussed with difficulty among the scientific community and environmental authorities. There seems to be a consensus that some adjustments in legislation are essential in order to allow the researcher greater autonomy in his work.

It is necessary to keep in mind that no researcher sacrifices specimens for whim or personal interest. When the objective is scientific knowledge and conservation, planned collection fully justifies itself. The process of soliciting pertinent licenses for the environmental agencies should be done by the contracting company with technical support of the consultant. One question no less polemical refers to the number of specimens that a cross-section should contain. There is no mathematical formula allowing for the definition of a standardized cross-section representative of general morphological variation, thus permitting precise identifications. In general, for reptiles and amphibians, cross-section size is defined in an arbitrary manner and by location. The ideal cross-section should be established case by case, and guided by the good sense of the specialist. So that abuses are avoided, it is necessary that there be open dialogue, free of preconceptions, between the consultant and environmental authorities during the process of soliciting licenses for undertakings.

3 Fish and Environmental Impact Evaluations: a Perspective on the Aquatic Environment

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e Patrícia Teresa Monteiro Cunningham

Diversity, Importance and Legislation

Fish are the most diverse group of vertebrate animals on the planet, presently counting around 28 thousand species, which is the approximate equivalent of the total quantity of amphibians, reptiles, birds and mammals. In other words, fish represent half of all vertebrates. While terrestrial fauna evolved, originating such heterogeneous groups as amphibians, reptiles, birds and mammals, the same diversification occurred in the lineage of fish in the many niches of the aquatic environment conquered by these animals. Thus, fish occupy a broad scale of environments; ranging from rivers and tropical lakes, to polar region cryogenic communities in deep marine abysses, to high altitude lakes at the top of mountain ridges. They exist in the depth of the oceans and the most restricted spaces in temporary puddles, caves, and water tables. The great diversification that occurred among fishes is reflected in the breadth of forms, colors and sizes that these animals present, including the most varied habits of feeding and reproductive strategies.

Many species have been exploited as a resource since the origins of mankind, whether as a source of food (for example, fishing and fish farming), sports and leisure (for example, sport fishing, aquaria, ornamentation), and biological control of insects. That is, besides many species having medical importance that represent potential sources of medications, as well as threats to human health (for example, bites, shock, poisoning). Thus, fish have as much intrinsic value in relation to the great diversity of the group, as well as economic value for human beings. Fish directly reflect the quality of the water, an essential resource for life, the scarcity of which is a preoccupation in various parts of the planet. They are directly affected by physical and chemical conditions of bodies of water where they occur, and by being restricted to the aquatic environment do not have a great capacity of escaping from the negative impacts generated in their environment, generally suffering great slaughters and local extinctions derived from human activities.

Brazil best exemplifies the planet's fish diversity, with approximately 300 marine species and 2,600 fresh water species (see Buckup et al., 2007), representing more than 10% of known species, which puts the country among the most diverse in the world in terms of ichthyofauna. This great diversity of fishes is derived from the fact that the national territory includes the greater part of the Amazon Basin, a major water basin of the planet which harbors the richest fauna of freshwater fishes known. Aside from this, Brazil boasts an important portion of the second largest basin of the South American continent, the Rio da

Plata Basin, and all of the third largest neo-tropical drainage, the São Francisco River. Brazilian fresh water environments also include an intricate fluvial network composed of large scale rivers, small streams, flooded regions and subterranean environments, generally associated with a regime of inundations. In relation to sea water, Brazil has more than eight thousand kilometers of coast that extend over a latitudinal range of approximately 38 degrees, including tropical, subtropical and hot-temperate regions of the Southern Hemisphere, especially including sandy beaches, estuaries, rocky coasts and reefs.

According to Diegues (2002), there is no specific legislation concerning the conservation of humid areas of Brazil, and the exiting laws that regulate the use of aquatic environments are dispersed among others that regulate the use of specific areas of the country. The Brazilian Constitution of 1988 declared the principal Brazilian biomes as National Patrimony (that is, Amazon Forest, Atlantic Rainforest, Serra do Mar, Pantanal, and Coastal Zone) and established as Union goods the lakes, rivers and other bodies of water in lands of its dominion, natural subterranean cavities, fluvial islands, lakes, coastal and ocean lands, beaches, the natural resources of the continental platform and the Exclusive Economic Zone and all of its territorial sea (ibid). There are even some laws or decrees that protect specific aspects related to aquatic environments, including: the permanent protection of all riparian forests (Forest Code from 1934 and 1965); the decree for control of continental and marine water contamination (1961); the decree-law that created the Superintendency of Fish Development (Sudepe, 1962); and the Waters Law (1997). On January 23, 1986 a resolution of the National Council of the Environment (CONAMA) established the necessity for Reports of Environmental Impact (RIMA) for projects involving exploitation or interference with water resources, such as the construction of dams, canal openings (navigation, draining or irrigation), straightening of waterways, opening of barriers and debouchments, transposition of basins and dikes, and the extraction of fossil fuel and industrial or agro-industrial undertakings (ibid). There are also specific laws for the defense of some species during their reproductive periods, for fresh water as well for marine fishes.

Principal Impact

The synergy between the great diversity of Brazilian ichthyofauna and the exacerbated fragility of the aquatic environments in which they occur make fish a group of special concern in the case of undertakings that affect the different Brazilian aquatic ecosystems. In Brazil, factors that merit highlighting as the principal human actions generating impact on fish are: (i) the construction of barriers for establishing reservoirs and hydroelectric energy station generators; (ii) implementation of allotments and real estate speculation, or agriculture and cattle-raising near watercourses; (iii) the construction of bridges, rectification and channeling of rivers, and undertakings that affect the flow of a body of water;

(iv) installation of aquiculture and fishing stations, besides sport and commercial fishing; (v) activities exploiting mineral resources associated with bodies of water such as petroleum and mineral prospecting; (vi) and industrial activities that affect bodies of water (ibid).

The impacts derived from these undertakings include: changes in the local water dynamic (for example, change of lotic systems for lentic ones, modification of coastal features); loss of riparian forest, salt marshes and mangroves; silting of riverbeds and bays; aside from the various forms of physical, chemical and biological pollution that generate imbalances like eutrophication, intoxication and bioinvasion (Courtenay Junior, 1993; Comase, 1995; Esteves, 1998; Barrella & Petrere Junior, 2003). In addition, it is necessary to keep in mind that bodies of water generally interconnect and transport material for long distances, obeying the *continuum* concept of the river proposed for some fresh water environments (Vannote et al., 1980; Menezes et al., 2007). In this manner, impacts generated at a specific point of a body of water probably affect regions far from the origin of impact.

Fishes as Environmental Indicators

On the basis of what has been presented here, fish should always be included in evaluations of impacts in cases of undertakings that can interfere with bodies of water, whether fresh water or marine. Some important questions should be discussed concerning environmental studies involving the surveying or monitoring of ichthyofauna. The still incomplete taxonomic knowledge of Brazilian fishes, coupled with the great diversity of ichthyofauna in the country, especially those of diminutive size, make identification of species while still in the field a very difficult task. Thus, the collection of cross-sections, and further sorting and identification in the laboratory are essential practices for an adequate ichthyofaunal survey. As a consequence, the study of fishes constitutes a time-demanding task in the laboratory, aside from the effort employed in the field to properly sample them. Unfortunately, this time is not always available for the ichthyofauna consultant, whose work is limited to the sampling effort, or restricted to a theoretical survey of fishes in a specific region based on secondary data, which is not always sufficiently precise.

Another important issue is the lack of comparable methodologies in ichthyofauna studies. The use of a single sampling method is impossible to be applied in all cases, since the bodies of water are quite heterogeneous. Therefore, more comprehensive methodologies should be found in order to guarantee that all the aquatic micro-habitats are adequately cross-sectioned. Thus, an approach with different fishing gear is encouraged, and the production of the collector's curves proves to be a sufficiently useful tool for defining whether the collection efforts in a specific area were sufficient (Mattox & Iglesias, in press). The great diversity of fishes includes species with very distinct circadian patterns, and there are many examples of typically daytime fish that are replaced by fish with nocturnal habits, besides intermediary examples of twilight fish. Assemblies of fish also vary seasonally, in a distinctive way in each region. Thus circadian variation as well as seasonal variation should be considered in environmental studies involving ichthyofauna. The samplings should be planned so as to encompass distinct periods of the day and seasons of the year.

Fishes constitute biological models that provide boundaries for robust population studies. This is especially true due to the abundance of some species, and the application of statistical descriptors of the populations provides additional tools that function as indicators of the quality of the ecosystem. Many times the diversity of ichthyofauna in an area has been depleted, but monitoring of the populations of one or more dominant species can furnish important aid in decision-making.

Lack of available exact data about Brazilian ichthyofauna constitutes an additional problem in studies of environmental impacts on fish. Some recent works dealing with ichthyofauna provide discussions on: specific regions as a whole (Pantanal [Britski et al., 1999, 2007]; the Atlantic Rainforest [Menezes et al., 2007]; the Exclusive Economic Zone of the Southeast-South Region [Figueiredo et al., 2002; Bernardes et al., 2005]), large basins (São Francisco River) [Britski et al., 1984; Sato & Godinho, 1999]; the Upper Paraná River [Agostinho & Júlio Jr., 1999; Graça & Pavanelli, 2007]; the Amazon Basin [Santos & Ferreira, 1999]; and the Ribeira River [Oyakawa et al., 2006]). However, the lack of more exact inventories in the region of undertakings at a specific locale where there may have been some environmental accident makes it difficult for diagnoses concerning the species of fishes that were in fact in that area. Yet, there are presently various free access on-line periodicals that publish inventories of fauna and flora, which constitute a potentially more specific depository of data regarding the ichthyofauna of a particular region. The publication of these inventories comprises an important means of recording and publicizing information about biodiversity generated in the many environmental studies produced recently.

Besides the lack of available comparative data in literature, environmental studies rarely promote integration of data between various consultants involved in the evaluation, which only serves to diminish that study's own quality. This negative point would be easily bypassed in the event that the consultant companies responsible for the study would promote greater interaction between professionals involved in the project, and generate exchange of information to better understand the problem as a whole. There are exceptions to this generalization, but our experience shows that in cases where interaction is stimulated the final result of the environmental study is much more concrete and pays better dividends in terms of decisions- making.

Environmental studies generally propose compensatory actions for the impacts generated by the undertaking. However, little is known in practical terms of the mitigating measures or management plans applied to fish. Implementation of stairs for fish, for example, has still not had assured success for all groups of fishes, and more studies are necessary to determine if this and other mitigating measures are effective in environmental compensation (see the issue dedicated to fish passage in the periodical *Neotropical Ichthyology*, v.5, n.2, 2007).

There is even an ecotoxicological approach, in a form quite distinct from determining quality of water by intermediation of fish. Examination of certain regions occupied by particular bodies of fishes can tell much about their environment, including the presence of toxic elements or unfavorable conditions. Many pollutants derived from the petrochemical industry, as well as chlorochemicals, cause severe lesions to the gills of fish which can be verified in more specific pathology exams (Al-Kindi et al., 2000). Accumulation of a series of toxic substances derived from agriculture and cattle-raising is accessed especially in studies of the liver by searching for traces of the pollutant in question. In turn, the work of ecotoxicology for accessing environmental quality is restricted to cases involving undertakings that generate specific types of pollution. It depends on a highly detailed and expensive clinical analysis that is not always available in evaluations of environmental impact.

Environments of Special Importance

It is evident that all aquatic environments and their biota should be preserved and, consequently, taken into consideration in environmental studies. However, some environments can have unique characteristics or shelter a peculiar ichthyofauna, thereby deserving special importance in the conservationist debate. Many of them are in truth reminiscent of a more widespread and diverse fauna that was totally suppressed by urban Brazilian growth.

Subterranean environments (that is, caves and water tables) frequently shelter unique fish fauna and represent highly fragile environments. Being located in areas suited to mineral exploitation, these environments are generally threatened. Many cave fishes show spectacular adaptations to underground and aphotic environments, such as loss of pigmentation and reduced eyes, among other elements. Mattox et al. (2008) lists 24 species of troglobitic fish (that is, without adaptations to the subterranean environment in relation to eyes and pigmentation) in Brazil, besides 13 species of troglophilic fish (that is, with adaptations evidently for subterranean life, and with populations established in the subterranean environment). The majority of these species are endemic to the caves in which they occur, and imbalance in one of them can mean the extinction of the respective ichthyofauna.

Temporary puddles, (often only some square meters, or constituting a small ditch) are depressions in the terrain that accumulate water in the rainy season and harbor species of annual fishes often endemic to each one. These fish grow rapidly and reproduce by depositing eggs in the peat at the bottom of the puddle. At the end of the rainy season the puddle dries completely and the eggs stay dormant in the turbary until the next rainy season, when they hatch and restart the cycle (Costa, 2002). The extreme fragility of this system causes many of the annual fish species to be on lists of endangered animals. There are temporary puddles and annual fishes in all of the largest Brazilian biomes, but some of them are of special importance owing to their diversity of species, such as Campos do Sul, the Atlantic Rainforest, Caatinga, the Cerrado and the Pantanal (ibid). The study of annual fishes also depends on the annual water cycle and their sampling only occurs in times of floods when the individuals are grown. In dry periods, the puddle is not easily noticeable and the eggs are buried in the substratum. It is in this period that they suffer most intensely from embankments or other consequences of undertakings which disturb land that can seem merely to be common terrain. It is obvious, therefore, that the samples should be coherent with the regional standard of rains in the locale where the undertaking occurs.

It is generally known that the Atlantic Rainforest represents one of the most threatened Brazilian biomes, especially due to the disorderly growth of human populations throughout its extension, which are responsible for the suppression of a great part of its original vegetative cover. In hydric terms, the Atlantic Rainforest includes a series of small and medium size basins that drain the coastal region of the continent and empty independently into the Atlantic Ocean. Some of the broader rivers of the Atlantic Rainforest are the Jequitinhonha, Doce, Paraíba do Sul, Ribeira de Iguape, and Jacuí rivers. The majority of other drainages result from streams of smaller dimensions with origins in the coastal mountains. One of the most marked characteristics concerning fish fauna of the Atlantic Rainforest is their higher degree of endemism. This endemism, associated with the rapid disappearance of the Atlantic Rainforest, is a critical factor in the conservation of Brazil's diversity of fish.

Urban centers are locales of greatest human concentration and, consequently, present serious cases of environmental impact. This is especially true in the case of the major Brazilian metropolises, many of them situated along what was originally the Atlantic Rainforest. Many of our capitals have restricted green areas, concentrated in small urban parks or remainders of native vegetation, which are suffocated by the concrete landscape of the rest of the city. An extreme example of this is São Paulo, one of the most populous cities of the world, whose natural aquatic environment is in a critical state in terms of its quality. Even so, a study of fishes in the São Paulo municipality reveals that the large green areas surrounding the city (Serra da Cantareira, Ecological Park of Tietê and the Billings and Guarapiranga Reservoirs) still harbor significant fish fauna, including species endemic to the Upper Tietê River and three endangered species (Mattox, 2008). These urban remnants of the native forest should be approached with special attention owing to their critical location and fragility.

In terms of marine ecosystems, all of the coast should receive intensified attention, since the greater part of urbanization in Brazil is along the coast, and the major part of marine diversity is located in the coastal zone (Rosa & Lima, 2008). Therefore, the different marine ecosystems such as estuaries, rocky coasts and beaches are under the immediate influence of anthropogenic impact derived from urbanization and industrialization. The port region of Santos, for example, shelters an extensive area of mangrove, but it is under heavy influence of the many chemical industries in the region of Cubatão and receives domestic effluents from Santos, one of the oldest cities of Brazil. Even so, the region still has some bodies of water that are considered well-preserved, which harbor relatively diverse ichthyofauna (Mattox & Iglesias, in press).

Endangered Fishes

The list of fishes threatened with extinction (Rosa & Lima, 2008) includes seven species of endangered osseous marine fish, and 24 others considered over-exploited or threatened by over-exploitation. The marine species threatened with extinction are all reef dwellers, and the causes of their decline are connected to degradation of the environment, over-fishing and the quest of aquaria fish. In relation to fresh water fishes, Rosa & Lima (2008) consider 135 species as endangered and another eight as over-exploited or threatened by over-exploitation, with 16 species from the Amazon Basin, 18 from the São Francisco River, 59 in basins of the East (associated with the Atlantic Rainforest), 29 from the Rio Paraná basin (especially in the region of the Iguaçu River and the Upper Tietê River), 9 from the Uruguay River, 11 from coastal drainage from the South of Brazil, and one from the Paraguay River basin. The great diversity of fish threatened with extinction is concentrated in annual fish, whose fragility of habitat represents a critical factor in their conservation (Costa, 2002; Rosa & Lima, 2008).

In spite of this text being focused on fishes from the class *Actinopterygii* (osseous fish with veined fins), the lineage of cartilaginous fishes (*Chondrichthyes*), with approximately a thousand species, holds special importance with respect to their conservation, since it includes sharks and rays, which are long-lived and slow growing, have late sexual maturity and low fertility. These are characteristics that aggravate the maintenance of these species. Brazilian ichthyofauna includes12 species of endangered cartilaginous marine fishes (Rosa & Lima, 2008), and in fresh water Brazil shelters an exclusive family of fresh water rays (*Potamotrygonidae*), endemic to the neo-tropical region. These fishes also should be taken into consideration in ichthyofaunistic studies, since they are subject to the same impacts as osseous fish.

In conclusion, the enormous diversity of Brazil's ichthyofauna and the accelerated rhythm in which undertakings that affect bodies of water are licensed and implement stress underlines the importance of discussions about environmental studies involving these organisms. There is a growing demand for standardization in environmental evaluations, including this major group of animals. Environmental studies involving fishes should be planned in such a way that approaches the greatest number of aquatic environments (distinct from sport fishing usage), along with considering circadian and seasonal cycles. The collection of samples to be placed in icthyiologic collections is suggested to promote greater taxonomic precision in these studies, beyond making available data in the form of published inventories. Brazil is among the countries with the most diverse ichthyofauna in the world, including many of commercial interest. A considerable quantity of them is threatened with extinction. It is necessary that this diversity be considered in all undertakings that generate influence, directly or indirectly, on the aquatic environments.

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ABSTRACT – Inventories of fauna directly access the diversity of a locality in a certain period of time. The primary data generated by these inventories comprise one of the most important steps in decision-making regarding the management of natural areas. However, several problems have been observed at different levels related to inventories of fauna in Brazil, that range from the training of human resources to lack of standardization of experimental design and selection of inappropriate methods. We present case studies of mammals, reptiles, amphibians and fishes, which discuss issues such as temporal variability and methods for detection of terrestrial fauna, suggesting that both inventories and monitoring programs should be extended for longer terms and that inventories should include different methodologies to ensure that their goals are fully achieved.

KEYWORDS: Biodiversity, Fauna, Sampling methods, Legislation.

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