

Comparative biochemistry and physiology in Brazil: A critical appraisal [☆]

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Abstract

Brazil stood out as the country with the highest number of submissions to the editorial project dedicated to Latin America by the journal *Comparative Biochemistry and Physiology*. Therefore, we felt that it was important to critically discuss the state of comparative biochemistry and physiology in this country. Our study is based on data collected from the ISI Web-of-Science. We analyzed publication trends through time, availability of novel approaches and techniques, patterns of collaboration among different geographical regions, patterns of collaboration with researchers abroad, and relative efforts dedicated to the study of biochemical and physiological adaptation of native fauna representing different terrestrial Brazilian biomes. Overall, our data shows that comparative biochemistry and physiology is a lively and productive discipline, but that some biases limit the scope of the field in Brazil. Some important limitations are the very heterogeneous distribution of research nuclei throughout the country and the absence of some important approaches, such as remote sensing and the use of molecular biology techniques in a comparative or evolutionary context. We also noticed that international collaboration far surpasses interregional collaboration, and discuss the possible causes and consequences of this situation. Finally, we found that Brazilian comparative biochemistry and physiology is biome-biased, as the Amazonian fauna has received far more attention than the whole pool of fauna representing other terrestrial biomes. We discuss the possible causes of these biases, and propose some directions that may contribute to invigorate the field in the country.

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1. Introduction

The editorial project dedicated to Latin America by the journal *Comparative Biochemistry and Physiology* aimed to expose the standing and trends of the field, enhance academic interactions among scientists, and highlight the questions and animal models used by researchers in that part of the world (Hermes-Lima and Navas, 2006; Zenteno-Savín et al., in press).

The response of the Latin American community to this initiative was overwhelming, but Brazil produced just over one half of the submissions (74 out of 140). Given the leading role evidenced by Brazil in this editorial project, we decided to present our critical view of the status of comparative biochemistry and physiology in this country. Our study focuses on the relative participation of Brazil on publication trends through time, the reference to novel approaches and techniques in papers with Brazilian authors, the patterns of collaboration among Brazilian regions and among Brazilian researchers and researchers abroad, and on the relative efforts to study biochemical and physiological adaptation in fauna from different Brazilian terrestrial biomes.

2. Brief historical perspective

Traditionally, the field of comparative biochemistry and physiology has focused on empirical questions about how

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animals survive in different environments, and how physiology supports the remarkable behavioral and ecological diversity observed in nature. Historically, however, comparative biochemistry and physiology emerged using research model animals to offer support and continuity to biomedical questions, choosing research species according to August Krogh's principle, in which an ideal animal research model exists for each physiological problem (Krogh, 1929; Krebs, 1975). Under the influence of this premise, environments, particularly those more challenging, became natural laboratories in which given taxa would exhibit exaggerated characteristics of interest, hence facilitating the study of physiological mechanisms. The generality of the findings, or their application to less exaggerated systems, particularly humans, could be investigated later. Classical examples of such an approach include jumping muscles in frogs (Hoyle, 1969), the giant axon of squid (Hodgkin and Huxley, 1952) and the kidney of desert rodents (Schmidt-Nielsen, 1983). Krogh's principle contributed to establish a clear conceptual link between physiological and biological diversity and led to the accumulation of an enormous physiological database that is essential to our current understanding of physiological processes (e.g. Mommsen, 2004).

Although a classical frame of reference to comparative biochemistry and physiology is still valid, other approaches have been incorporated into the field. Briefly, an important shift occurred between the 60s and 80s, when Krogh's ceased to be the chief principle in the field, partially because some influential researchers proposed a stronger ecological context to physiological research, and a greater emphasis on organismal performance (for example see Huey and Hoffmann, 2005 for an overview of G. Bartholomew's input to the field of comparative biochemistry and physiology). The rationale to this proposal was that environmental challenges are faced by whole organisms and not by their parts. A later approach, evolutionary physiology, complemented previous trends in comparative biochemistry and physiology by asking what are the evolutionary mechanisms involved in the emergence and maintenance of physiological traits? The evolutionary approach to comparative biochemistry and physiology shed new lights on the concept of physiological adaptation and postulated interesting alternative principles, for example the "Unity in Diversity" concept (Hochachka, 1988; Somero, 2000), meaning that the striking physiological diversity observable in the animal world has evolved within the context of the same basic underlying biochemical possibilities. This approach to the study of physiology has been extremely active in the last decade, as is evident by the large number of conceptual papers on evolution and physiology that have been published recently (Bartholomew, 2005; Bennett and Lenski, 1999; Chown, 2001; Feder et al., 2000; Garland and Adolph, 1991; Garland and Carter, 1994; Levchenko, 1990; Natchin and Chernigovskaya, 1997; Svidersky, 2000), including important contributions by the late P. W. Hochachka (Hochachka, 1988, 1997, 2000; Mangum and Hochachka, 1998).

Comparative biochemistry and physiology exhibits a well-deserved status as one of the most integrative biological disciplines, which nonetheless has its own questions, paradigms, concepts and techniques. The field has established close

bonds with other disciplines such as animal behavior, ecology and evolution, while benefiting from modern advances in mechanistic physiology, molecular physiology and theoretical biology. Reciprocally, comparative biochemistry and physiology produces new insights regarding the process of adaptation, offers new research system-models to science, solves current problems of practical nature, and plays a primary role in developing new tools for analysis of biological data (for example in the context of phylogenetic comparative methods). Additionally, comparative biochemistry and physiology is now envisioned as a discipline with the potential to solve practical issues such as the consequences of climate change on the patterns of distribution of animal species (Huey and Kingsolver, 1998; Root et al., 2003), pest control and public health (Gade and Goldsworthy, 2003) or the limits to animal distribution (Navas, 2002). Furthermore, our comprehension of medical problems such as the evolutionary origin and current role of fever (Kluger et al., 1998; Kluger et al., 1975), the adjustment of pharmacological doses to body size (Paxton, 1995; Zhou et al., 2002), or the limits of athletic performance (Taylor et al., 1987; Van Damme et al., 2002) have received important contributions from comparative biochemistry and physiology.

3. The Brazilian scenario

Comparative biochemistry and physiology research in Brazil started in the 30s, a few years after August Krogh was awarded the Nobel Prize for Medicine (1922). This area of research was consolidated by the foundation of the Department of Animal Physiology, by Paulo Sawaya and his disciples, among them Erasmo Garcia Mendes, at the former Faculty of Philosophy and Sciences of the University of São Paulo. This Department soon became an international reference, and over the decades following its foundation became a leading institution promoting research in comparative biochemistry and physiology and stimulating the establishment of other research centers throughout the country. A recent landmark was the symposium "New Directions in Comparative Physiology", held in São Sebastião, São Paulo, in 1989, which boosted collaboration among local researchers, and between Brazilian researchers and counterparts abroad. After this symposium, several workshops and congresses on comparative physiology and biochemistry took place in the following years and nurtured a sequence of additional successful collaborations. In the near future, Brazil will host the VII International Congress on Comparative Physiology and Biochemistry (ICCPB) that will take place in Salvador, Bahia, Brazil, in August 2007. The theme of the congress is "Integrative Physiology meets Biodiversity," emphasizing the importance of Comparative Biochemistry and Physiology within the realms of a large scale problem which encompasses the consequences of economical growth and global warming on the preservation of the earth's biodiversity.

Presently, some of the most representative Brazilian nuclei for research in comparative biochemistry and physiology focus on a diverse range of topics and approaches. We opted not to review the subjects represented in the country, as such a list is not essential to our discussion and probably would not be fair to

Table 1
Number of papers published during the three last decades in Comparative Biochemistry and Physiology A, CBP; Journal of Experimental Biology, JEB; Journal of Comparative Physiology, JCP; and Physiological and Biochemical Zoology, PBZ

	CBP			JEB			JCP			PBZ			GP		
	Total	BR	%	Total	BR	%	Total	BR	%	Total	BR	%	Total	BR	%
1975–1984	7831	152	1.9	1381	3	0.2	479	3	0.6	2364	6	0.3	13,066	25	0.2
1985–1994	9951	244	2.5	2306	7	0.3	748	7	0.9	2484	12	0.5	27,541	72	0.3
1995–2004	5806	211	3.6	3782	46	1.2	814	16	2.0	1972	27	1.4	33,869	235	0.7

“Total” is the total number of papers registered in the Science Citation Index for the period. BR and % are the number of Brazilian papers followed by its percentual value. For comparison purposes, the last column, GP, accounts for General Physiology, and encompasses data from more biomedical or applied journals (combined values for American Journal of Physiology, Journal of Applied Physiology and European Journal of Applied Physiology).

many small groups. We can say, however, that important nuclei are found at National Institute for Amazonian Research (INPA, at Manaus, Amazonas state), the State of São Paulo University (UNESP, campuses at Rio Claro, Botucatu and Jaboticabal, São Paulo state), the University of São Paulo (USP, campuses at Ribeirão Preto and São Paulo, São Paulo state), the Federal University of São Carlos (UFSCar, São Paulo state), the Federal Universidade of Rio Grande do Sul (UFRGS, at Porto Alegre, Rio Grande do Sul state), and the University of Brasília (UnB, in the Federal District). To this list, one should add the efforts of other scientists around the country, for example in Curitiba, Londrina, Recife, Rio Grande, Salvador and other cities, and some researchers who focus on comparative problems but work on biomedical research centers.

3.1. Brazilian comparative biochemistry and physiology in numbers

The current contribution of Brazil to the international field of comparative biochemistry and physiology may be illustrated with numbers. We searched publication records in the Web of Science, ISI, using different search codes and time periods as described later in different sections of this paper. Our option to locate papers with Brazilian authors was to search for the words Brazil or Brasil in the address field. This excludes papers from Brazilian authors in foreign institutions, but adds only a minor error to major trends and papers in which Brazilians participate from local institutions are anyhow more relevant to our objectives. The main patterns of the data are 1) about one out every 500 scientific papers produced in Brazil relate to topics in comparative biochemistry and physiology, 2) the number of Brazilian papers published in the area has duplicated over the last two decades, and that 3) the relative growth of the discipline in Brazil has been significant, even if compared with biomedical or applied physiology. Some of these patterns are well illustrated by numbers in Table 1. Although this is a promising scenario, less exciting insights come from a more elaborated analysis using as an example the publication records for Comparative Biochemistry and Physiology-A. From the journals used to build the first four columns in Table 1, CBP-A features the highest total number of Brazilian contributions. In the 1980's, 1.9% of the total number of papers published in this journal had the participation of Brazilian institutions, and the number increased to 4% in the 1990's. However, it has remained rather constant since (Fig. 1) despite the growing

contribution of Brazilian science to many other biological disciplines. Overall, these values are consistent with a broader trend in which Brazil is responsible for about 1.5% of the world share of publications in science and engineering (data for 2000, see Science Watch, 2001).

Both classical and ground-breaking approaches and technologies lead modern comparative biochemistry and physiology, so asking whether Brazilian research follows mainstream trends is important to diagnose the status of the field. Because this is a difficult question to answer, however, we must focus on specific examples. We chose to explore in detail the status of Brazilian comparative biochemistry and physiology regarding 1) discussion of broad conceptual issues regarding the goals, purposes and methods in comparative biochemistry and 2) the presence of two contemporary tools, ecophysiological data logging (see examples in Bennett et al., 2001; Block, 2005; Mitchell et al., 2002; Wilson et al., 2003) and molecular techniques (see examples in Feder, 1996; Gracey and Cossins, 2003; Pennisi, 2002; Powell, 2003; Wiseman and Singer, 2002). These tools have permeated current comparative biochemistry and physiology over the past 5 years. To offer a few among many possible examples, the American Physiological Society held in 2002 a meeting titled “The Power of Comparative Physiology: Evolution, Integration and Application”, highlighting symposia dedicated to the interaction between comparative biochemistry and physiology and molecular and evolutionary biology. In this meeting, Dr. B. Block emphasized the relevance

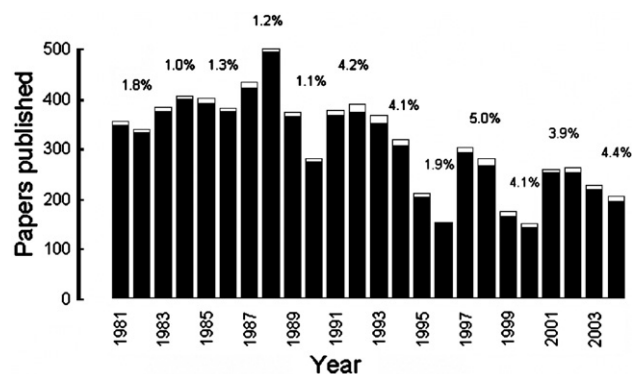


Fig. 1. Bar charts showing by year number of papers published in the journal Comparative Biochemistry and Physiology A. Black bars: worldwide production, white bars: papers in which Brazilian institutions are represented (source: Science Citation Index, August 2005). The numbers above the bars indicate relative participation of Brazil (even years only).

of automated data acquisition (The Fire Inside: Saving Atlantic Bluefin Tuna) as “the other revolution”, in an analogy with recent advances in genomics, and expanded her perspective in a recent paper (Block, 2005). The Society for Experimental Biology (SEB), on the other hand, held in 2003 the 5th International Workshop on Field Techniques for Environmental Physiology, featuring new developments in automated data acquisition in various physiological contexts, and the IUPS meeting in 2005 focused “on the vibrant new role that physiology is playing in relating the genome to complex functions of many life forms” (as stated in the official web page). Furthermore, the specialized journal *Comparative Biochemistry and Physiology* opened recently a new section on proteomics and genomics.

Fig. 2A is derived from the database that generated Table 1, and illustrates Brazilian contribution to debate directions and tendencies in comparative, ecological, and evolutionary biochemistry and physiology. Fig. 2B refers to the use of remote sensing techniques. These data show that Brazil has had some

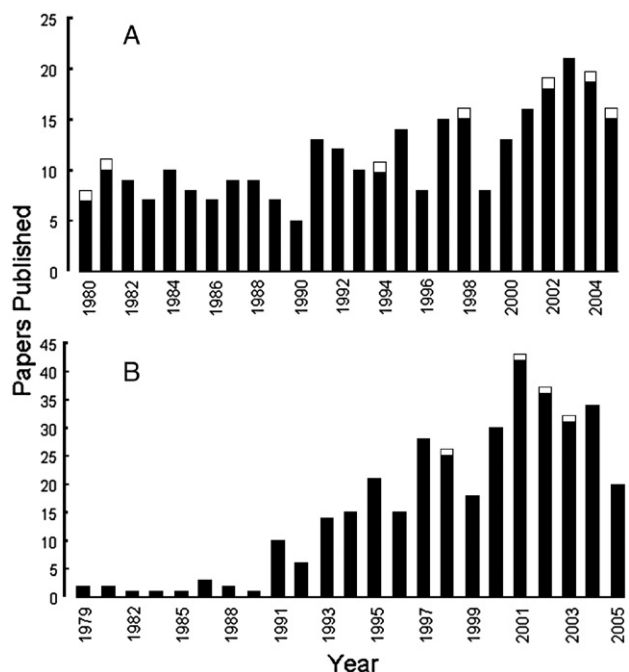


Fig. 2. Bar charts showing by year paper production according to a database constructed using the ISI Web-of-Science. The search was limited to four well-known journals that publish papers in comparative, ecological and evolutionary physiology, using the following code: source title: “Comparative Biochemistry and Physiology A OR Comparative Biochemistry and Physiology B OR Comparative Biochemistry and Physiology C OR Journal of Experimental Biology OR Physiological and Biochemical Zoology OR Physiological Zoology OR Journal of Comparative Physiology A OR Journal of Comparative Physiology B”. Publication year: “1996–2005”. Papers with Brazilian authors were found using “Brazil OR Brasil” in the address field. For further analysis, the database was then imported into Endnote 8.0 using a filter that recognized the correspondence author address. (A) shows number of papers discussing broad conceptual issues and directions in the above cited disciplines. These papers were found through a combination of discipline names applied to the title field. (B) shows papers reporting use of telemetric, remote sensing or biollogging techniques in the study of physiology (search expression extended to “data logg* OR telemetr* OR remote sensing”). Black bars: worldwide production, white bars: papers in which Brazilian institutions are represented.

sporadic contributions debating general subjects in comparative biochemistry and physiology that become more frequent after 1990, but do not parallel international trends towards a greater number of papers after that year. Regarding remote sensing, in the 1995 to 2004 database we found a total of 79 papers, with no paper with Brazilian authors. For the same period, the search code “molecular biology OR gene expression OR proteomics OR micro array OR microarray” produced 247 hits, only four of them (1.5%) with Brazilian authors. These results do not necessarily indicate that the field has become stagnated, indeed good Brazilian papers continue to be published in top comparative biochemistry and physiology journals. Rather, our data suggest that Brazil may be side-stepping some vigorous international tendencies, and would benefit from new nuclei prepared to apply such innovative techniques in comparative, ecological and integrative contexts.

3.2. Distribution and collaboration

The patterns of distribution and collaboration say much about the status of a scientific discipline in a country. A well-established discipline must exhibit 1) important nuclei across the country, 2) evident but not indispensable international collaboration, and 3) interaction among local research groups. In terms of distribution of the field over the country, Brazilian comparative biochemistry and physiology definitely does not pass the test. Although the field is somehow represented in most Brazilian states, few concentrate most of the scientific production (Fig. 3). Indeed, the State of São Paulo, that accounts for one third of Brazil’s gross domestic product and 22% of the population, produces far more than half the total Brazilian papers in the field of comparative biochemistry and physiology. The CBP-Latin Americas project also illustrates this tendency. The State of São Paulo contributed to about one fourth of the 140 studies submitted. São Paulo was also responsible for 47% of the 34 submitted papers focused on classic comparative physiology.

Fig. 4A and B points up to patterns of national and international collaboration respectively, and concentrate on Amazonas, São Paulo and Rio Grande do Sul, three states that stand out in terms of papers on comparative biochemistry and physiology. These two figures show that international collaboration prevails over local collaboration. At the local level, the State of São Paulo acts as the most important promoter of collaboration, with noteworthy contributions to other Brazilian states. Other than that, Brazilian nuclei of comparative biochemistry and physiology favor international collaboration over interstate collaboration, perhaps because the overall production of papers tends to be greater in developed countries than in Brazil. However, some nuclei may base their production mainly on international collaboration. We will come back to this issue in the next section.

3.3. Comparative physiology across Brazilian biomes

Because of its geography and diverse fauna, the Brazilian territory has long been a natural laboratory for the study of

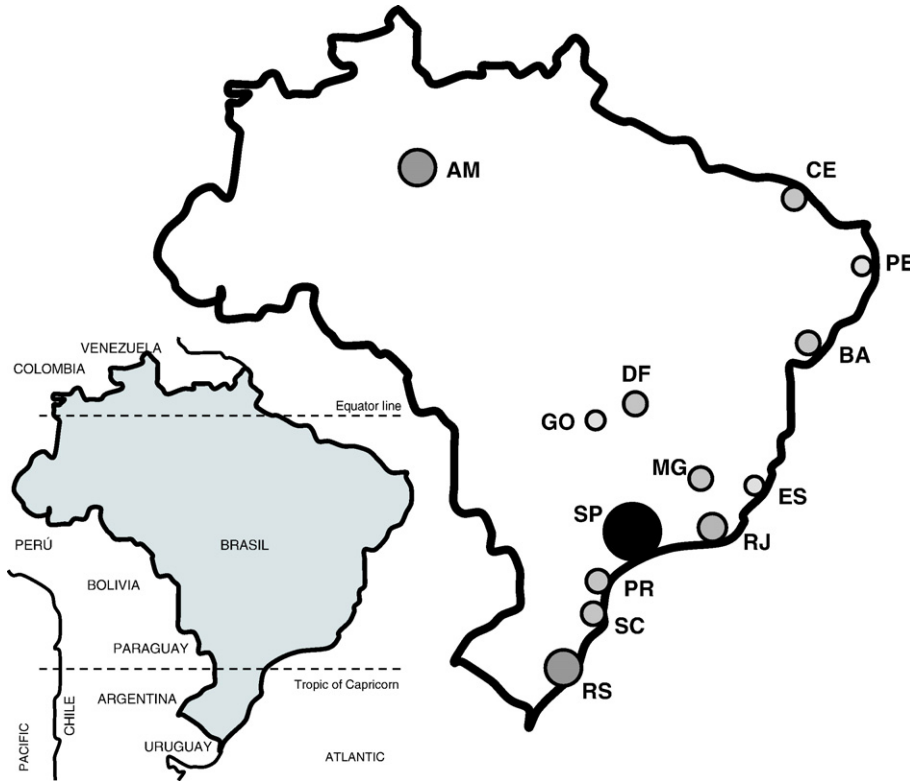


Fig. 3. Brazilian national production of scientific articles in comparative physiology over the last decade represented over a map of the country. The diameter and gray scale of the circles is proportional to the number of papers published. The State of São Paulo encompasses 65% of total production, so that circle diameter alone could not be used to code production in the figure; Amazonas and Rio Grande do Sul 11% each; and Rio de Janeiro 6%. All other circles exhibit values between 1 and 2%. The total number of papers is 202. State codes: AM, Amazonas; BA, Bahia; CE, Ceara; DF, Brasília; ES, Espírito Santo; GO, Goiás; MG, Minas Gerais; PE, Pernambuco; PR, Paraná; RJ, Rio de Janeiro; RS, Rio Grande do Sul; SC, Santa Catarina; SP, São Paulo. A wider view of the continent is shown in the inset.

animal adaptation. Studies of Brazilian fauna, however, may be influenced by two realities. First, the country is home to the largest part of the Amazon rainforest, one of the most familiar biomes in the world. Second, Brazil is considered a mega-diverse country, and this title is unambiguously linked to contrasting biomes that have favored the ecological radiations of different taxa. An analysis of the status of comparative biochemistry and physiology in Brazil requires asking how these two non-exclusive views, the Amazonian and the biome-rich, diverse country, have influenced to a greater extent biochemical and physiological studies with native fauna. Furthermore, we can verify to which extent the field of comparative biochemistry and physiology in Brazil reflects the biological diversity and the conservation status of the different terrestrial biomes that characterize the country. This question can be addressed by analyzing the publication records together with published data regarding biological diversity, number of threatened species and remaining biome area for some of the most important terrestrial biomes in the country.

Our results are clear-cut: regarding physiological adaptation, the fauna of the Amazon Rainforest has enjoyed far more attention than that of any other Brazilian terrestrial biome (Table 2). Furthermore, the number of studies on the comparative biochemistry and physiology of Amazonian fauna virtually match, for the period under analysis, those on the fauna of structurally analogous non-Brazilian biomes (i.e., other forested

biomes across the world, see Table 2). This bias may have complex causes. Research on the Amazon has been strengthened by the traditionally large number of programs at INPA, which is responsible for most of the publications in comparative biochemistry and physiology that are produced in the state of Amazonas. INPA is well known as a leading research center focused on the physiology of Amazonian fish, a subject that was highly stimulated in Brazil by the Alpha Helix expeditions to the Amazon. The first of these expeditions occurred in 1967 and was directed by Knut Schmidt-Nielsen. Later, the 1976 expedition was directed by Drs. David Randall and Peter Hochachka and produced 44 papers that were published in a special volume of the *Canadian Journal of Zoology* (Volume 56, number 4, April 1978) and still today influence directions for the field (Val, 2002). Another important consequence of these expeditions was to promote collaboration between Brazilian scientists and researchers abroad (Val, 2002). Indeed, and as noticed in Fig. 4, international collaboration greatly contributes to the comparative biochemistry and physiology research produced in the state of Amazonas. The observable emphasis on Amazonian fauna, then, has strong historical roots, and has been influenced by the many interesting questions regarding fish physiology and environmental challenge that were first explored in the days of the Alpha Helix expedition and are still timely (Val, 2002). Other factors may be important, however. It is also possible that researchers in developed countries have enhanced chances of obtaining

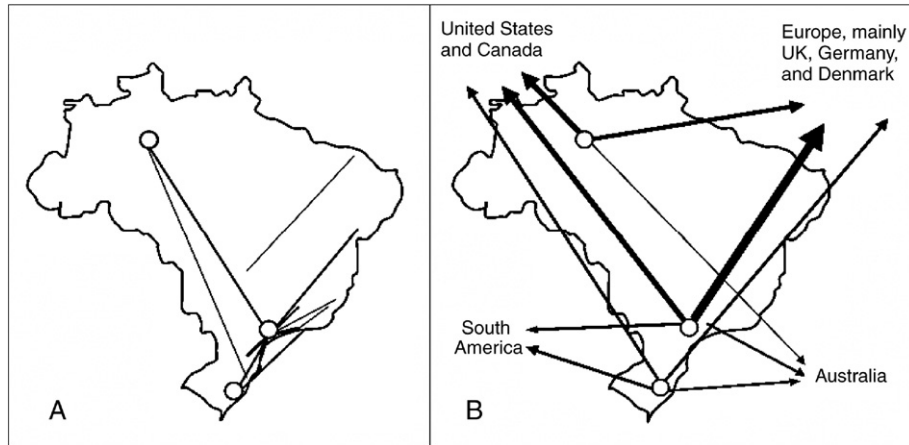


Fig. 4. Local interaction among Brazilian centers of comparative physiology and biochemistry (A) and international interaction (B) with Brazilian centers of comparative physiology and biochemistry. The width of the arrows indicates the strength of the cooperation (number of shared publications). The scale of line width is the same in both panels.

financial support when their projects involve Amazonian fauna. A detailed scrutiny of our database indicates that non-Brazilian researchers figure as correspondence authors in 38.2% of the papers related to comparative biochemistry and physiology of the Amazonian fauna, and that 9 out of 21 papers with Brazilian participation had non-Brazilians as correspondence authors.

Does the observed bias towards the study of Amazonian fauna reflect the ecological status of Brazilian biomes? We analyzed this question from the standpoints of biological diversity, number of vertebrate endemics and estimated remaining portion of the original biome. Obviously the Ama-

zonian rainforest is an important component of the striking animal diversity of Brazil, but is hardly isolated in this role (Table 2). On the other hand, the Amazonian rainforest does not rank first either in the fraction of deforested area or in number of threatened vertebrates. Other biomes, particularly the Atlantic Forest, exhibit comparatively much poorer status of conservation and consequently a much higher number of threatened species. We certainly support the growing national efforts to better understand physiological adaptation in the Amazonian fauna and consider that a strong international input on this research field is beneficial. Indeed, the Amazonian case may serve as an example to be followed, as weak research programs on other biomes are undesirable and limit contributions of physiological research to pure science and conservation programs. The non-Amazonian biomes discussed above are mostly represented in states with either limited comparative physiology nuclei or with dominant programs in mainstream biomedical physiology. The later is the case in Southeastern Brazil.

The bias reported in this section limits our understanding of how animals exploit the contrasting environments of Brazil as a mega-diverse country, and how they may react to habitat disturbance in time and space. Many important questions in comparative biochemistry and physiology of Brazilian fauna must not remain unasked. Key issues are how does the Caatinga (a large semiarid and unpredictable biome) wildlife respond to increasingly frequent extreme and unpredictable climatic events? How does the aquatic fauna of the Pantanal (the biggest wetlands in the world) deal with the dry season? Why do specific subsets of the original fauna survive in fragments of the Atlantic forest? How do the animals of the Cerrado (the savanna-type biome that is typical of Brazil) face frequent fires?

4. Conclusions

Our analysis shows that Brazilian comparative biochemistry and physiology is productive and lively, but that a number of biases prevent Brazil from playing a stronger role in the field.

Table 2
Publications on animal comparative biochemistry and physiology and standing of some Brazilian biomes*

Biome	TPBF (N)	TPBA (N)	BRA (%)	RTV (N)	ETV (%)	TTV (%)
Amazonian rainforest	34 (38)	21	84* ¹	2,381* ⁵	39.1* ⁵	4.7* ⁵
Atlantic forest	0 (38)	0	8* ²	1,807* ⁵	30.6* ⁵	8.5* ⁵
Cerrado	1 (16)	1	22* ²	1,362* ⁵	7.8* ⁵	6.0* ⁵
Caatinga	1 (11)	1	40–70* ³	825* ³	4.4* ^{5,6}	4.4* ⁵
Pantanal	0 (23)	0	<60* ⁴	805* ⁴	≈ 0* ⁴	6.5* ⁵

* TPBF is the total number of papers featuring physiology of native Brazilian fauna. The numbers in parenthesis indicate papers focusing on structurally analogous non-Brazilian biomes and are offered for comparison. TPBA indicates how many of the papers in TPBF feature Brazilian authors. BRA stands for biome remaining area and indicates the proportion of the original biome area that maintains typical biota and ecological processes. RTV is the richness of terrestrial vertebrates (the number of species of mammals, birds, reptiles and amphibians). ETV is the proportion of endemic terrestrial vertebrates (mammals, birds, reptiles and amphibians). TTV is the percent of threatened terrestrial vertebrates that are critically endangered, endangered or vulnerable according to the Brazilian red list of threatened animal species. The full database included all papers published between 1996 and 2005 in Comparative Biochemistry and Physiology, Journal of Experimental Biology, Physiological and Biochemical Zoology and Journal of Comparative Physiology. The codes to identify authors in the literature cited are (1) Fearnside, 2005; (2) Mittermeier et al., 2004 (3) Leal et al., 2005; (4) Harris et al., 2005; (5) Lewinsohn, 2006; (6) Rodrigues, 2003.

The first bias is geographical: research in the field is distributed across the country in an irregular and heterogeneous manner, so that few states conduct most of the research. The second bias deals with local insulation and restricted patterns of collaboration, as the country loses with the limited interactions among well-established centers in different states. The research nuclei established in the most productive state, São Paulo, collaborate mainly with authors in developed countries. Whereas this pattern strengthens Brazilian comparative biochemistry and physiology, international collaboration should not be either dominant or essential for the scientific production of research nuclei. The third bias is thematic, perhaps more technological than conceptual. Some important techniques and approaches that over the past years became important in mainstream comparative biochemistry and physiology are not yet well represented in Brazil. Perhaps Brazilian nuclei have been conservative in their research topics, a conjecture that would require additional analysis for confirmation. Independently of causes, however, this bias must be corrected, otherwise the field may progressively depart from mainstream research. Finally, comparative biochemistry and physiology on native fauna is biome-biased. Studies on animal environmental physiology focusing on Brazilian biomes other than the Amazonian forest are less than a handful, and attention to the fauna of understudied and increasingly endangered Brazilian biomes is urgent.

We think that some of the concerns stated in this paper could be ameliorated in the near future. Brazil enjoys a tradition in research focused on mechanistic and biomedical physiology, financial support is limited but available, some states count with highly competitive research foundations, and important nuclei focusing on comparative biochemistry and physiology already exist in a number of states. Additionally, we must emphasize that some of the technologies and equipment mentioned here, for example for studies in genomics and proteomics, are well represented in the country. A good start, therefore, would be to strengthen local collaboration. However, to promote the emergence of the field where it is underrepresented, it is necessary that well equipped and funded nuclei are able to produce well trained comparative Physiologists that are conceptually up-to-date and prepared to answer simple but relevant questions with basic equipment. Professional researchers with such a profile could take advantage of the amazing ecological and biological diversity, and the remarkable environmental gradients that characterize the country. Meeting these steps will grant the invigoration of Brazilian comparative biochemistry and physiology and lead to a deserved outstanding position on the international scene.

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