Are the functional diversity terms functional? The hindrances of functional diversity understanding in the Brazilian scientific community

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Abstract

Interest in functional diversity has grown in recent years, indicating that knowledge on ecosystem functions gain importance. However, the incongruent use of terms may lead to misunderstandings and incomparable results. We aimed to review terms used in functional diversity among the Brazilian scientific community to identify if there is a lack of consensus in the terminology used. We applied online surveys to assess how these terms have been used by the Brazilian academics and searched for their definitions in the scientific literature. The definition of "ecological function" by Brazilian academics is like that of the niche, but we only found two articles defining such a term in the literature. Thus, it seems that "ecosystem function" is a more commonly used term outside of Brazil. The definition of "guilds" coincided with that used in the literature, although we still observed a lack of consensus in the latter. For "traits," "functional group," and "functional diversity" concepts, we found some discrepancy between the literature and questionnaires. These inconsistencies can be related to the use of different organizational levels for the definition of traits and to the practice of replacing species with functional groups in standard taxonomic diversity metrics, considering them as measurements of functional diversity. The adoption of cohesive terminology is crucial to ensure the comparability of scientific results in the scientific literature. However, finding a consensus in ecology represents a hard task; therefore, we encourage that, at least, researchers make clear which key concepts they adopted in their research to avoid misunderstandings.

KEYWORDS

ecological function, functional ecology, functional group, guild, trait

INTRODUCTION

Biological diversity, or biodiversity, covers the diversity of genes, phenotypes, populations, species, communities, and ecosystems (Mouchet et al., 2010). Such a broad concept has raised problems in quantifying the role of diversity in ecosystems. Traditional diversity measurements (i.e., species richness or diversity indices) have little predictive power over community functioning, as species do not have equal functions in their ecosystems (Cianciaruso et al., 2009; Mouchet et al., 2010; Ricotta, 2005). Thus, functional diversity has been recognized by quantifying the value and range of traits that influence ecosystem functioning (McGill et al., 2006; Mouillot et al., 2013). A wide range of impacts on ecosystem functions stem from differences in the identity of the organisms and their functional traits (Cardinale et al., 2012; Oliver, Heard, et al., 2015; van der Plas, 2019), and metrics of functional diversity are generally stronger predictors of ecosystem functioning than taxonomic diversity (van der Plas, 2019). Such an approach is especially useful in megadiverse countries, which have several threatened ecosystems (Mittermeier et al., 2005), and where functional diversity can be a key mechanism in promoting the resilience of ecosystem functions (Oliver, Isaac, et al., 2015). This is the case for Brazil, one of the most biodiverse countries in the world.

Interest in functional diversity has been growing in recent years in many ecological disciplines and in studies with various taxonomic groups, indicating that knowledge on ecosystem functions has been gaining importance (Laureto et al., 2015; Petchey & Gaston, 2006). The widely adopted definition of functional diversity is "the range and value of those species and organismal traits that influence ecosystem functioning" (Tilman, 2001). Trait and functional trait approaches improve our understanding of community assembly, species coexistence, and biodiversity loss (Dawson et al., 2021). The most used definition of trait is "measurable property of organisms, usually measured at the individual level and used comparatively across species" (McGill et al., 2006). The term "ecological function," which can have some geographical differences, being similar to "ecosystem function," can become confusing, especially when functions of both species and ecosystems are considered (Akçakaya et al., 2020). Farnsworth et al. (2017) defined "ecological function" as "an act performed by a living system 'within the context of' an ecosystem." For "functional groups" the usual concept is "groups of organisms that play similar roles in ecosystem processes" (Levin et al., 2001), while guild is defined as a "group of species that exploit the same class of environmental resources in a similar way" (Moran & Southwood, 1982). All these terms are widely used in functional diversity studies, and understanding what different authors mean when they use each term is essential to improve studies on biodiversity and ecosystem conservation in a mega diverse country like Brazil.

One approach to evaluate functional diversity is the measurement of functional traits to infer the functional component of biodiversity. The rapid increase in the number of studies seeking to answer complex ecological questions from the functional perspective has pushed researchers to develop different indices (e.g., Fontana et al., 2015; Laliberté & Legendre, 2010; Villéger et al., 2008) and analytical approaches (e.g., Chalmandrier et al., 2013; De Bello et al., 2009) in order to fulfill this demand. However, current studies using such techniques seem to be far from reaching a consensus on which are the best methods to evaluate ecological features (e.g., community assembly) through the functional aspects of biodiversity. Additionally, there is still a lack of consensus on what might be considered as a functional trait, or even whether the studies are truly evaluating functional aspects of biodiversity (Bunderson & Sutcliffe, 2002; Mason et al., 2005). Therefore, prior to the development and discussion of techniques and

methods, the fundamental terminology of functional diversity needs to be clarified, and not just in the literature (e.g., McGill et al., 2006; Mlambo, 2014; Tilman, 2001; Violle et al., 2007).

Currently, approaches based on functional diversity are applied to investigate different aspects of the community or ecosystem structure by measuring many traits without complete knowledge about their role in ecosystem processes (Fontana et al., 2015; Tilman, 2001; Violle et al., 2007). Thus, the wide use of the "functional diversity" term and several useless and/or unnecessary traits in ecological research has created a high degree of confusion and incongruence among community ecologists (Mlambo, 2014; Violle et al., 2007). The erroneous use of the "functional trait" term directly linked to disciplines of functional ecology also increases the misinterpretation of definition, usage, and measure of functional diversity (Violle et al., 2007).

The virtual synonymy of important terms is one of the implications of the imprecise use of scientific language (Fauth et al., 1996). The use of a same term with distinct meanings is not only a problem of communication, but also leads to indeterminacy while building theories, practices, and production of knowledge in general (Schwarz & Jax, 2011), therefore negatively affecting the scientific understanding and development of students (Stroud et al., 2015). Besides the lack of consensus, ecological concepts are under constant change due to new findings from research (e.g., the niche concept), which increases the pressure to clarify and improve the understanding of conceptual foundations of ecology (e.g., Bunderson & Sutcliffe, 2002; Frazier, 1994; Grimm & Wissel, 1997; Schwarz & Jax, 2011; Stroud et al., 2015).

Considering that the lack of consensus regarding basic concepts on ecology precludes the construction of a strong theoretical framework (Schwarz & Jax, 2011), the present study aimed to review terms related to "functional diversity." We aimed to identify if such lack of consensus is present in the terminology used by Brazilian researchers and students, evaluating how they conceptualize such terms related to functional diversity, as well as to identify the main concepts used in the literature. We also aimed to identify if there is a broadly accepted current definition for these terms by Brazilian academics.

MATERIAL AND METHODS

We selected five terms widely used in functional diversity studies and ecology subjects in Brazil and evaluated how they have been conceptualized in Brazil: ecological function (similar to ecosystem function, but more widely used in Brazil), guild, trait, functional group, and functional diversity. To assess how these terms have been used by the academic community in Brazil, we created a Google Form survey (Text S1) that included questions about their definition and use. The questionnaire was written in Portuguese and sent to Brazilian researchers and students through several mailing lists and social media outlets (e.g., Facebook groups) from November 10th 2017 to March 29th 2018. We also asked responders about their professional occupation and current location.

Moreover, we searched for these term definitions on the Web of Science database in May 2018 to assess how they have been used in the scientific literature. We carried out five independent searches, each with one of the terms entered directly into the search engine. The resulting list of articles was filtered by the theme "ecology" and organized by decreasing number of citations. Based on this procedure, we listed and extracted 10 definitions for each term presented by the most cited articles.

Data analysis

We used basic lexicographic analysis, descending hierarchical classification (DHC) (Reinert, 1983), and similitude analysis (SA) (Marchand & Ratinaud, 2012) to obtain word frequencies and text segments of concepts provided by the respondents. We also used SA on literature definitions to compare with the questionnaire results. The terms were lemmatized in all lexical analysis. Lemmatization is a text treatment technique that groups inflected words together as lemmas (e.g., transforming inflected verbs to the infinitive form and adjectives to singular) to analyze them as a single item (Khushi et al., 2019).

DHC identifies co-occurrences of terms and places segments of texts into classes by proximity. Then, the relative presence of each term is ranked within classes (Reinert, 1990). In this sense, the vocabulary is similar within each class and different among classes (Camargo, 2005). Associations between word forms and classes were assessed by using a chi-square test, in which high chi-square values ($\chi 2 \geq 3.84$) represent the strength of association and p-values represent the confidence level ($p < 0.05$) (Camargo & Justo, 2013; Oltramari & Camargo, 2010). In this analysis the terms are lemmatized transforming conjugated verbs to the infinitive form and adjectives to singular, so that only nouns, adjectives, verbs, and adverbs are analyzed. Thus, the analysis outcome is a text classification based on lexical similarity.

SA is a technique based on graph theory (Flament, 1962), which represents the ideal mathematical model to study the relationship among discrete objects and their co-occurrence. In SA's output, frequency (≥3) and connections among terms are visually represented. Term sizes and width of links between terms are proportional to the term frequency and co-occurrence, respectively (Mandják et al., 2019). We used SA to analyze the connectivity among words and their relative presence. Results are presented in a single graph by term.

All analyses were performed on Iramuteq (Interface de R pour les Analyses Multidimensionnelles de Textes et de Questionnaires), a visual interface supported by the software R for analysis of textual data (http://www.rproject.org). For each term, lower amounts of word forms identified in the questionnaire answers were interpreted as an indicator of greater congruence for this term definition among Brazilian researchers. Therefore, the use of a large set of word forms to define the terms was considered a reflection of loose definitions, consequently indicating a lack of consensus for a given term among researchers. The same reasoning was used regarding concepts found in the literature. Moreover, keywords of questionnaire answers and literature concepts were compared to verify the existence of a broadly accepted definition for each investigated term.

RESULTS

Overall, 220 people answered the survey and only six of them did not provide answers to any question (3%). We received responses from 22 of the 26 Brazilian states. Regarding the professional occupation of respondents, 85 were graduate students (39%), 70 undergraduate students (32%), 47 academic professors (21%), 11 academic postdoctoral researchers (5%), and seven did not report any of these occupations (3%). The DHC analysis indicated that locality and occupation were not associated with any classes (Table S1).

Ecological function

We analyzed 207 answers for the term “ecological function.” Overall, 748 word-forms were used to define it, among which ORGANISMO (organism), ECOSSISTEMA (ecosystem), ESPÉCIE (species), and PAPEL (role) were the most frequent. SA showed that DESEMPENHAR (develop), DETERMINADO (determined), and AMBIENTE (environment) tended to occur together in the sentences, forming a core from which other words were less connected (Figure 1). Even though a search of the literature for this term returned 492 articles (Table 1), only two of them defined “ecological function,” probably because this term is less familiar outside of Brazil. Due to this low number of definitions, it was not possible to perform SA.

FIGURE 1 Similitude analysis (SA) of the definition of “ecological function” from the questionnaire responses. The size of words is related to their frequency of use (larger = more). Due to the low number of definitions found in the literature, it was not possible to perform the SA word cloud analysis for concepts of “ecological function” described in the literature.

TABLE 1 Definition of concepts following a literature review of terms related to functional diversity.

Concept	Definition	Reference	No. of citations
Ecological function	An act performed by a living system "within the context of" an ecosystem.	Farnsworth et al. (2017)	16
	Role of processes and structures in the overall dynamics of ecosystems.	Morelli and Tryjanowski (2016)	8
Guild	Group of species that exploit the same class of environmental resources in a similar way. This term groups together species, without regard to taxonomic position, that overlap significantly in their niche requirements.	Simberloff and Dayan (1991)	412
	Group of species that exploit the same class of environmental resources in a similar way and thus brings together species that overlap significantly in their niche requirements.	Hermy et al. (1999)	395
	Species that use the same class of resources in a similar way, the term groups together species, without regard to taxonomic position, that overlap significantly in their niche requirements.	Dayan and Simberloff (2005)	297
	Groupings based on morphological traits and operational traits, so that species with common character syndromes are grouped.	Weiher et al. (1998)	286
	Group of species that exploit a common resource base in a similar fashion.	Feinsinger (1976)	274
	Group of species that exploit the same class of environmental resources in a similar way.	Moran and Southwood (1982)	247
	Group of phylogenetically and morphologically dissimilar species utilizing overlapping benthic resources.	Hines et al. (1990)	228
	Group of species that seem to exploit the same kinds of resources in similar ways.	Holmes et al. (1979)	220
	Groups of species that generally did not differ significantly on canonical axes of microhabitat use data.	Grossman et al. (1998)	207
	Species of similar trophic position.	Zanden and Rasmussen (1996)	206
Trait	A well-defined, measurable property of organisms, usually measured at the individual level and used comparatively across species.	McGill et al. (2006)	2331
	Any morphological, physiological or phenological feature measurable at the individual level, from the cell to the whole-organism level.	Violle et al. (2007)	1933
	Any measurable feature of an individual organism, including phenotype as well as demographic parameters.	Bolnick et al. (2011)	1119
	Any measurable feature of an individual that potentially affects performance or fitness and can be physical, biochemical, behavioral or temporal or phenological.	Cadotte et al. (2011)	885
	Any morphological, physiological, phenological or behavioral feature measurable at the individual level.	Violle et al. (2012)	768
	A measurable aspect of an organism which impacts its interaction with the environment, its capacity to find and acquire resources, and which therefore affects the fitness of a species via its effects on growth, reproduction, and survival.	Flynn et al. (2009)	623
	Are characteristics of species that are often used to define some biological feature of the organism or its direct relation to the environment.	Poff et al. (2006)	482

(Continues)

TABLE 1 (Continued)

Concept	Definition	Reference	No. of citations
	The joint expression of underlying biophysical and biochemical properties and processes of an organism.	Díaz et al. (2013)	255
	Variable that is characterized by a state of membership or affinity, which may be binary or continuous.	Schmera et al. (2015)	47
	Are measurable features of individuals affecting their performance or fitness.	Ebeling et al. (2017)	17
Functional group	Species can be divided into functional groups based upon their ecological roles.	Peterson et al. (1998)	1853
	Unrelated species that share critical organismal features.	Steneck and Dethier (1994)	1203
	Species that control processes fundamental to the persistence of ecosystems.	Levin (1998)	1869
	Species that share a trait that influences an ecosystem function.	Naeem and Wright (2003)	734
	A set of species that have similar effects on a specific ecosystem-level biogeochemical process.	Swift et al. (2004)	905
	Groups of species that share traits of physiology, phenology, and morphology and thus play similar effects on ecosystem processes.	Haddad et al. (2001)	537
	Categorization of species by physiognomic and life history traits.	Hooper (1998)	525
	Groups of organisms that play similar roles in ecosystem processes.	Levin et al. (2001)	497
	Sets of species that are responsible for essential ecosystem processes.	Barrios (2007)	879
	Species with similar biological traits resulting in similar responses to ecological processes.	Sternberg et al. (2000)	402
Functional diversity	Component of biodiversity that generally concerns the range of things that organisms do in communities and ecosystems.	Petchey and Gaston (2006)	2048
	Key driver of ecosystem processes, ecosystem resilience to environmental change, and ecosystem services.	Laliberté and Legendre (2010)	2107
	The extent of functional differences among the species in a community.	Petchey and Gaston (2002)	1595
	A facet of biodiversity quantifying the value and range of organismal traits that influence their performance and thus ecosystem functioning.	Villéger et al. (2008)	1934
	The composition of and variation in community traits, and its spatial distribution across landscapes.	Olden et al. (2004)	734
	An important feature of biological assemblages, enabling prediction of the rate and reliability of ecosystem processes.	Mason et al. (2005)	1294
	Trait variation or multivariate trait differences within a community.	Cadotte et al. (2011)	1387
	The distribution of species in a functional space whose axes represent functional features.	Mouchet et al. (2010)	1040
	Variation of traits in organisms.	Flynn et al. (2009)	952
	The value and range of species traits.	Díaz and Cabido (2001)	566

Guild

In the 204 answers used to define the term “guild,” a total of 385 word-forms were used, with ESPÉCIE (species), RECURSO (resource), and MESMO (same) representing the most frequent ones. We identified RECURSO (resource) as the central term for the concept of “guild” and it

was strongly connected to the words MESMO (same) and ESPÉCIE (species) (Figure 2a). In the literature (Table 1), 60 word-forms were used to define “guild.” The SA of “guild” concepts presented SPECIES as the central term and it was strongly connected to the words GROUP, RESOURCE, and SIMILAR. (Figure 2b).

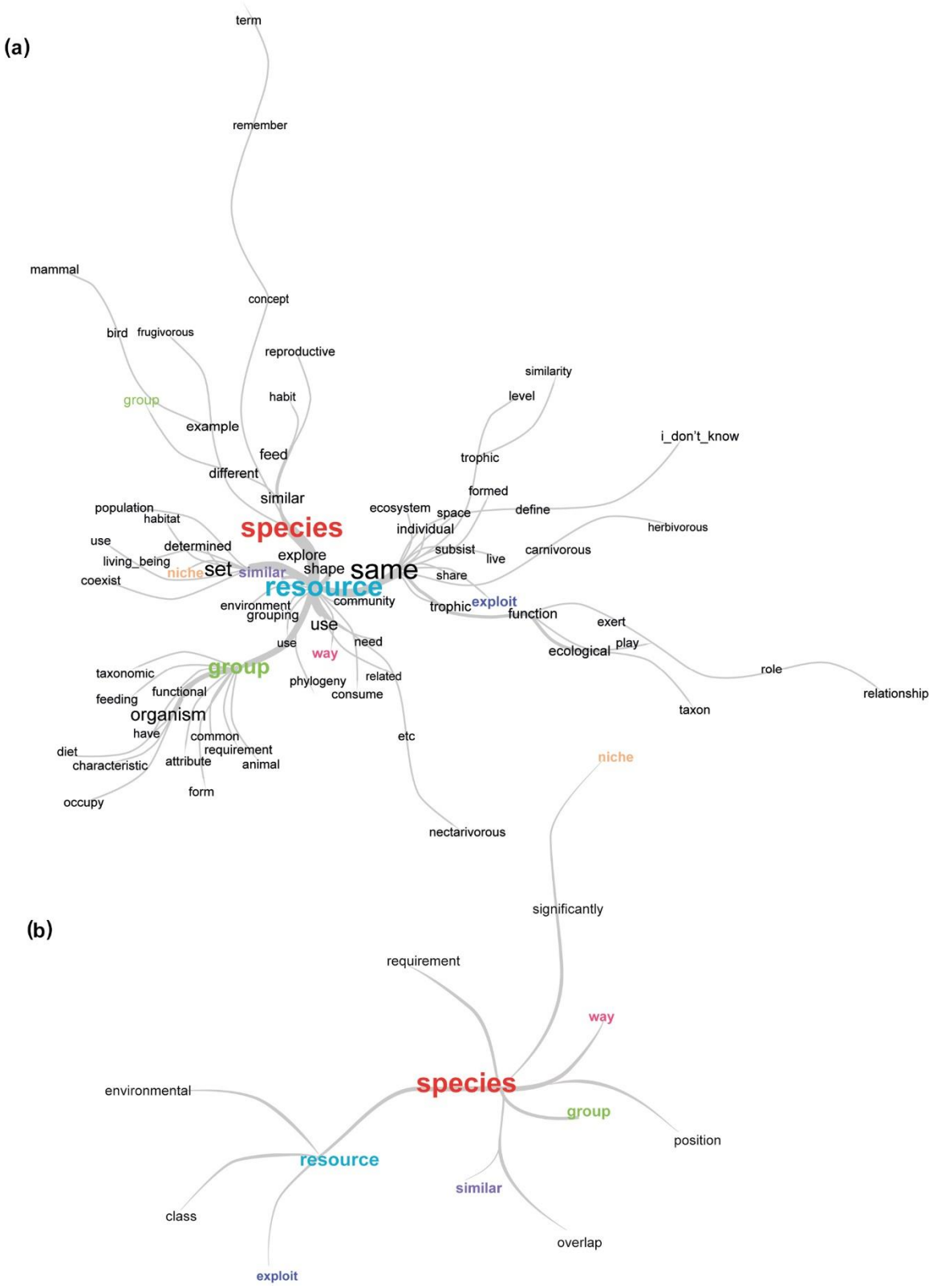

FIGURE 2 Similitude analyses of the definition of “guild” from the questionnaire responses (a) and the literature review (b). The size of words is related to their frequency of use (larger = more). Colored words were identified in both the questionnaire responses and the literature review.

Trait

We received 201 definitions of “trait.” Among the 405 word-forms used to define it, CARACTERÍSTICA (feature) was the central and most frequently used, followed by ESPÉCIE (species) and ORGANISMO (organism). The words INDIVÍDUO (subject), MORFOLÓGICO (morphological), and FISIOLÓGICO (physiological) were closely connected to the central word-form. From our literature search (Table 1), we registered 87 word-forms that were used to define the term trait. The SA of “trait” concepts highlighted, and indicated strong connections among, the following words: MEASURABLE, FEATURE, INDIVIDUAL, and ORGANISM (Figure 3).

FIGURE 3 Similitude analyses of the definition of "trait" from the questionnaire responses (a) and the literature review (b). The size of words is related to their frequency of use (larger =

more). Colored words were identified in both the questionnaire responses and the literature review.

Functional group

We received 201 definitions of “functional group” with a total of 366 terms used. Among them, the most frequent and closely connected were FUNÇÃO (function) and ESPÉCIE (species). We identified the terms DESEMPENHAR (play), ECOLÓGICO (ecological), MESMO (same), and ORGANISMO (organism) as being closely connected to FUNÇÃO (function), while other terms such as ECOSSISTEMA (ecosystem), CONJUNTO (set), SIMILAR, and SEMELHANTE (both meaning similar) were connected to ESPÉCIE (species). From the literature we registered 60 word-forms used to define the term “functional group” (Table 1). SA highlighted, and indicated strong connections among, the following words: SPECIES, PROCESS, and ECOSYSTEM (Figure 4).

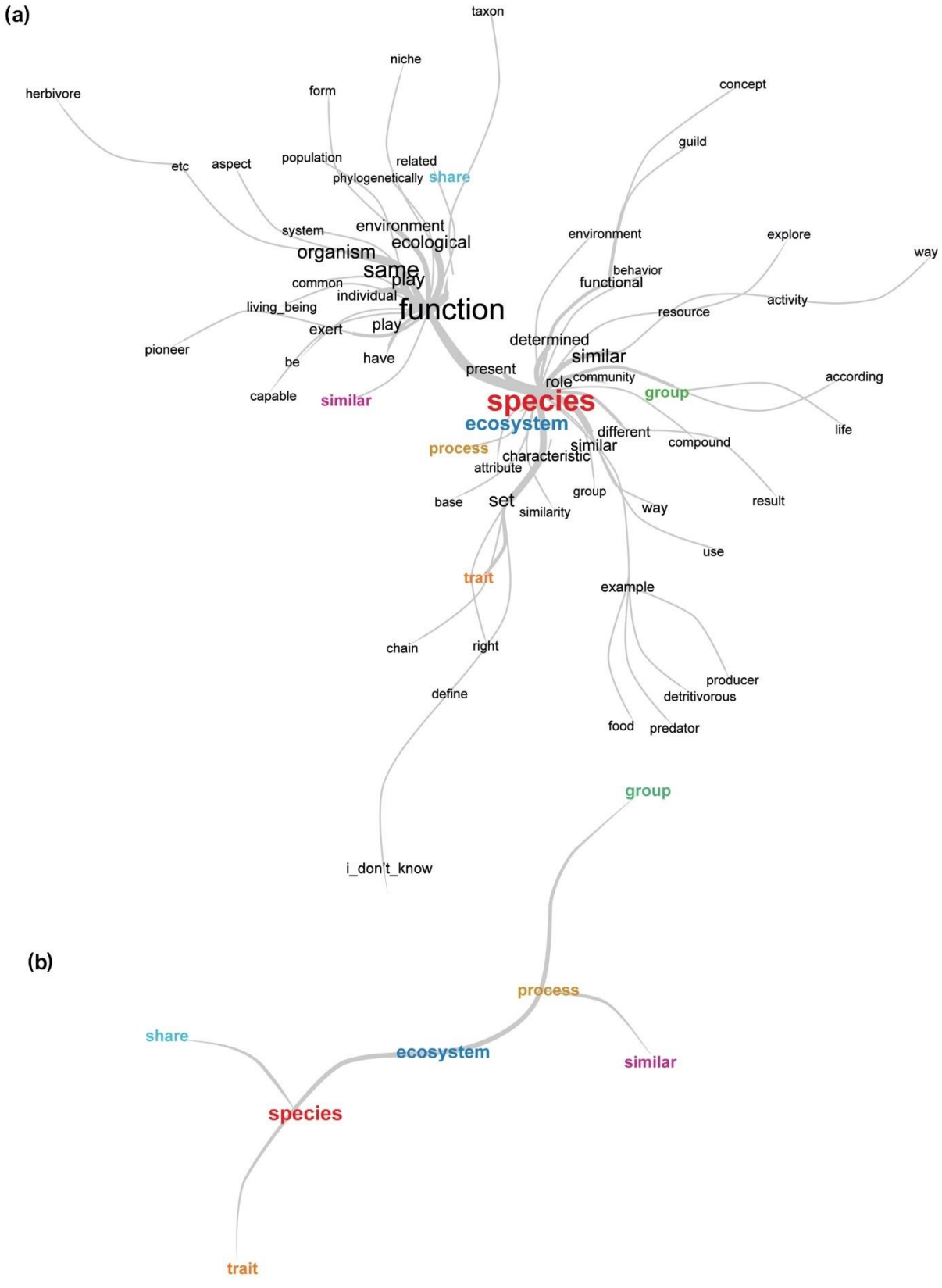

FIGURE 4 Similitude analyses of the definition of "functional group" from the questionnaire responses (a) and the literature review (b). The size of words is related to their frequency of use (larger = more). Colored words were identified in both the questionnaire responses and the literature review.

Functional diversity

We analyzed 199 answers for the term “functional diversity,” in which 400 word-forms were used. Among them, FUNÇÃO (function), FUNCIONAL (functional), ESPÉCIE (species), and GRUPO (group)were the most frequent. There was no central term; however, we identified two poles, FUNÇÃO (function) and GRUPO (group). FUNÇÃO (function) was closely connected to ESPÉCIE (species) and together terms had more abundant connections with other frequent terms such as DESEMPENHAR (play), ECOLÓGICO (ecological), COMUNIDADE (community), DIFERENTE (different), and ECOSSISTEMA (ecosystem). GRUPO (group) was closely connected to the word FUNCIONAL (functional) and lightly connected to other terms. The literature review (Table 1) returned 63 wordforms used to define “functional diversity.” SA highlighted the words ECOSYSTEM, TRAIT, and COMMUNITY, and showed that all terms, except for SPECIES, were strongly connected (Figure 5).

Respondents used the least number of distinct word forms to conceptualize “functional group,” followed by “guild,” “functional diversity,” “trait”, and “ecological function.” For the literature, the term with the least number of word forms used to describe it was also “functional group,” followed by “functional diversity,” “trait,” and “guild.”

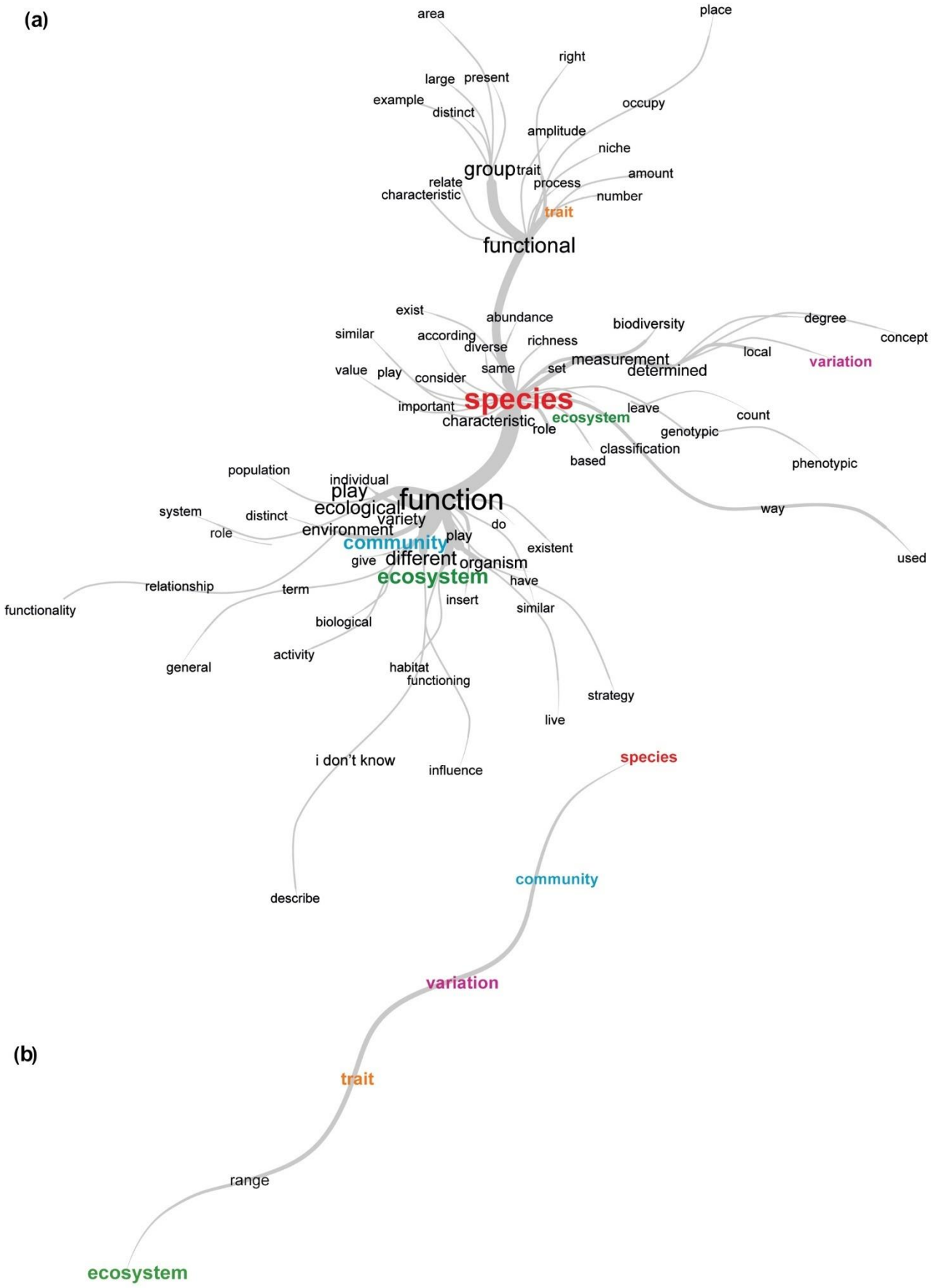

FIGURE 5 Similitude analyses of the definition of "functional diversity" from the questionnaire responses (a) and the literature review (b). The size of words is related to their frequency of use (larger = more). Colored words were identified in both the questionnaire responses and the literature review.

DISCUSSION

In this study we surveyed a range of people, from undergraduate students (students of Biological Sciences) to professors, from different regions of Brazil. We assessed if their interpretation of the terms "ecological function," "guild," "trait," "functional group," and "functional diversity" were aligned with definitions provided in the literature. We did not find a widely accepted definition for most terms. We observed discrepancies in how "ecological function," "trait," "functional group," and "functional diversity" have been used in the scientific literature and by Brazilian academics, suggesting that confusion over these terms is still widespread in Brazilian ecology. A lack of agreement on the use of these terms may negatively affect scientific communication, therefore it is important to define them clearly.

One of the terms frequently used in ecology in Brazil is "ecological function." According to our results, "ecological function" is used by Brazilian researchers and students to describe the role that species/organisms can play in the ecosystem (see Figure 1). Here, we can see confusion about the meaning of "ecological function," which matches with some definitions of another term, "ecological niche." Niche has already been defined as "the physical space and the functional role of a species in the community and its position in environmental gradients of temperature, moisture, pH, soil and other conditions of existence" (Odum & Barrett, 1971), the "intracommunity role of the species" (Whittaker et al., 1973), and "the complete functional role of a species within a given community" (Whittaker & Levin, 1975). Another important thing to highlight is that besides being widespread among Brazilian academics, the term "ecological function" might not be widely used in the literature, since "ecosystem function" is a more usual term outside of Brazil. The term "ecological function" has not been strictly defined until recently and this may be the reason why only two definitions (Klein et al., 2015; McCauley et al., 2017) could be found from 492 papers. This highlights the importance of making explicit the definitions of key concepts so that we can avoid generating jargon, imprecise ideas, and synonymy of important terms, and also so that we can facilitate scientific communication (Fauth et al., 1996; Stroud et al., 2015). As Brodie et al. (2018) mentioned "loose definitions of what it means is one of the barriers that have hindered the more widespread incorporation of ecological functionality."

We also evaluated the term "guild" and observed that the words SPECIES and RESOURCES were among the most used keywords for this term in both questionnaire answers and the literature. However, we found an incongruency in the definition of "guild": respondents to the questionnaire used the word SAME (e.g., identical; not different), while the literature used the word SIMILAR (e.g., resembling without being identical). We also found the use of the word GROUP in the literature (Figure 2). Root (1967) conceptualized "guild" as a group of species (regardless of their taxonomic relationship) that exploit the same class of environmental resources in a similar way. Therefore, the inclusion of SAME, SIMILAR, and GROUP in the original definition explains the use of these words in the questionnaires and literature and indicates that there is no misunderstanding regarding their use.

Although we observed a likely consensus in the conceptualization of "guild" (Figure 2), there is a long debate in the literature about its correct meaning (Korňan & Kropil, 2014; Simberloff & Dayan, 1991). Some authors suggest that "in a similar way" should be excluded from the concept due to its subjectivity (e.g., Jaksić & Jaksic, 1981; MacMahon et al., 1981). Additionally, the MacMahonian concept of "guild" suggests a community approach to the definition, in which species can be grouped regardless of their taxonomic group (e.g., fishes, birds, and mammals can all be members of an insectivorous guild regardless of their different

foraging strategies). On the other hand, the Rootian concept is more appropriate for taxonomic assemblages that can be described through similar foraging strategies (Korňan & Kropil, 2014; MacMahon et al., 1981). However, we agree with Korňan and Kropil (2014) who highlighted the need for a valid definition of "guild" and suggested that it should be based on the community centered approach (applicable to all organisms).

We assessed the term "trait" and noted that the words FEATURE, and ORGANISM were the keywords most frequently found in questionnaire answers and literature definitions (Figure 3). However, we also found an incongruence in the definition of "trait": Brazilian academics often used SPECIES to conceptualize "trait," while in the literature INDIVIDUAL was more frequently used (Figure 3). This difference may have occurred because most studies on trait variation along environmental gradients focus on differences among species, with little or no attention to within-species variation (Albert et al., 2011; Jung et al., 2010; Messier et al., 2010). Furthermore, we believe that the confusion surrounding the biological level of the meaning of "trait" is related to how the definition is often presented in the literature. For example, McGill et al. (2006) defined "trait" as a well-defined, measurable property of organisms, usually measured at the individual level and used comparatively across species. As "trait" can be used comparatively across species this point may have generated confusion for Brazilian researchers and students. Additionally, trait-based approaches used in studies ranging from the organism to ecosystem level, in which diverse types of traits are used to explain complex processes defined at higher organization levels (Violle et al., 2007) may have contributed to the misunderstanding about the biological level involved in the definition of "trait."

Indeed, "traits" are defined at the individual level (McGill et al., 2006; Webb et al., 2010). Examples of "traits" include growth form, leaf area, height and dispersal mode, basal metabolic rate, beak size, seed or egg size, body size, dietary specialization, nesting location, length and age at maturity, and offspring size (Forrest et al., 2015; Mayfield et al., 2010; McGill et al., 2006; McLean et al., 2019). The distinction among INDIVIDUAL and SPECIES is essential because many species in different biomes are known to display intraspecific variability, and a growing number of studies have suggested that it can influence community structure (Hulshof & Swenson, 2010; Jung et al., 2010; Messier et al., 2010; Whitlock et al., 2007). Although traits are measured at the individual level, in some cases they are used to attribute species to functional groups, which also may have caused confusion regarding the biological level of "trait."

Since the emergence of the discipline "functional ecology," there is still a high degree of confusion between the use of "trait" and "functional trait" (Calow, 1987; Keddy, 1992). The current definition of functional trait is "any trait which impacts fitness indirectly via its effects on growth, reproduction and survival" (Violle et al., 2007). In addition, functional traits must be related to traits "whose contribution is demonstrated or hypothesized to effect or respond to ecosystem processes," indicating how an individual relates (effect traits) and responds (response traits) to its environment (Messier et al., 2010; Mlambo, 2014; Mori et al., 2013). Therefore, given the wide range of research fields that use the term "trait" (e.g., genetics, ecology, systematics), a consensus on a clear definition, at least in the same research field, is essential to avoid misuse and improve communication.

We also noticed that questionnaire answers did not correspond to literature definitions in relation to "functional group" (Figure 4), since the word FUNCTION was a central element in the concepts provided by Brazilian researchers, but this word was not frequently used in the literature. However, Blondel (2003) highlighted the importance of how a resource, or any other ecological component is processed by different species to provide the same function when

defining functional groups. In this sense, recent definitions have been broader, defining "functional groups" as "groups of species that share traits of physiology, phenology and morphology and thus play similar effects on ecosystem processes" (Weisser et al., 2017). Therefore, the high frequency of the word FUNCTION instead of "process" in the questionnaires highlights the need to disseminate the broader definition of "functional group" among Brazilian academics.

The correct definition of "functional group" is extremely important because this term frequently appears linked to "functional diversity," causing misinterpretations in debates on ecological research. For "functional diversity" we observed that GROUP was one of the most frequent words and was linked to FUNCTIONAL in the questionnaire responses (Figure 5). Tilman (2001) published one of the most frequently cited definitions of "functional diversity": "the range and value of those species and organismal traits that influence ecosystem functioning." Such a definition shows that "functional diversity" is not restricted to diversity of functional groups but is based on functional traits. The inconsistency between literature and questionnaire definitions may be related to the practice of replacing species with functional groups in standard taxonomic diversity metrics (e.g., species richness, individual abundance, community composition), thereby considering it as a measurement of "functional diversity."

We are aware that restricting the understanding of functional diversity to the diversity of functional groups is not wrong, but it might restrict the potential of the research field since it groups species artificially based on the average value of individual attributes of one or more traits. Many tools have been developed to measure the variation of trait attributes, even considering the weight of intraspecific variation (e.g., see metrics examples in Fontana et al., 2015; Mouillot et al., 2013). Thus, the definition of "functional diversity" goes beyond functional groups, since it considers the range of attributes in one or more functional traits measured at an individual level.

Academics are fully aware of the importance of linking "functional diversity" to ecosystem functioning (Violle et al., 2007), which is confirmed by the commonness of the keyword ECOSYSTEM in concepts from both questionnaires and literature. However, it seems that the "response" approach is commonly neglected and the "effect" approach of "functional diversity" receives far more attention. FUNCTION was the term with more abundant connections with others and was more frequently cited in other definitions than "functional diversity." It might seem logical that the "effect" approach is more relevant to ecosystem functioning; however, the establishment of a species (here considering the nichebased theory) or its interactions can be closely related to its role in ecosystem functioning (e.g., Laughlin & Laughlin, 2013). Both response and effect traits are linked to each other and to ecosystem functioning, as the ecological responses of organisms shape their distribution and have strong consequences on the effect traits distribution in a community (Díaz et al., 2013; Webb et al., 2010). "Functional diversity" is not exclusively a measure of how a community modulates the ecosystem processes (via "effect traits") but is also related to the community assembly. In other words, it also indicates how the ecological interactions shape the community ("response traits").

CONCLUSION

We observed a lack of consensus in most of the evaluated terms related to functional diversity. The confusion in the terminology is still widespread among Brazilian researchers likely because of a lack of consensus in the literature (as observed for the "guild" concept). Although the terms "ecological function," "guild," "trait," "functional group," and "functional diversity" are popular

in current ecology literature, some variability remains in the definition of these concepts. The multiplicity of definitions for the same term may occur because “functional diversity” is a relatively new area in ecology. In the early stages of any ecological theory the proposition of new concepts by researchers is common, resulting in an initial storm of ideas and terms. Over time and development of the study area, the concepts tend to be used with greater consensus or to fall into disuse.

Different concepts for the same term can generate false synonyms and contribute to the widespread misunderstanding of the use of ecological terms. Therefore, it is necessary to find a consensual concept for all terms related to functional diversity described in our study. However, we know that finding a consensus in ecology is a difficult task. In this sense we strongly recommend that authors, regardless of the concept they choose, make the key concepts and the adopted definitions in their research explicit to avoid misunderstandings.

The adoption of a cohesive terminology for the next generations is extremely important to ensure comparability of scientific results and unity of terminology in the scientific literature (Korňan & Kropil, 2014). Accordingly, we propose that some terms, such as “guilds,” need to be reviewed and updated in line with new terms that have emerged in ecology in recent decades. Here, we have attempted to clarify current terms rather than propose new ones, showing the main aspects that can lead to confusion. Through our results, we expect to show the importance for future studies using more cohesive concepts for these fundamental terms in functional diversity.

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SUPPORTING INFORMATION

Text S1 - Google Form survey about functional diversity terms applied (in Portuguese) to Brazilian students and researchers.

1) Please define the following terms:

- Ecological function
- Guild
- Functional group
- Trait
- Functional diversity

2) What is your current occupation?

- Professor
- Post-doctoral researcher
- Graduation student
- Undergraduate student
- Other

3) In which Brazilian state do you currently live?

- Acre (AC)
- Alagoas (AL)
- Amapá (AP)
- Amazonas (AM)
- Bahia (BA)
- Ceará (CE)
- Distrito Federal (DF)
- Espírito Santo (ES)
- Goiás (GO)
- Maranhão (MA)
- Mato Grosso (MT)
- Mato Grosso do Sul (MS)
- Minas Gerais (MG)
- Pará (PA)

- Paraíba (PB)
- Paraná (PR)
- Pernambuco (PE)
- Piauí (PI)
- Rio de Janeiro (RJ)
- Rio Grande do Norte (RN)
- Rio Grande do Sul (RS)
- Rondônia (RO)
- Roraima (RR)
- Santa Catarina (SC)
- São Paulo (SP)
- Sergipe (SE)
- Tocantins (TO)

Supporting Information 2. Descending Hierarchical Classification of questionnaire concepts. Classes group text segments with similar vocabularies. Table shows amount of classified segments in the text and proportion of classified segments per classes. Word forms shown are lemmatized forms with $x^2 \geq 3.84$. Chi-square (x^2) values represent strengh of association between terms and classes, p-values represent the confidence level ($p<0.05$). Variables about respondent current location (*UF - AM 1; BA 2; CE 3; DF 4; GO 5; MA 6; MG 7; MS 8; MT 9; PA 10; PB 11; PE 12; PI 13; PR 14; RJ 15; RN 16; RO 17; RS 18; SC 19; SE 20; SP 21; TO 22), professional occcupation (*ocup - Graduate degree =1; Postgraduate degree = 2; Postdoctoral degree = 3; Professor = 4; Others = 5) and respondent number (*n) are listed below terms. Word-forms are presented in Portuguese (as provided in the questionnaires) and English in parentheses.

Ecological function		192 segments classified on 212 (90.57%)									
Class 1			Class 2			Class 3			Class 4		
18.75%			39.58%			18.75%			22.92%		
Word-form	X^2	p	Word-form	X^2	p	Word-form	X^2	p	Word-form	X^2	p
ambiente (environment)	63.48	<0.001	ecossistema (ecosystem)	26.34	<0.001	indivíduo (individual)	44.76	<0.001	biótico (biotic)	66.81	<0.001
relação (relationship)	32.9	<0.001	organismo (organism)	20.74	<0.001	nicho (niche)	30.47	<0.001	abiótico (abiotic)	62.74	<0.001
viver (live)	21.6	<0.001	desempenhar (develop)	15.75	<0.001	característica (trait)	25.98	<0.001	componente (component)	30.54	<0.001
presente (present)	4.59	0.030	papel (role)	15.54	<0.001	forma (way)	22.25	<0.001	ser_vivo (living being)	23.26	<0.001
desenvolvido (developed)	4.59	0.030	funcionamento (functioning)	10.24	0.001	determinado (determined)	14.29	<0.001	manutenção (maintenance)	16.22	<0.001
Variable			vivo (living)	7.84	0.010	interação (interaction)	11.34	0.001	achar (find)	13.74	<0.001
*n_010	4.59	0.032	grupo (group)	7.21	0.010	espécie (species)	9.1	0.003	meio_ambiente (environment)	12.82	<0.001
			polinização (pollination)	6.24	0.010	ação (action)	7.03	0.010	ambiental (environmental)	12.8	<0.001
			exercer (play)	4.95	0.030	vida (life)	4.59	0.030	capacidade (capacity)	10.25	0.001
			modo (way)	4.65	0.030	comportamental (behavioral)	4.59	0.030	fator (factor)	9.68	0.002
			nutriente (nutrient)	4.65	0.030	Variable			equilíbrio (balance)	9.68	0.002
			afetar (affect)	4.65	0.030	*n_127	8.76	0.003	nicho_ecológico (ecological niche)	8.21	0.004
						*UF_1	4.59	0.030	habitar (inhabit)	6.27	0.010
Trait	158 segments classified on 202 (78.22%)								estudo (study)	4	0.050
Class 1			Class 2						Variable		
81.01%			18.99%						*UF_10	7.4	0.007
Word-form	x^2	p	Word-form	x^2	p				*n_039	6.8	0.009
característica (characteristic)	62.14	<0.001	não_sei (I don't know)	151.71	<0.001				*ocup_4	6.69	0.010

ser (being)	14.19	<0.001	Variable								
espécie (species)	13.85	<0.001	*ocup_1	8.42	0.004						
organismo (organism)	10.54	0.001	*UF_21	4.67	0.031						
indivíduo (individual)	6.31	0.012									
poder (can)	5.06	0.024									
traço (trait)	4.64	0.031									
funcional (functional)	4.46	0.035									
atributo (attribute)	4.17	0.041									
função (function)	3.88	0.049									

morfológico (morphological)	3.88	0.049									
Guild	141 segments classified on 204 (69.12%)										
Class 1			Class 2								
56.74%			43.26%								
Word-form	x²	p	Word-form	x²	p						
recurso (resource)	108.22	<0.001	função (function)	27.06	<0.001						
espécie (species)	35.32	<0.001	ecológico (ecological)	18.74	<0.001						
mesmo (same)	25.74	<0.001	alimentar (feed)	17.2	<0.001						
utilizar (use)	20.79	<0.001	desempenhar (play)	12.61	<0.001						
explorar (explore)	18.81	<0.001	funcional (functional)	9.66	0.002						
conjunto (set)	13.68	<0.001	característica (characteristic)	9.66	0.002						
forma (way)	4.42	0.036	hábito (habit)	8.22	0.004						
tipo (type)	4.41	0.036	animal (animal)	8.22	0.004						
subsistir (subsist)	3.95	0.047	grupo (group)	7.88	0.005						
Variable			diferente (different)	6.8	0.009						
*UF_10	3.95	0.046797	dieta (diet)	6.8	0.009						
			alimentação (feeding)	6.8	0.009						

			agrupar (group)	6.8	0.009						
			indivíduo (individual)	6.61	0.010						
			exemplo (example)	5.41	0.020						
			relação (relationship)	5.4	0.020						
			táxon (taxa)	5.4	0.020						
			papel (role)	5.4	0.020						
			exercer (play)	5.4	0.020						
			organismo (organism)	4.47	0.034						
			etc	4.02	0.045						
			ter (have)	4.02	0.045						
			Variable								
			*UF_15	5.38	0.020						
Functional group		155 segments classified on 201 (77.11%)									
Class 1			Class 2			Class 3					
44.52%			18.71%			36.77%					
Word-form	x²	p	Word-form	x²	p	Word-form	x²	p			
traço (trait)	20.7	<0.001	realizar (do)	93.58	<0.001	desempenhar (play)	27.53	<0.001			

apresentar (present)	17.51	<0.001	diferente (different)	18.62	<0.001	exercer (play)	17.06	<0.001			
possuir (have)	14.76	<0.001	similar (similar)	17.26	<0.001	função (function)	11.6	0.001			
forma (way)	14.76	<0.001	ecossistema (ecosystem)	10.24	0.001	mesmo (same)	8.93	0.003			
funcional (functional)	13.8	<0.001	espécie (species)	7.38	0.007	ecossistema (ecosystem)	7.15	0.007			
compartilhar (share)	10.51	0.001	Variable			determinado (determined)	5.33	0.021			
semelhante (similar)	9.59	0.002	*UF_20	8.8	0.003	conjunto (set)	4.72	0.030			
recurso (resource)	9.14	0.003	*UF_10	5.43	0.020						

atributo (attribute)	9.14	0.003	*UF_6	4.37	0.040						
ser (being)	9.09	0.003									
grupo (group)	8.85	0.003									
definir (define)	7.78	0.005									
característica (characteristic)	6.71	0.010									
organismo (organism)	5.28	0.022									
sistema (system)	5.12	0.024									
similaridade (similarity)	5.12	0.024									
processo (process)	5.12	0.024									
explorar (explore)	5.12	0.024									
aspecto (aspect)	5.12	0.024									
agrupar (group)	5.12	0.024									
Functional diversity		128 segments classified on 203 (63.05%)									
Class 1			Class 2								
72.66%			27.34%								
Word-form	x^2	p	Word-form	x^2	p						
função (function)	19.61	<0.001	medida (measurement)	39.93	<0.001						
organismo (organism)	7.88	0.005	atributo (attribute)	28.82	<0.001						
mesmo (same)	4.98	0.026	biodiversidade (biodiversity)	17.98	<0.001						
comunidade (community)	4.54	0.033	funcionamento (functioning)	16.73	<0.001						
			relacionar (relationship)	13.83	<0.001						
			nicho (niche)	13.83	<0.001						
			importante (important)	10.97	0.001						
			contar (count)	10.97	0.001						
			processo (process)	9.93	0.002						
			local (local)	8.16	0.004						

			funcional (functional)	7.93	0.005						
			determinado (determined)	7.26	0.007						

			diverso (diverse)	7.24	0.007						
			levar (lead)	7.24	0.007						
			ecológico (ecological)	5.92	0.015						
			estar (be)	9.93	0.002						
			Variable								
			*UF_20	5.4	0.020						