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Insights into sex- and age-related feeding habits of the common bottlenose dolphin (*Tursiops truncatus truncatus*) in Southern Brazil

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The common bottlenose dolphin (*Tursiops truncatus truncatus*) (Delphinidae) is an offshore ecotype widely distributed in the western South Atlantic Ocean. It is observed not only in deeper open waters, but also occasionally near the coast (Ott et al., 2016; Fruet et al., 2017; Simões-Lopes et al., 2019). Although *T. t. truncatus* is sometimes sighted close to shore (Simões-Lopes et al., 2019), isotopic data suggest that it primarily feeds on prey different from those consumed by the Lahille's bottlenose dolphin (*T. t. gephyreus*), the coastal ecotype (Pereira et al., 2020).

Although the diet of the common bottlenose dolphin has been documented in several regions worldwide, information on prey species remains limited in southern Brazil. Available information refers generically to *T. t. truncatus* and indicates that the species exhibits opportunistic feeding behavior, foraging predominantly near the surface, either alone or in groups, and consuming mainly fish and cephalopods, and occasionally crustaceans (Wedekin et al., 2008; Kiszka et al., 2014; Milmann et al., 2016; Giménez et al., 2017; Neri et al., 2022). Thus, diet composition may vary according to prey availability, leading to regional differences. Additionally, other factors such as seasonality, age, and sex may influence dietary patterns (Barros & Odell, 1990; Bearzi, 2005). Females, for example, may increase their consumption of cephalopods during pregnancy (Kastelein et al., 2002).

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Aiming to contribute to the understanding of the feeding ecology of the common bottlenose dolphin in the South Atlantic, this study provides new data on the diet of this ecotype in southern Brazil and investigates potential dietary variations related to sex and age class.

Samples were obtained from stranded carcasses collected along the northern coast of Santa Catarina State, between latitudes 26°07′03″ S and 26°22′13″ S (Fig. 1). Given that in this area occasionally strandings of Lahille's bottlenose dolphin occur, the identification of the offshore ecotype was performed through skull morphology analysis, as described by Costa et al. (2016), following complete cleaning procedures. The skulls, complete skeletons, and samples analyzed in this study are preserved in the Acervo Biológico Iperoba (ABI) collection at the University of the Region of Joinville.

The carcasses were recovered between 2006 and 2020. Until July 2015, collections were conducted opportunistically and relied on reports from residents. From August 2015 onward, carcasses have been collected through systematic effort by the Santos Basin Beach Monitoring Project (Projeto de Monitoramento de Praias da Bacia de Santos – PMP-BS) team. Biological data for each individual, including sex, age, and total length, were obtained from the Aquatic Biota Monitoring Information System (*Sistema de Informação de Monitoramento da Biota Aquática* – SIMBA), an online database (https://simba.petrobras.com.br/simba/web/).

The carcasses were transported to the laboratory for necropsy procedures, during which the stomach was retrieved, longitudinally sectioned, and washed over a set of stacked stainless-steel sieves (500 µm, 2 mm, and 1 mm). Prey remains were sorted, with otoliths stored dry and cephalopod beaks preserved in 10% glycerol. Sex was determined through external morphological inspection of the ventral region. Due to varying stages of decomposition, this assessment was not possible for all individuals. When feasible, sex identification was confirmed by the examination of the gonads during necropsy.

Age estimation followed the method proposed by Hohn (1980), based on growth-layer counts in tooth sections obtained by histological analysis when teeth were available. Total body length was measured from the tip of the rostrum to the center of

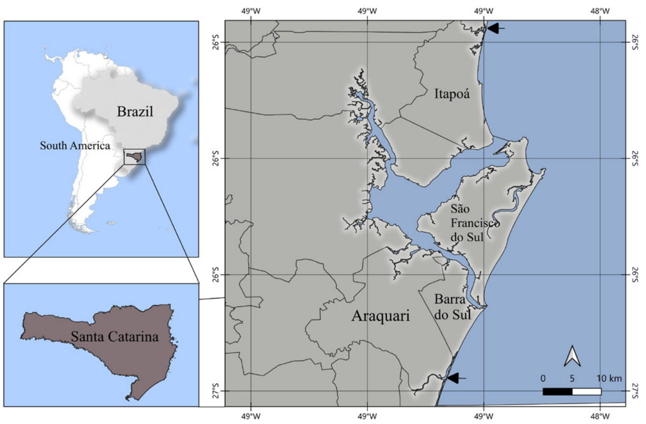

Figure 1. Study area located on the north coast of Santa Catarina State, southern Brazil. The arrows indicate the boundaries of the area where the carcasses of common bottlenose dolphins *Tursiops truncatus truncatus* were recovered (26°07'03" S to 26°22'13" S).

the fluke following Norris (1961). Age-class categories (juvenile and adult) were defined primarily based on age. Individuals up to 10 years old were generally classified as juveniles and older individuals as adults, following thresholds adapted from Wells et al. (2025). However, considering the natural variation in growth and sexual maturation reported for *T. truncatus*, body length was also considered when interpreting developmental stage. When age data were unavailable, total body length was used as an indicator; individuals up to 250 cm were considered juveniles, whereas larger individuals were classified as adults, based on estimates by Mead & Potter (1990), Siciliano et al. (2007), and Vollmer & Rosel (2013). Although the estimates made by Siciliano et al. (2007) are for southeast Brazil, in the absence of specific thresholds for each region these references were used as the best available estimates, even though these parameters may vary geographically. Fish species were identified based on sagittal otoliths (calcified structures located in the inner ear) using a ZEISS Stemi DV4 binocular microscope and identification keys (Corrêa & Vianna, 1992; Lemos et al., 1995; Nunes, 2012; Haimovici et al., 2024). Otoliths that were too deteriorated to allow species identification were discarded, following the criteria of Fitch & Brownell (1968). Cephalopods were identified based on beak morphology, examined under the same microscope and compared with taxonomic references (Vasque, 2006; Xavier & Cherel, 2009). The number of fish and cephalopods consumed was estimated by counting pairs of otoliths and beaks, matching left and right sides. In cases of an odd otolith count, the side with the highest number was used to estimate the minimum number of individuals.

Prey species were classified by habitat type, according to Milmann et al. (2016), Froese & Pauly (2024), and Haimovici et al. (2024) considering the following categories: pelagic, those species that occupy the entire water column, excluding the bottom; demersal, the species associated with the bottom; demersal-pelagic, those that utilize both the water column and the benthic zone; and pelagic-neritic, species that are coastal and occupy the full water column. After classification, the percentage of prey species in each ecological group was calculated. The seasons were considered as summer (January, February, and March), autumn (April, May, and June), winter (July, August, and September) and spring (October, November, and December) (Table 1). Seasonal data refer to the stranding period of each dolphin, assuming that the prey items reflected the recent diet at the time of collection. Thus, stomach contents were assigned to the corresponding stranding season.

The importance of each prey item in the common bottlenose dolphin diet was assessed using two metrics: numerical frequency (%NF), defined as the number of individuals of each prey species divided by the total number of preys identified; and frequency of occurrence (%FO), defined as the number of dolphins in which a given prey species occurred divided by the total number of dolphins analyzed (Pinkas et al., 1971). Both %NF and %FO were also calculated separately for each sex. Due to the high number of digested otoliths that prevented accurate biomass estimation, we applied an adapted version of the Index of Relative Importance (IRI) proposed by Pinkas et al. (1971), calculated as: IRI = %NF × %FO. The IRI was calculated separately for teleosts and cephalopods, as well as for each sex.

In total, 20 common bottlenose dolphins were analyzed, including eight females and seven males; sex could not be determined for five individuals due to advanced carcass decomposition. Age was estimated for 12 individuals, ranging from one to 16 years (Table 1) and total length varied from 211 to 290 cm for males (260 ± 0.28), and 206 to 298 cm for females (256 ± 0.4). Most strandings occurred in spring (42.8%), followed by winter (33.3%).

A total of 162 prey items were identified, distributed across six teleost families (Trichiuridae, Batrachoididae, Mugilidae, Engraulidae, Sciaenidae, and Carangidae) and two cephalopod families (Octopodidae and Loliginidae) (Table 2). Sixteen prey species were identified, including 13 teleosts and three cephalopods; pelagic fish represented 9.15%, demersal 13.41%, pelagic-neritic 3.66%, and demersal-pelagic 73.78% of the total.

Trichiurus lepturus was by far the most important prey species in the diet, presenting the highest IRI values for both males (83.14) and females (65.63), followed by *Porichthys porosissimus* (M = 14.0 and F = 11.72) for both males and females. *Trichiurus lepturus* is widely distributed in coastal and estuarine waters of the southwestern Atlantic Ocean and its predominance in the diet likely reflects its high local availability and schooling behavior, which may facilitate dolphin predation. Similar patterns have been reported for bottlenose dolphins and other coastal cetaceans in southern Brazil, where demersal and neritic fish frequently dominate the diet (Santos & Haimovici, 2001; Milmann et al., 2016). *Porichthys porosissimus*, a benthic species associated with soft substrates, was the second most important prey for both sexes, reinforcing the importance of demersal resources in the feeding ecology of dolphins. Among cephalopods, *Doryteuthis plei* presented the highest IRI (3.13), indicating that although cephalopods were not dominant, they represent a complementary trophic resource, as also reported for odontocetes in the southwestern Atlantic (Santos & Haimovici, 2001).

Mugil platanus and *Anchoa tricolor* were the most important prey for females, having the same IRI for both (1.56), while for males it was *Ctenosciaena gracilicirrhus* (1.75). Although *Trachurus lathami* was represented by a relatively high number of individuals (n = 17), it was found in only one dolphin and therefore received

Table 1. Stranding date, sex, age, total length, number of otoliths, and cephalopod beaks found in the stomach of common bottlenose dolphins *Tursiops truncatus truncatus* stranded on the south coast of Brazil. ABI = Acervo Biológico Iperoba, F = female, M = male, NI = Non Identified, J = juvenile, A = adult; SP = spring; AU = autumn; WI = winter; SU = summer.

ABI Number	Sex	Age (years)	Development stage	Total length (cm)	Season	Date	Number of otoliths	Number of cephalopod beaks
64	F	NI	NI	206	SP	27 Sep 2006	13	0
135	F	NI	NI	257	AU	10 Jun 2007	2	0
361	M	NI	NI	234	WI	14 Aug 2012	48	0
412	M	NI	NI	273	SU	2 Mar 2013	5	0
559	M	NI	NI	260	WI	7 Aug 2014	6	1
561	M	NI	NI	272	WI	7 Aug 2014	9	0
686	NI	NI	NI	255	AU	20 May 2015	17	0
696	M	NI	NI	211	WI	29 Jul 2015	13	0
703	M	14	A	290	WI	16 Sep 2015	12	0
705	M	9	A	280	WI	21 Sep 2015	7	0
1122	F	15	A	298	SP	1 Nov 2017	18	2
1123	NI	11	A	272	SP	1 Nov 2017	0	1
1124	NI	14	A	295	SP	1 Nov 2017	0	1
1126	F	16	A	283	SP	3 Nov 2017	1	0
1127	F	12	A	NI	SP	3 Nov 2017	0	2
1131	F	11	A	281	SP	6 Nov 2017	2	2
1159	NI	12	A	267	SU	30 Jan 2018	1	0
1217	NI	2	J	NI	WI	2 Aug 2018	2	0
1444	F	5	J	NI	SU	31 Jan 2020	10	0
1543	F	1	J	210	SP	2 Dec 2020	2	0

Table 2. Prey species identified in the stomach of common bottlenose dolphins *Tursiops truncatus truncatus* stranded on the coast of Santa Catarina, southern Brazil, considering the number of preys (N), numerical frequency (%NF), frequency of occurrence (%FO), and index of relative importance (IRI). DP = demersal-pelagic; D = demersal; P = pelagic; PN = pelagic-neritic. SU: summer; AU: autumn; WI: winter; SP: spring.

Family	Species	Ecological group	N	%FO	%FN	IRI	Score	SU	AU	WI	SP	%NF Male	IRI	%NF Female	IRI
Class Actinopterygii															
Batrachoididae	*Porichthys porosissimus*	D	45	35	14.75	16.8	2	2	0	3	2	15.24	14.0	9.43	11.72
Carangidae	*Naucrates ductor*	P	5	5	1.64	2.2	9	1	0	0	0	0.95	0.22	0	0
	Trachurus lathami	DP	18	5	5.90	2.2	9	0	0	0	1	0	0	32.08	13.28
	Selar crumenophtalmus	P	5	5	1.64	2.2	9	1	0	0	0	0.95	0.22	0	0
Engraulidae	*Anchoa tricolor*	PN	15	10	4.92	5.0	5	2	0	0	0	0.95	0.22	3.77	1.56
	Anchoa filifera	PN	10	5	3.28	2.8	8	1	0	0	0	0	0	1.89	0.78
Pristigasteridae	*Pellona harroweri*	PN	14	10	4.59	4.9	6	0	1	1	0	0.95	0.22	1.89	0.78
Mugilidae	*Mugil platanus*	DP	14	15	4.59	6.6	3	0	2	2	1	3.81	0.01	3.77	1.56
Sciaenidae	*Cynoscion virescens*	D	1	5	0.33	1.8	11	0	0	0	0	0	0	0	0
	Cynoscion guatupuca	DP	5	5	1.64	2.2	9	0	1	1	0	0.95	0.22	0	0
	Cynoscion leiarchus	D	1	5	0.33	1.8	11	1	0	0	0	0	0	0	0
	Ctenosciaena gracilicirrhus	D	24	10	7.87	6.0	4	0	0	2	0	3.81	1.75	0	0
Trichiuridae	*Trichiurus lepturus*	DP	135	55	44.26	33.6	1	2	1	6	3	72.38	83.14	39.62	65.63
Class Cephalopoda															
Loliginidae	*Doryteuthis plei*	P	8	15	2.62	6.0	4	0	0	0	5	0	0	3.77	3.13
	Doryteuthis sanpaulensis	P	2	10	0.66	3.6	7	0	0	0	2	0	0	1.89	0.78
Octopodidae	*Octopus vulgaris*	DP	3	5	0.98	2.0	10	0	0	0	1	0	0	1.89	0.78
	TOTAL		305	--	100	--	--	--	--	--	--	100	--	100	--

a low score on the IRI, suggesting a localized feeding event. Overall, the low number of prey species per individual suggests that dolphins may concentrate their foraging on locally abundant prey resources. No individual consumed more than five different prey species (Table 3).

In southern Brazil, different populations of the Lahille's bottlenose dolphin are residents to lagoons and estuaries (Simões-Lopes, 1991; Ott et al., 2016), mainly preying upon demersal fish (*e.g.*, Secchi et al., 2017). The diet of common bottlenose dolphins stranded in Santa Catarina State revealed three important prey species: *T. lepturus*, *P. porosissimus* and *M. platanus*. This result is very similar to that observed for *T. truncatus* in the southern region of Brazil, where *T. lepturus*, *Paralonchurus brasiliensis,* and *M. liza* were recorded as the main species by Milmann et al. (2016). *Trichiurus lepturus* was the most important prey item considering the IRI, suggesting its key role in the species' diet.

The predominance of a particular prey species may reflect not only its abundance and availability but also factors such as energetic return and facility to capture. This species is abundant in the region, occurring from coastal areas to depths up to 350 meters, and exhibits economic relevance particularly within the state of Maranhão (Garcia et al., 2021). Its importance in the diet of the common bottlenose dolphin suggests potential trophic overlap and an increased risk of fishery interactions. Although other studies made on the coast of Brazil did not specify the bottlenose dolphin ecotype, some comparisons were made (Bearzi et al., 2011; Milmann et al., 2016; Moura et al., 2017). Overlap between bottlenose dolphin diet and targeted fishes captured in fisheries has been reported in other regions, raising concerns about bycatch and feeding competition (Bearzi et al., 2011; Milmann et al., 2016). However, the high level of wear observed on the otoliths prevented a more detailed analysis of the biomass consumed. The presence of *P. porosissimus*, a species with nocturnal habits, and previous reports of nocturnal foraging in *T. truncatus* (Klatsky et al., 2007) suggest that dolphins may forage across diel cycles, possibly exploiting different habitats and behaviors to maximize energy intake.

Despite *T. lepturus* being the most frequently occurring species, *M. platanus* may also represent an important prey item due to its higher biomass, considering the large body size of this species in the region. Milmann et al. (2016) reported a higher numerical frequency of *T. lepturus* in the diet of bottlenose dolphins on the Rio Grande do Sul State coast, although its total biomass was lower compared to that of *M. platanus*. The use of IRI provided a more balanced interpretation of prey importance by integrating occurrence and numerical contribution, preventing overestimation from isolated high counts. However, caution is warranted due to the limited sample size and incomplete age data. Increasing sample size and incorporating complementary techniques (*e.g.*, stable isotope analysis) would strengthen interpretations and clarify seasonal and interannual patterns. Furthermore, integrating fishery effort data could help assess the degree of ecological overlap, informing conservation strategies in this region of intense human activity.

The Sciaenidae was the most diversified family identified in the diet of common bottlenose dolphins, but the IRI was low for all the four species identified. Sciaenid fishes were the most important prey recorded for bottlenose dolphins in the southern region in Brazil (Milmann et al., 2016). Many species within this family produce sounds that the dolphins can perceive, making it easy for the dolphins to detect this prey (Wells & Scott, 2009). In the Gulf of Mexico, Wilson et al. (2017) reinforced the importance of this family in the species' diet across different regions. However, in this study their importance was not confirmed.

Differences in prey diversity between males and females could be related to ecological and behavioral factors. Males presented a higher frequency of dominant fish species, whereas females showed a more diversified diet and included cephalopods in their diet. Social segregation has been recorded for the species and may influence diet, considering that females with newborns require higher energetic intake while nursing (Kastelein et al., 2002; Naranjo-Ruiz et al., 2024). The occurrence of cephalopods exclusively in females diet support the hypotheses of sexual segregation in foraging ecology, potentially linked to reproductive energetic demands (Kastelein et al., 2002; Amir et al., 2005). This pattern was also observed for franciscana dolphins, *Pontoporia blainvillei*, where authors suggest that the consumption of cephalopods could be related to water demand during nursing

Table 3. Prey consumed by each common bottlenose dolphin *Tursiops truncatus truncatus* analyzed, with individual information of age (years), sex, and total length (cm) (when available). ♂ = males; ♀ = females; I = indetermined.

ABI	64	135	1122	1126	1127	1131	1444	1543	361	412	559	561	696	703	705	686	1123	1124	1159	1217
Age	-	-	15	16	12	11	5	1	-	-	-	-	-	14	9	-	11	14	12	2
Length	206	257	298	283	-	281	-	210	234	273	260	272	211	290	280	255	272	295	267	-
Sex	♀	♀	♀	♀	♀	♀	♀	♀	♂	♂	♂	♂	♂	♂	♂	-	-	-	-	-
Class Actinopterygii																				
Anchoa filifera	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Anchoa tricolor	-	-	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-
Ctenosciaena gracilicirrhus	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-
Cynoscion guatupuca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
Cynoscion leiarchus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Cynoscion virescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-
Mugil platanus	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-
Naucrates ductor	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
Pellona harroweri	-	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-	-	-	-	-
Porichthys porosissimus	-	-	-	X	-	X	X	-	-	X	X	-	-	X	X	-	-	-	-	-
Selar crumenophthalmus	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
Trachurus lathami	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichiurus lepturus	X	-	X	-	-	-	X	X	X	X	-	X	X	X	-	X	-	-	-	X
Class Cephalopoda																				
Doryteuthis plei	-	-	X	-	X	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Doryteuthis sampaulensis	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-
Octopus vulgaris	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-

or pregnancy periods (Rodríguez et al., 2002). The presence of cephalopods only in females was also recorded for Guiana dolphins *Sotalia guianensis* and *P. blainvillei* in the same region as considered in this study (Cremer et al., 2012). Despite the differences, the teleosts most consumed by both sexes are of the same species, being *T. lepturus* and *P. porosissimus*, which may indicate potential competition (Secchi et al., 2017).

Older dolphins foraged over a broader prey diversity compared to juveniles, suggesting ontogenetic dietary shifts. This suggests improved hunting skills in older individuals, as also observed in other dolphin species (Wilson et al., 2017). Older individuals exhibited a more diversified diet, which may be related to their learning process and increased ability to exploit different prey species. *Mugil platanus* was not recorded in the diet of juvenile females; however, this result could be influenced by the small sample size. Increasing the sample size could help to better understand these ontogenetic changes in diet.

This study contributes with new information on the feeding ecology of the bottlenose dolphins in the south Atlantic Ocean, and the first that considered the discrimination of the common bottlenose dolphin. The diet was composed of various prey species, with a predominance of *Trichiurus lepturus* and *Porichthys porosissimus*, which showed the highest values of relative importance. It also provides preliminary evidence of sex-related and ontogenetic dietary variation. Further research should evaluate temporal trends and potential competition with fisheries to guide management and mitigation measures.

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