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Ecologia alimentar de dois predadores de topo em uma situação de simpatria: o boto (*Tursiops truncatus*) e o leão-marinho (*Otaria flavescens*) no estuário da Lagoa dos Patos e costa marinha adjacente

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ÍNDICE

RESUMO

Neste estudo foram investigados a ecologia alimentar e a potencial competição por recursos entre o leão-marinho (*Otaria flavescens*) e o boto (*Tursiops truncatus*) que vivem em uma situação de simpatria no estuário da Lagoa dos Patos e costa marinha adjacente. As análises foram baseadas em conteúdos estomacais de 72 leões-marinhos e 46 botos, coletados no período de 2002-2012 e 2008-2012, respectivamente. Ambos os predadores comsumiram uma ampla variedade de presas. Apesar de peixes demersais-bentonicos, pelágicos, cefalópodes e crustáceos terem sido consumidos, peixes demersais e demersal-pelágicos predominaram na dieta. *Otaria flavescens* parece ter um nicho trófico mais amplo que *Tursiops truncatus*. Essa diferença pode ser atribuída, ao menos em parte, ao comportamento comensal de leões-marinhos machos adultos, os quais se alimentam de descartes de pescarias. Diferenças intra-específicas na dieta foram encontradas entre os sexos (apenas para leões-marinhos) e classes de maturidade para ambas as espécies. Essas duas espécies apresentaram também diferenças na utilização de recursos em curto (estações) e longo (inter-decadal) prazo na escala de tempo. Mesmo em baixas densidades, esses dois predadores de topo simpátricos estão explorando o ecossitema com alguma separação de nicho ou divisão de recursos intra e inter-específica, o que traz vantagem para suas populações por minimizar a competição por recursos.

Palavras-chave: dieta, competição por recursos, *Otaria flavescens, Tursiops truncatus*

ABSTRACT

We investigated the feeding ecology and the potential resource competition between the South American sea lion (*Otaria flavescens*) and the common bottlenose dolphin (*Tursiops truncatus*) living in sympatry in a sub-tropical estuary and the adjacent marine coast in western South Atlantic. Analyses were based on stomach contents from 72 sea lions and 46 bottlenose dolphins, collected during 2002-2012 and 2008-2012, respectively. Both predators consumed a wide variety of prey. Although some demersal-benthic and pelagic fish, cephalopods and crustaceans were consumed, demersal and demersal-pelagic teleost fish predominated. *Otaria flavescens* seems to have broader tropic niche than *Tursiops truncatus*. This difference can be attributed, at least in part, to the commensal behavior of adult male sea lions that feed upon discarded bycatch from fisheries. Intraspecific differences in diet were also found between sexes (only for sea lions) and status of maturity for both species. These two species also varied their resources utilization in short (seasons) and long (inter-decadal) time scales. Even at relatively low abundances, these two sympatric top predators are exploring the ecosystem with some intra and interspecific niche separation or resource partitioning, which brings advantage to their populations by minimizing resources competition.

Key words: diet, resource competition, *Otaria flavescens, Tursiops truncates*

INTRODUÇÃO

Avaliar hábitos alimentares de mamíferos marinhos é importante para determinar a sua posição na cadeia alimentar e definir seu papel ecológico no ecossistema (Pauly et al. 1998). A posição trófica e papel no ecossistema, no entanto, podem variar entre os componentes da população, devido a diferenças na utilização dos recursos. Variações intra e interpopulacionais na dieta podem trazer vantagens para a população, minimizando efeitos das competições intra e interespecíficos entre as espécies/ populações simpátricas (Schoener 1974, Ford et al. 1998, Saulitis et al. 2000, Bizzarro et al. 2007).

O leão-marinho-do-sul (*Otaria flavescens* - aqui referido como leão-marinho) e o golfinho-nariz-de-garrafa (*Tursiops truncatus*- aqui referido como boto) (Figura 1) são definidos como generalistas, mas têm mostrado uma dieta particular em diferentes regiões, refletindo plasticidade nos hábitos alimentares, os quais variam de acordo com a abundância de presas e sazonalidade em seus locais de ocorrência (George-Nascimento et al. 1985 no Centro do Chile; Koen-Alonso et al. 2000 na costa sul da Argentina; Szteren et al. 2004 no Uruguai; Raya Rey et al. 2012 na Ilha dos Estados, Argentina; Barros e Wells 1998 no sudeste dos Estados Unidos; Barros et al. 2000 no Mar da China Meridional; Blanco et al. 2001 na Espanha; Cockcroft e Ross 1990 na África do Sul). O leão-marinho ocorre em ambos os oceanos, Pacífico e Atlântico, do Peru até o sul do Brasil (Vaz-Ferreira 1981, Cappozzo 2002). O boto é uma espécie de ampla distribuição que habita tanto as áreas costeiras como oceânicas de zonas tropicais e temperadas (Kenney 1990) de todos os oceanos, incluindo estuários e rios (Wells e Scott 1999).

Figura 1. Macho adulto de leão-marinho (*Otaria flavescens*) e o boto (*Tursiops truncatus*) fotografados no estuário da Lagoa dos Patos. Fotos: Rodrigo Genoves

O leão-marinho se alimenta de uma grande variedade de presas, incluindo peixes, cefalópodes, crustáceos e ocasionalmente aves marinhas (George-Nascimento et al. 1985, Koen-Alonso et al. 2000, Suarez et al. 2005; Soto et al. 2006, Raya Rey et al. 2012). Embora existam diferenças ontogenéticas e entre sexos na dieta em diferentes escalas temporais e espaciais, os leões-marinhos parecem predar principalmente sobre espécies demersais e bentônicas em ambas as costas de América do Sul (Siefield 1999, Naya et al. 2000, Suarez et al. 2005). Alguns desses estudos têm relatado diferenças intra-específicas nos hábitos alimentares atribuindo isso, pelo menos parcialmente, a diferenças no uso de áreas de forrageamento entre as classes de maturidade ou sexos (Koen-Alonso et al. 2000, Campagna et al. 2001, Drago et al. 2009). A espécie apresenta um dimorfismo sexual acentuado e sistema reprodutivo de poligamia, com cuidado parental por parte das fêmeas (Beck e Austin 2009). Diferenças nas áreas de forrageamento, por conseguinte, podem ser atribuídas tanto à estratégia de reprodução, o que limita a área em que as fêmeas se alimentam (Vaz Ferreira 1981, Campagna et al. 2001) quanto ao dimorfismo sexual, o qual dá maior potencial fisiológico para machos

adultos realizarem mergulhos mais longos e mais profundos e períodos de jejum mais longos, o que favorece a dispersão para locais de forrageio mais distantes (Boyd 2002).

Estudos prévios sobre a dieta do boto mostraram que a espécie preda sobre uma grande variedade de espécies, incluindo peixes pelágicos e demersais, cefalópodes e crustáceos em diferentes localidades (Norris e Prescott 1961, Pate e McFee 2012 no sudoeste dos Estados Unidos e em águas mexicanas; Barros e Odell 1990; Barros e Wells 1998 no sudeste dos Estados Unidos; Barros et al. 2000 no Mar da China Meridional; Blanco et al. 2001; Santos et al. 2007 na Espanha; Van Waerebeek et al. 1990 no Peru; Cockcroft e Ross 1990 na África do Sul). Além disso, diferenças ontogenéticas na dieta e relacionadas ao sexo foram observadas. Cockcroft e Ross (1990) constataram que machos adultos consomem uma maior proporção de peixes maiores que fêmeas adultas, e que predam espécies que não são consumidas por outros indivíduos da população. Santos et al. (2007) observaram que animais maiores predam peixes maiores, de certas espécies, e em maior quantidade. Blanco et al. (2001) observaram que botos adultos predam sobre uma maior variedade de tamanhos de presas que os juvenis. Pate e McFee (2012), por outro lado, constataram que machos imaturos predam predominantemente sobre peixes em cardumes. Uma tendência de maior consumo de lulas por fêmeas maturas foi observada em algumas regiões (Blanco et al. 2001, Gannon 2003, Pate e McFee 2012). O requerimento de fêmeas maduras por uma dieta de maior qualidade pode estar relacionado com os custos energéticos de reprodução.

Tem sido sugerido que tanto a disponibilidade dos recursos quanto o valor nutricional (tamanho e composição proximal da presa, tais como o conteúdo de gordura, carboidratos, proteínas e água) influenciam na escolha da presa e, portanto, na relação

predador-presa (Gurevitch e Hedges 1999, Costa 2002, Reid et al. 2005). Animais rotineiramente ajustam sua fisiologia e comportamento quando se deparam com mudanças na dieta e condições ambientais (Boyd 2002, McNab 2002). Entretanto, existem limites nos ajustes que um animal é capaz de fazer, e os esforços podem ser insuficientes para compensar declínios significativos no consumo de energia (Jeanniard du Dot et al. 2008). Mudanças na quantidade e qualidade das presas afetam a quantidade de lipídios e proteínas catabolizadas pelos animais para atender as demandas energéticas, que, por sua vez, podem afetar a sobrevivência e a reprodução dos mamíferos marinhos (Rosen e Trites 2004, 2005; Wolf et al. 2006; Trites et al. 2007; Österblom et al. 2008).

Assim como existe variação na composição energética das presas, há uma variação sazonal na necessidade de consumo de calorias por mamíferos marinhos. A exigência total de energia é considerada maior no inverno do que no verão, devido aos custos energéticos mais elevados associados a temperaturas mais baixas, como apontado em um estudo do leão-marinho do norte, *Eumetopias jubatus* (Winship et al. 2002). No entanto, pode-se argumentar que pelo menos fêmeas maduras ou lactantes irão consumir presas mais energéticas ou aumentarão o consumo de alimentos durante a gestação ou lactação, independentemente da estação (Cockcroft e Ross 1990, Kastelein et al. 2002). Embora variações na dieta relacionadas à ontogenia ou ao sexo possam existir devido a diferenças na demanda energética ou capacidade fisiológica/ comportametal de capturar alguns tipos de presas, é provavel que todos os componentes da população se beneficiem ao se minimizar sobreposições tróficas intra e interespecificas. Da mesma forma, as diferenças temporais na dieta, devido à variação sazonal na demanda

energética ou disponibilidade de presas, representam uma adaptação ideal de nicho para maximizar a utilização dos recursos locais.

A disponibilidade de presas pode variar, naturalmente, devido aos efeitos estocásticos em taxas de sobrevivência e reprodução e, portanto, sobre o seu recrutamento, ou devido a causas relacionadas à ação antrópica, tais como a pesca excessiva. A competição entre mamíferos marinhos e pesca é bem documentada (Trites et al. 1997, Plagányi e Butterworth 2005, Bearzi et al. 2008). A sobrepesca pode afetar mamíferos marinhos reduzindo a disponibilidade de suas presas (Plagányi e Butterworth 2005), entretanto, poucos estudos detectaram a relação causa-efeito entre colapso dos estoques pesqueiros devido à pressão de pesca e mudanças na dieta de mamíferos marinhos (Whitehead e Carscadden 1985, Livingston e Tjelmeland 2000, Politi e Bearzi 2004).

O leão-marinho e o boto são predadores de alto nível trófico, e ocorrem em simpatria em alguns locais de suas distribuições, como no oeste do Atlântico Sul, entre a região sul do Brasil e central da Argentina (Bastida et al. 2007). Apesar de não existirem colônias reprodutivas no Brasil, dois assentamentos de algumas dezenas de leões marinhos machos adultos acorrem ao longo do Rio Grande do Sul, na Ilha dos Lobos (29°20´S, 52°06´W), e no Molhe Leste, no estuário da Lagoa dos Patos (32 ° 11'S, 52 ° 04'W) (Vaz-Ferreira 1981, Rosas et al. 1994). Este estuário subtropical é uma importante área de desova e criação de vários peixes e crustáceos (Castello e Möller 1978, Chao 1985, Vieira et al. 1998), que sustentam a pesca comercial e predadores de topo na plataforma continental adjacente (Pinedo 1997, Vooren 1998, Haimovici et al. 2006). O estuário da Lagoa dos Patos é também o habitat de uma população residente de botos, recentemente estimada em 87 indivíduos (Fruet et al. 2011). Esta população é

parte de uma metapopulação que inclui grupos que ocorrem ao longo das zonas costeiras marinhas adjacentes (Genoves 2013, Fruet et al. no prelo).

A razão sexual da população residente do estuário é viesada às fêmeas (ca. 2:1), enquanto a razão sexual de botos encontrados encalhados ao longo da costa é altamente desviada para os machos, na sua maioria jovens (Fruet et al. 2012, no prelo). Isto sugere que, provavelmente, exista um certo grau de separação de habitat como um meio para minimizar a sobreposição trófica com membros da mesma espécie, assim como com a população simpátrica de leãos- marinhos. Os leões-marinhos observados no sul do Brasil são provavelmente originários de colônias reprodutivas do Uruguai, de onde realizam movimentos sazonais à procura de alimento durante o período não reprodutivo (Castello e Pinedo 1977, Artico et al. 2010). Esses movimentos sazonais são realizados em sua maioria por machos adultos e subadultos, talvez para minimizar a competição por recursos com as fêmeas perto das colônias (Castello e Pinedo 1977, Pavanato et al. no prelo). Os movimentos de forrageio das fêmeas são mais restritos a áreas adjacentes às colônias, visto que elas estão envolvidas com o cuidado parental (Vaz-Ferreira 1981, Campagna et al. 2001). Encalhes desta espécie ocorrem durante todo o ano ao longo do litoral do Rio Grande do Sul, com menor frequência durante o verão austral (dezembro a fevereiro) (Kinas et al. 2005, Pavanato et al. no prelo), quando a maioria dos indivíduos reprodutivamente ativos volta para suas colônias de reprodução na costa uruguaia (Campagna 1985, Silva 2004).

Estudos sobre a ecologia alimentar das duas espécies na área de simpatria são principalmente descritivos e não foram publicados. Tem sido demonstrado que os peixes teleósteos demersais predominam na dieta dessas espécies (Pinedo 1982, Pinedo e Barros 1983, Rosas 1989, Falco 2008, Lopez 2009). Também foi observado que botos

se alimentam exclusivamente de peixes teleósteos (Pinedo 1982, Lopez 2009), enquanto os leões marinhos podem consumir elasmobrânquios, cefalópodes, crustáceos, bem como peixes teleósteos (Falco 2008), incluindo rejeitos de barcos de pesca (Bozzeti 2007, L. G. Cardoso comun. Pessoal[1]). No entanto, não foi feita nenhuma tentativa de avaliar sobreposição trófica interespecífica. Semelhanças na composição de presas e nos comprimentos dessas (Falco 2008, Lopez 2009) sugerem uma potencial competição entre as duas espécies de predadores. As hipóteses deste estudo são: i) existem diferenças sazonais na dieta de ambos os predadores devido a padrões temporais da disponibilidade das presas; ii) o dimorfismo sexual e a estratégia reprodutiva do leão-marinho refletem em diferenças ontogenéticas e relacionadas ao sexo na dieta desse predador; iii) difereças no padrão de uso do habitat entre machos e fêmeas adultos de botos conduz a diferenças na sua dieta ; iv) diferenças intra e interespecíficas nas dietas dos dois predadores ocorrem para minimizar a sobreposição trofica.

OBJETIVOS

Objetivo Geral

O objetivo deste estudo foi investigar a ecologia alimentar de dois predadores em simpatria que habitam o estuário da Lagoa dos Patos e costa marinha adjacente

Objetivos Específicos

- Relacionar o tamanho do predador com o tamanho das presas ingeridas;

-Analisar as diferenças nos componentes alimentares entre sexos e classes de maturidade;

- Investigar a existência de variações sazonais e inter-decadais na alimentação;

[1] L.G. Cardoso – Laboratório de Recursos Pesqueiros Demersais e Cefalópodes – Universidade Federal do Rio Grande.

-Analisar a existência de sobreposição intra e interespecífica na dieta dessas duas espécies;

- Quantificar o valor nutricional dos principais itens alimentares desses predadores.

MATERIAIS E MÉTODOS

Área de estudo e coleta de dados

O litoral do Rio Grande do Sul, sul do Brasil, caracteriza-se pela presença de praias arenosas contínuas, distribuídas ao longo de seus 618 km de extensão, ocorrendo interrupções na desembocadura da Lagoa dos Patos, Lagoa do Peixe e rio Tramandaí (Seeliger et al. 2004). A porção sul deste litoral (355 km), delimitada ao norte pela Lagoa do Peixe (31°21'S – 51° 02'W) e ao sul pelo Arroio Chuí (33°45'S-53° 22'W) (figura 2), é monitorada sistematicamente desde 1979, exceto entre 1987 e 1991, para registrar a ocorrência e coletar material biológico de mamíferos marinhos encalhados.

As amostras dos botos e leões-marinhos foram obtidas durante os anos 2002-2012 e 2008-2012, respectivamente.

Figura 2. Área de coleta das amostras analisadas nesse trabalho: Barra da Lagoa do Peixe e do Arroio Chuí nas extremidades norte e sul respectivamente.

Informações como comprimento total e sexo foram registradas e estômagos foram coletados de leão-marinhos e botos em estado de decomposição até o código 4 (*sensu* Geraci e Lounsbury 2005). Os estômagos foram retirados fazendo-se um corte no final do esôfago e outro no início do intestino delgado e amarrados em ambas as extremidades para não perder o conteúdo.

Cada estômago foi colocado em um saco plástico, etiquetado e congelado para posterior análise. Os conteúdos estomacais foram lavados com água corrente sobre uma peneira de 200 µm. Os otólitos foram separados, lavados e armazenados secos em frascos. Bicos de cefalópodes, crustáceos e elasmobrânquios foram conservados em

álcool 70%. Os otólitos e bicos de cefalópodes foram separados em direito e esquerdo (otólitos) e superior e inferior (bicos). Para cada estômago o número máximo de otólitos direito ou esquerdo e bicos superior ou inferior foi considerado como número mínimo de peixes e cefalópodes ingeridos (Barros e Odell 1990).

Todos os otólitos e bicos de cefalópodes foram identificados com o auxilio de um microscópio esterioscópico e comparados com a coleção de referência do *Laboratório de Recursos Demersais e cefalópodes* (*Universidade Federal do Rio Grande - FURG*), com auxilio de especialistas. Para minimizar a subestimação dos valores de tamanho e biomassa das presas ingeridas, as medições foram tomadas somente para os otólitos inteiros e pouco gastos. Para os otólitos gastos ou quebrados foram atribuídas medidas obtidas aleatoriamente de otólitos inteiros das respectivas espécies que estavam presentes no mesmo estômago (Koen-Alonso et al. 2000). Nenhuma medida foi considerada para os otólitos muito gastos e quebrados quando não havia outros otólitos da mesma espécie no mesmo estômago que pudessem ser medidos.

O comprimento total dos otólitos foi medido como a maior distância longitudinal. No caso dos otólitos estarem quebrados nas extremidades utilizou-se a medida da largura, definida como a maior distância perpendicular ao eixo longitudinal. Estas medições foram tomadas com um paquímetro digital com resolução entre 0, 005 e 0,01 mm.

Os elasmobrânquios e crustáceos foram identificados com o auxílio de especialistas dos respectivos laboratórios da FURG. A identificação de elasmobrânquios foi muito limitada devido ao grau de digestão do material. A quantificação também foi prejudicada, pois os peixes cartilaginosos não possuem estruturas resistentes à digestão,

que possibilitam a identificação. Para esse estudo somente os peixes inteiros ou pouco digeridos foram identificados e utilizados para propósito de quantificação.

Análise dos Dados

Os valores obtidos para as dimensões dos otólitos e bicos de cefalópodes foram utilizados para estimar o comprimento total (CT) (teleósteos), comprimento do manto (CM) (cefalópodes) e a biomassa desses itens alimentares. Esses valores foram calculados a partir de equações de regressão específicas (disponíveis no *Laboratório de Recursos Demersais e Cefalópodes- FURG*). Os estômagos vazios foram excluídos das análises. A partir da identificação, contagem dos itens alimentares e os valores de CT dos otólitos, calculou-se a Frequência de Ocorrência (FO%): Número de estômagos em que um determinado táxon ocorre dividido pelo número total de estômago com itens alimentares; Freqüência Numérica (N%): Número total de indivíduos de um táxon dividido pelo número total de presas consumidas; Biomassa (W%): Contribuição numérica de biomassa de cada presa dividida pela biomassa total; e o Índice de Importância Relativa (IIR%): IIR= (N%+W%) FO% (Pinkas et al. 1971).

Sazonalidade

Variação intra-anual na dieta foi avaliada agrupando-se meses quentes e frios de acordo com a temperatura média superficial da água do estuário da Lagoa dos Patos, registrada de 2002 a 2012. A Estação Fria compreendeu os meses de maio a outubro, e a Estação Quente considerou os meses de novembro a abril (figura 3).

Utilizou-se o teste Mann-Whitney para verificar se existe diferença nos comprimentos totais e biomassas dos itens alimentares encontrados entre os estômagos coletados nessas duas estações.

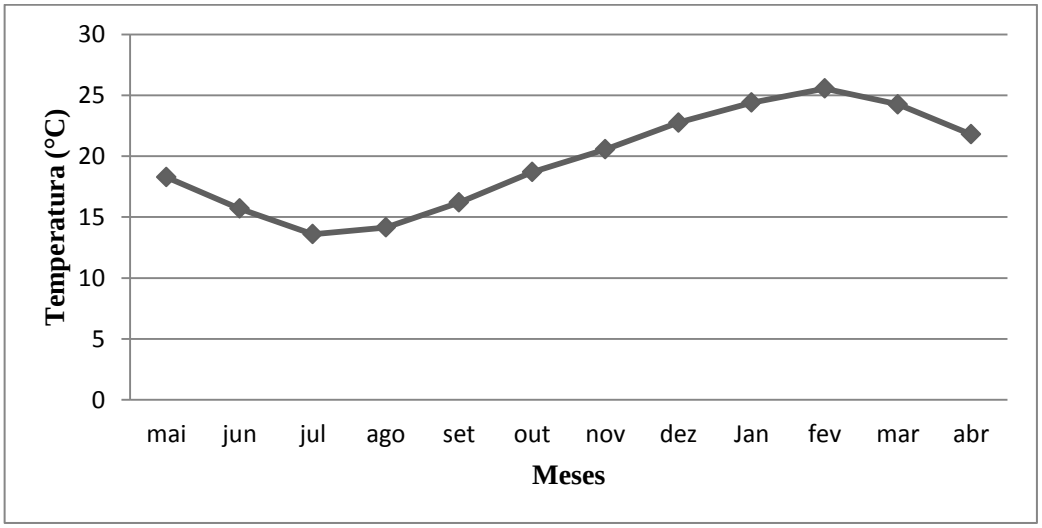

Figura 3. Valores médios mensais de temperatura superficial da água durante o período de coleta dos dados.

Classes de maturidade e sexo

Devido à ausência de informações detalhadas sobre o crescimento e idade em que botos e leões-marinhos atingem a maturidade sexual na região, alguns critérios foram aplicados para definir a classe de maturidade das carcaças coletadas nesse estudo.

As carcaças foram classificadas de acordo com duas classes: juvenis (sexualmente imaturos) e adultos (sexualmente maturos). Fêmeas de mamíferos marinhos são consideradas maturas sexualmente quando atingem aproximadamente 85% de seus comprimentos assintóticos (Laws 1956, Chivers 2002). O critério adotado para definir a maturidade sexual foi baseado em estudos realizados com as mesmas espécies em diferentes regiões.

Para botos, foi utilizado o mesmo critério adotado por Fruet et al. (2012), baseado nas estimativas de Sergeant et al. (1973) para uma população da costa leste da Flórida, Estados Unidos. Nessa região machos e fêmeas maiores de 245 cm e 225 cm,

respectivamente, são sexualmente maturos. Esses comprimentos correspondem a 82.4% e 81.8% de seu comprimento máximo registrado (Sergeant et al. 1973). Fruet et al. (2012) utilizou essa proporção para obter o comprimento aproximado de maturação sexual para machos e fêmeas de botos do Estuário da Lagoa dos Patos. Para aquelas carcaças que não foi possível determinar o sexo, o comprimento de maturidade sexual foi assumido como ponto médio entre os comprimentos estimados para definir a maturidade sexual de machos e fêmeas. De acordo com esses critérios, as classes foram definidas como segue (ver Fruet et al. 2012): i) adultos: machos e fêmeas medindo mais de 318 cm e 278 cm, respectivamente, e indivíduos de sexo indeterminado maiores de 298 cm. ii) juvenis: machos medindo até 318 cm, fêmeas até 278 cm e indivíduos de sexo indeterminado com comprimento total até 298 cm.

Para leões-marinhos, o critério foi baseado nos comprimentos nos quais machos e fêmeas atingem a maturidade sexual na Patagônia, Argentina (Grandi et al. 2010). Segundo esses autores, fêmeas e machos atingem a maturidade sexual em média com 147 cm e 183,5 cm, respectivamente. Para carcaças de sexo indeterminado, o ponto médio (165.5 cm) entre os comprimentos estimados para machos e fêmeas foi utilizado.

A existência de alguma correlação entre o tamanho dos predadores e de suas presas foi testada utilizando-se a correlação de Spearman. Para ambos os predadores diferenças no comprimento médio de cada uma das principais espécies de presas (IIR% >1) foram testadas entre machos e fêmeas e entre adultos e juvenis utilizando-se o teste t- Student ou o equivalente não paramétrico Mann-Whitney, para dados não normais. A normalidade foi verificada com o teste Kolmogorov-Smirnov.

Diferenças em biomassa e número de presas consumidas pelos predadores de diferentes classes de maturidade, sexos e estações do ano foram testadas usando Mann-Whitney, após o teste Kolmogorov- Smirnov.

Períodos interdecadais

Para analisar mudanças temporais na dieta de ambos os predadores foram utilizados dados de Falco (2008), 1977-1983, para leões-marinhos (n = 66) e Pinedo (1982), 1976-1980, para botos (N = 12) como período I. Os resultados do presente estudo foram considerados como período II.

Índices de Sobreposição de Nicho

A existência de uma sobreposição intraespecífica na dieta entre classes de maturidade, sexos, estações e períodos, bem como entre as duas espécies de predadores foram testadas através dos Índices de Sobreposição Específica (SO) e Índice de Sobreposição Geral (GO) (Petraitis 1979, Ludwig e Reinolds 1988). SO e GO contêm valores entre 0 e 1. SO pode ser descrito como a probabilidade de uma curva de amplitude de nicho ser explicada pela outra. Neste caso, é testado se a curva de utilização de um subgrupo (machos, por exemplo) se sobrepõe completamente com a curva de utilização de outro subgrupo (fêmeas) e vice- versa. Isso se dá por tratar-se de curvas assimétricas. Isso quer dizer que a curva *1* pode explicar a curva *2*, mas não necessariamente a curva *2* explique a curva *1* (Petraitis 1979). O GO, por outro lado, testa a probabilidade de se obter a curva de utilização de cada subgrupo de uma curva comum de todos os subgrupos (Petraitis 1979). Para calcular os índices SO e GO, o número de ocorrências das espécies de presa em seus diferentes subgrupos é requerido (ver Ludwig e Reynolds 1988).

O valor de SO é alcançado através da equação:

SO1, 2= e^{E12}

Onde,

$E_{1,2}$=$\sum_j^r.(p_{1j}lnr_jp_{2j})-\sum_j^r.(p_{1j}lnr_jp_{1j})$

Dado que:

p_{1j}= probabilidade de ocorrência do item alimentar j no subgrupo 1;

p_{2j}= probabilidade de ocorrência do item alimentar j no subgrupo 2;

r= grupos de itens alimentares que apresentaram valores de IIR% superiores a 1%.

Para testar a hipótese nula de que a sobreposição específica de curva 1 sobre a curva 2 é completa, utilizaremos a estatística U definida como: U = -2 * N_i * ln (SO_1, $_2$) e que segue uma distribuição qui-quadrado com graus de liberdade r – 1 (Ludwig e Reynolds 1988).

O valor de GO é dado por: GO= e^E

Onde,

E =$\sum_j^s.\sum_j^r.\frac{(nij\ (lncj-lnpij\ ))}{T}$

Dado que:

n_{ij}= número de ocorrências do item alimentar j no subgrupo i;

c_j = proporção combinada do item alimentar j;

p_{ij} = probabilidade de ocorrência do item alimentar j no subgrupo i;

r= grupo de itens alimentares que apresentaram valores de IIR% superiores a 1%.

T= total de ocorrências dos itens alimentares em todos os subgrupos;

Para testar a hipótese de sobreposição geral completa entre os subgrupos (GO = 1), foi utilizado o Teste estatístico V definido como: V=-2*T*ln (GO) e que segue uma distribuição qui-quadrado com graus de liberdade (s - 1)*(r - 1) (Ludwig e Reynolds 1988), como teste U e teste V, ambos são testes estatísticos conhecidos pelo nome de "teste G", que segundo Zar (1984), é descrito como: G= $2*\sum_j^r . O_j *$ln ($O_j E_j$)

Onde,

O_j= valor observado;

E_j= valor esperado.

No caso de SO_{12}, por exemplo, onde o objetivo é avaliar se a curva de amplitude 1 explica a curva de amplitude 2, o valor esperado se torna os dados do subgrupo 1, enquanto o observado, os dados do subgrupo 2. No caso de GO, o teste G é um teste de homogeneidade das duas distribuições.

As análises estatísticas foram realizadas utilizando-se o programa Bioestat 5.3. Para calcular os índices de sobreposição (SO e o GO), foi usado o software da Microsoft Corporation Office, *Excel* 2010. Todos os testes foram feitos adotando um nível de significância de 5%.

Análise energética das principais espécies de presas

A composição proximal e o conteúdo energético foram determinados para as principais presas de ambos os predadores. As espécies foram coletadas um por navio de pesquisa ou obtidos em indústrias locais de pescado entre 2011 e 2012. Os tamanhos dos espécimes amostrados foram selecionados de acordo com seus tamanhos reportados em estudos prévios de dieta do boto e do leão-marinho na região (Falco 2008, Lopez

2009). Sempre que possível, os tamanhos dos peixes amostrados foram os mais próximos ao tamanho médio da espécie na dieta de predadores adultos e juvenis, assim como um tamanho intermediário consumido por essas duas categorias. A determinação da composição proximal das presas foi realizada segundo metodologia oficial (AOAC 1995) para quantificação de proteína, umidade, lipídios e cinzas, em triplicata para cada análise.

As amostras de peixes inteiros foram homogeneizadas utilizando um liquidificador. Para análise da umidade, uma amostra de 5 g foi seca em estufa a 105ºC até peso constante (Método 950.46). Lipídios foram extraídos de uma amostra de 5g com o método de extração por Soxhlet (Método 960.39). Para determinação de cinzas, 1,5 g de amostra foi incinerado em mufla a 600ºC até peso constante (Método 920.153). As proteínas foram determinadas por micro Kjeldahl, de uma amostra de 0,2g (Método 928.08).

A quantidade de carboidratos em peixes não foi medida, pois seu valor energético é praticamente zero (Payne et al. 1999). O valor energético foi obtido indiretamente, utilizando-se o coeficiente de Rubner para organismos aquáticos: 9.5 kcal g^{-1} para lipídios; 5.65 kcal g^{-1} para proteínas (Winberg 1971), e expressos em kJ g^{-1} (massa úmida).

SÍNTESE DOS RESULTADOS

Esta sessão apresenta apenas uma breve síntese dos resultados referentes às análises. A apresentação completa dos resultados encontrados está inserida no Apêndice 1.

A dieta do leão-marinho, *Otaria flavescens.*

Estômagos de 72 leões-marinhos foram analisados. A maioria dos espécimes era macho (n = 48), seguido de fêmeas (n = 15) e indivíduos para os quais o sexo não pôde ser determinado (n = 9). Sessenta e um leões-marinhos eram adultos e onze eram juvenis. As amostras foram coletadas com maior frequência durante os meses frios (n = 47), comparados com meses quentes (n = 25).

A maria-luíza, *Paralonchurus brasiliensis,* e a pescadinha ou pescada-real, *Macrodon atricauda,* foram as espécies de presa mais frequentes (64,7%, 45%) e importantes numericamente (63,6%, 7,8%). A corvina, *Micropogonias furnieri,* e *P. brasiliensis* foram as mais representativas em massa (27,2%, 24,9%) e importância relativa (IIR = 14,1% e 61%).

Análises comparativas

Sexo

Para machos, *Paralonchurus brasiliensis* e *M. atricauda* foram as presas mais importantes em relação a número (59,7%, 9,1%) e ocorrência (82,8%, 48,5%), enquanto as espécies que mais contribuíram em biomassa foram *M. furnieri* (29,5%) e *P. brasiliensis* (23,6%). As presas mais importantes de acordo com IIR% foram *P. brasiliensis* (61,9%) e *M. furnieri* (15,3%).

Para fêmeas, as presas mais importantes numericamente foram *P. brasiliensis* (21%) e a pescada-olhuda, *Cynoscion guatucupa* (20%). *Macrodon atricauda* e *C. guatucupa* (ambos 40%) foram as mais frequentes. Em relação à massa, o peixe-espada, *T. lepturus* (31,3%) e *M. furnieri* (21%) foram os mais importantes, enquanto *Trichiurus lepturus* e *C. guatucupa* demonstraram os maiores IIR% (26,1%, 23,4%).

Os comprimentos das presas mais importantes, exceto *M. atricauda*, ingeridas pelas fêmeas, foram significativamente maiores do que daquelas ingeridas por machos ($p < 0,05$).

Classes de maturidade

Para adultos, *P. brasiliensis* e *M. atricauda* foram, numericamente, as presas mais importantes (65,3%, 7,9%). *Paralonchurus brasiliensis* foi também a mais frequente (65,9%) na dieta desse predador, seguido de *M. atricauda* e *U. brasiliensis* (45,4% cada). *Paralonchurus brasiliensis* e *M. furnieri* foram as espécies mais representativas em massa (25,7%, 29%) e de acordo com IIR (61,4%, 15,0%).

Para os juvenis, *Cynoscion guatucupa* e o mamangá-liso, *Porichthys porosissimus* foram as presas mais importantes em número (31%, 18,4%), biomassa (34,9%, 18,5%) e IIR (31,8%, 17,8%). A presa mais frequente, entretanto, foi *P. brasiliensis* (71,4%). Não existiu correlação entre os tamanho dos predadores e das presas ingeridas por machos ($rs = 0,03$, $p = 0,86$) e por fêmeas ($rs = 0,46$, $p = 0,20$). Os comprimentos de *U. brasiliensis*, *C. guatucupa* e *M. furnieri* ingeridos por juvenis foram significativamente maiores que aqueles ingeridos por adultos ($p < 0,05$).

Sazonalidade

A biomassa ingerida durante os meses frios (média = 5724,4g, DP= 8923,2) não foi significativamente diferente daquela ingerida em meses quentes (média = 5697,9, DP = 7318,2) ($U = 317$, $p = 0,58$).

Durante os meses frios, *P. brasiliensis* e *M. atricauda* foram as presas mais importantes em número (76,9%, 7,5%), frequência de ocorrência (60%, 56,6%) e

importância relativa (70,4%, 11,4%). Em termos de biomassa, a contribuição de *P. brasiliensis* (34,4%) foi a mais importante, seguida de *M. furnieri* (22,5%).

Durante os meses quentes, *P. brasiliensis* (33%) e língua-de-vaca, *Symphurus jenynsi* (20,1%) foram as espécies, numericamente, mais importantes. *Paralonchurus brasiliensis e M. furnieri* (71,4% e 57,1%) foram as mais frequentes e obtiveram as importâncias relativas mais altas (37,4%, 29,2%). A contribuição de *M. furnieri* em biomassa foi a mais alta (35%), seguida de *T. lepturus* (19%).

A dieta do boto, *Tursiops truncatus*

Estômagos de 46 botos foram analisados, incluindo 29 machos, 14 fêmeas e três animais para qual o sexo não pôde ser determinado. A maioria dos animais foi coletada durante os meses quentes (n = 35), enquanto apenas 11 foram coletados em meses frios. Dezessete botos foram classificados como adultos e 29 como juvenis.

Micropogonias furnieri e *P. brasiliensis* foram as presas mais importantes em número (35,3%, 19,9%) e IIR (70,5%, 8,9%). *Micropogonias furnieri* e o papa-terra, *Menticirrhus* sp., foram os mais frequentes (54,8%, 35,4%), enquanto que em termos de biomassa, *M. furnieri* (68,7%) e *T. lepturus*, (14%) foram as espécies mais representativas.

Análises comparativas

Sexo

Para machos, *M. furnieri* e *P. brasiliensis* foram as presas mais importantes em número (32,6%, 24%), frequência de ocorrência (55%, 35%) e IIR (70,3%, 12,2%). A maior contribuição em biomassa foi de *M. furnieri* (67,2%) e *T. lepturus* (17,2%).

Para as fêmeas, por outro lado, *M. furnieri* e *Menticirrhus* sp. foram as presas mais importantes em número (43,8%, 26,7%) e frequência de ocorrência (60% ambos). A espécie mais representativa em massa foi *M. furnieri* (78,8%), seguida de *M. liza* (9,2%) e *Menticirrhus* sp. (8,9%). De acordo com IIR, *M. furnieri* (67,4%) e *Menticirrhus* sp. (20,4%) foram as espécies mais relevantes. Não houve diferenças significativas nos comprimentos médios das presas ingeridas por machos e fêmeas ($p > 0,05$ para todas as comparações).

Classes de maturidade

Para adultos, *M. furnieri* e *T. lepturus* foram as presas mais importantes em número (57,6%, 19,8%), massa (77,4%, 13%) e IIR (84,4%, 6,8%), entretanto *M. furnieri* (60%) e *M. liza* (33,3%) foram as espécies predadas mais frequentemente.

Para juvenis, *M. furnieri* e *P. brasiliensis* foram mais representativas em número (27,5%, 26,1%), ocorrência (50%, ambos) e IIR (53,5%, 21%). As presas mais importantes em massa foram *M. furnieri* (54,6%) e *T. lepturus* (15,3%).

Não houve correlação entre o tamanho dos predadores e o comprimento médio das suas presas ingeridas ($rs = 0,11$ $p = 0,57$). Entretanto quando testados separadamente, *M. furnieri* e *Menticirrhus* sp. ingeridos por adultos foram significativamente maiores que aqueles consumidos por juvenis ($p < 0,05$).

Sazonalidade

A biomassa média ingerida por botos durante os meses quentes (6349,4 g, DP= 8168,8) foi significativamente maior que aquela consumida em meses frios (996,2 g, DP = 758,5) ($U = 29$, $p = 0,01$).

Durante os meses frios, *Menticirrhus* sp. e *P. brasiliensis* foram as presas mais importantes em número (23,3%, 37,9%), ocorrência (50%, 37,5%) e IIR (48,5%, 28,5%). *Menticirrhus* sp. (41,3%) e *T. lepturus* (16,1%) foram as mais representativas em massa.

Nos meses quentes, as presas mais ingeridas, em número, foram *M. furnieri* (41%) e Engraulidae (18,1%). *Micropogonias furnieri* (65,2%) seguido de *T. lepturus* e *M. liza* (34,7% ambos) foram as presas ingeridas mais frequentemente. Essas três espécies foram também as mais importantes em biomassa (72,1%, 13,8% e 8,4%) e importância relativa (77,4%, 8,6% e 5,7%).

Análises intra e inter-específicas de sobreposição de nicho trófico

Considerando GO, não foram encontradas diferenças na dieta de *O. flavescens* entre sexos, estações, classes de maturidade ou períodos. SO, por outro lado, indicou diferenças nas curvas de utilização de recursos entre sexos (machos-fêmeas), classes de maturidade (adultos-juvenis), estações (meses quentes-meses frios e meses frios-meses quentes) e períodos (período I – período II e período II- período I).

Quando a dieta entre sexos foi analisada em botos, não foram encontradas diferenças de acordo com GO e SO. Apesar do GO não ter indicado diferenças na curva de utilização de recursos entre classes de maturidade, algumas diferenças foram detectadas em SO (juvenil - adulto).

Não houve diferenças na dieta dos botos entre as duas estações e períodos de acordo com GO. Entretanto, a hipótese nula de sobreposição completa na utilização de recursos foi rejeitada de acordo com SO para comparações sazonais (meses quentes-meses frios) e períodos (período I- período II e período II- período I), indicando que

existem diferenças sazonais e decadais na dieta dos botos que habitam o estuário da Lagoa dos Patos e área costeira adjacente.

Diferenças significativas foram encontradas na curva de utilização de recursos entre os dois predadores de acordo com ambos, GO e SO. A hipótese nula de sobreposição completa entre as dietas de leões-marinhos e botos foi rejeitada.

Análise energética das principais presas

Apenas pequenas diferenças foram encontradas entre os valores energéticos das principais presas consumidas pelos predadores. A presa mais energética foi *M. liza* (7,3 KJ/g) seguida de *M. furnieri* (6,7 KJ/g) e *Menticirrhus* sp. (6 KJ/g), enquanto a maioria das presas apresentou valores energéticos de cerca de 4 kJ/g .

CONSIDERAÇÕES FINAIS

Os resultados deste estudo indicaram que ambos os predadores são generalistas-oportunistas, isso porque suas dietas são constituídas por um número pequeno de itens dominantes no ambiente e um número relativamente alto de presas menos abundantes.

A comparação das duas dietas sugere que esses predadores compartilham o mesmo perfil de presas, sendo as demersais as mais importantes. Os padrões de forrageamento desses predadores refletem a abundância e distribuição das presas e, em simpatria, as condições ambientais locais podem levar essas espécies a comportamentos alimentares similares (Robinson et al. 2002). Muitas espécies de presas são comuns na dieta dos dois predadores e, até mesmo, o tamanho médio de presas importantes, como *P. brasiliensis*, *M. furnieri* e *T. lepturus*, é semelhante.

Os resultados sugerem que os dois predadores apresentam sobreposição parcial das principais dimensões do nicho alimentar: perfil das presas, habitat de forrageamento, espécies de presas e tamanhos dessas presas. Entretanto, algumas diferenças significativas na dieta do leão-marinho e do boto foram encontradas, demonstrando que a alimentação dessas duas espécies tem algumas diferenças. Essas divergências foram provavelmente devido a diferenças nas frequências de ocorrência de várias das principais presas. Espécies como *M. atricauda, U. brasiliensis, P. brasiliensis* e *C. guatucupa* ocorreram mais frequentemente na dieta de leões-marinhos, enquanto que *M. furnieri, M. liza* e *Menticirrhus* sp. apresentaram frequências mais altas em estômagos de botos.

Otaria flavescens parece ter um nicho trófico mais amplo, apresentando uma dieta mais diversa. Isso pode ser explicado, ao menos em parte, por sua interação com pescarias, o que os proporciona acesso a presas em proporções diferentes daquelas naturalmente disponíveis. Além disso, o habitat de botos costeiros é muito mais restrito a águas rasas que o de leões-marinhos no sul do Brasil (p.ex. Di Tullio 2009, Fruet et al. 2012, Campagna et al. 2001). Mesmo em densidades relativamente baixas, essas duas populações simpátricas estão explorando o ecossistema com alguma separação de nicho ou divisão de recursos, o que traz vantagens para ambos os predadores, minimizando a competição por recursos. Isso é especialmente relevante para populações (ou parte de populações) que habitam áreas costeiras espacialmente restritas.

Algumas diferenças foram encontradas na dieta entre os sexos de leões-marinhos. Essas diferenças podem ser devido a variações nas áreas de forrageamento de machos e fêmeas, comportamento, limite fisiológico de mergulho e podem minimizar a competição intra-específica por recursos. Diferenças nos hábitos alimentares de machos

e fêmeas nas colônias reprodutivas da Patagonia Argentina foram atribuídas, pelo menos em parte, a variações nas áreas de forrageamento (Koen-Alonso et al. 2000). Fêmeas adultas precisam amamentar seus filhotes por vários meses após o parto (Bastida et al. 2007), por isso sua área de forrageamento é limitada aos arredores da colônia, enquanto que machos podem explorar áreas mais afastadas (Koen- Alonso et al. 2000, Campagna et al. 2001, Drago et al. 2010). Além disso, no Sul do Brasil, o leão-marinho, especialmente machos, tiram proveito de descartes de pescarias de arrasto (L. G. Cardoso com. pessoal[2]), o que pode explicar a dominância de *P. brasiliensis* em seus estômagos.

No caso dos botos, não foram encontradas diferenças significativas na dieta de machos e fêmeas. Essa ausência de variação na utilização de recursos entre os sexos pode indicar que competição entre machos e fêmeas pode existir. Apesar da ausência de diferenças significativas, a segunda e a terceira espécies mais importante para fêmeas e machos não foram as mesmas. A importância de *Menticirrhus* sp. e *Mugil liza* na dieta das fêmeas pode ser devido a diferenças nos padrões de uso de habitat. Fêmeas são duas vezes mais frequentes nas águas estuarinas, mais produtivas e protegidas, que machos (Fruet et al. no prelo). Assim como na África do Sul, parece que áreas mais protegidas e rasas são favorecidas a fêmeas (Cockcroft and Ross 1990).

A dieta de *O. flavescens* juvenis não explica a dieta dos adultos. Por outro lado, a amplitude de nicho trófico de juvenis é completamente sobreposta pela dos adultos, indicando que adultos têm uma amplitude de nicho maior. Como comentado anteriormente, diferenças na dieta se devem provavelmente a interações de machos

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adultos com pescarias de arrasto. Essa interação pode causar diferenças importantes na composição da dieta em comparação a fêmeas adultas e juvenis de ambos os sexos.

No caso dos botos, a amplitude de nicho dos adultos é completamente sobreposta pela dos juvenis. Por outro lado, a dieta dos juvenis não é explicada pela dieta dos adultos, indicando que os juvenis têm um nicho trófico mais amplo. Isso pode sugerir que juvenis compensam sua menor experiência, em capturar e selecionar presas, se alimentando oportunisticamente de uma maior variedade de presas. À medida que os botos ganham experiência, presas de maior qualidade ganham importância em sua dieta (p.ex. Santos et al. 2007). De fato, nesse estudo presas maiores e mais energéticas foram consumidas por adultos, especialmente fêmeas.

As diferenças sazonais na dieta de ambos os predadores foram devido a variações na amplitude de nicho entre meses quentes e frios, demonstrando o comportamento oportunista desses predadores. Diferenças na abundância de espécies associadas a meses quentes e frios são determinadas por variações na dinâmica do sistema oceanográfico do sul do Brasil (Haimovici et al. 1996).

A hipótese de que predadores ingerem presas mais energéticas durante os meses frios não foi confirmada. Pelo contrário, presas mais energéticas, como *M. liza* (7,3 KJ/g) e *M. furnieri* (6,7 KJ/g), ocorreram mais frequentemente durante meses quentes na dieta de ambos os predadores. De acordo com Fruet et al. (2012) essa população de botos possui uma estação de nascimentos bem definida, de dezembro a início de março, com pico em janeiro/fevereiro. A ingestão de presas mais energéticas, durante os meses quentes, coincide com o período em que fêmeas de botos dão a luz e precisam de mais energia para amamentar os filhotes. Fêmeas lactantes perdem muita energia através do

leite (Ridgway et al. 1995). Se fêmeas selecionam *M. liza*, por seu valor calórico, ou predam sobre as presas mais abundantes permanece sem resposta, entretanto, se a motivação fosse a abundância, seria esperado um aumento similar no consumo dessa presa por machos.

Os estoques de *M. furnieri* colapsaram devido à exploração extensiva pelas pescarias (Reis 1994), enquanto que a abundância de *Mugil liza* varia inter-anualmente devido à pressão pesqueira e à estocasticidade ambiental (Garcia et al. 2003, Miranda et al. 2006), tornando- as menos disponíveis para esses predadores, pelo menos durante alguns anos. Se mudanças na composição da dieta de presas calóricas para presas pouco energéticas ocorrem, isso pode ter consequências no potencial reprodutivo e sobrevivência desses predadores. Trites e Donelly (2003) mostraram evidências fortes da relação entre o declínio de leões-marinhos-do-norte, *Eumetopias jubatus*, no Golfo do Alasca e Ilhas Aleutas, e a reduzida disponibilidade de presas adequadas, com alta qualidade nutricional.

A composição da dieta de ambos os predadores não é muito diferente de cerca de 30 anos atrás. Entretanto, as frequências de ocorrência das principais presas variaram, e algumas espécies trocaram de posição em importância. Para os leões-marinhos as diferenças encontradas entre os períodos foram principalmente devido a variações nas frequências de ocorrência de espécies como *M. atricauda, M. furnieri* e *U. canosai* que eram mais importantes durante o período I, enquanto que *P. brasiliensis* e *U. brasilinesis* passaram a ser mais importantes no período II.

Para os botos, as diferenças encontradas em SO podem ser explicadas principalmente pelo declínio na frequência de ocorrência de *M. furnieri* e pelo aumento

de espécies como *T. lepturus* e *P. brasiliensis*. Além disso, durante o primeiro período *Menticirrhus* sp. esteve ausente, enquanto que no período II foi uma presa importante. Esse decréscimo na ocorrência de *M. furnieri*, *M. atricauda* e *U. canosai* coincide com o período no qual houve um acentuado declínio nos desembarques dessas espécies na região (Reis 1992, Haimovici 1998, Cardoso e Haimovici 2011). Esses dados também corroboram estudos sobre o status dos estoques de corvina no sul do Brasil (Haimovici 1997). De acordo com esse autor, a corvina foi sobre-explorada entre as décadas de 80 e 90. Por outro lado, espécies que não são tão importantes comercialmente, como *P. brasiliensis* e *T. lepturus* (no caso dos botos), tornaram- se mais importantes com a redução da disponibilidade de espécies comercialmente exploradas. A mesma tendência de decréscimo na ocorrência de *M. furnieri* e *M. atricauda* e de aumento de importância de *T. lepturus* foi observada na dieta da toninha, *P. blainvillei*, nessa região (Bassoi 1997, 2005; Secchi et al. 2003). Isso sugere que mudanças na abundância de espécies comercialmente importantes podem afetar a ecologia alimentar de mamíferos marinhos de nível trófico alto.

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APÊNDICE 1

Artigo a ser submetido à revista Marine Mammal Science

Feeding ecology of two sympatric top predators inhabiting a subtropical estuary and adjacent coast in western South Atlantic

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Abstract

We investigated the feeding ecology and the potential resource competition between the South American sea lion (*Otaria flavescens*) and the common bottlenose dolphin (*Tursiops truncatus*) living in sympatry in a sub-tropical estuary and the adjacent marine coast in western South Atlantic. Analyses were based on stomach contents from 72 sea lions and 46 bottlenose dolphins, collected during 2008-2012 and 2002-2012, respectively. Both predators consumed a wide variety of prey. Although some demersal-benthic and pelagic fish, cephalopods and crustaceans were consumed, demersal and demersal-pelagic teleost fish predominated. *Otaria flavescens* seems to have broader tropic niche than *Tursiops truncatus*. This difference can be attributed, at least in part, to the commensal behavior of adult male sea lions that feed upon discarded bycatch from fisheries. Intraspecific differences in diet were also found between sexes (only for sea lions) and status of maturity for both species. These two species also varied their resources utilization in short (seasons) and long (inter-decadal) time scales. Even at relatively low abundances, these two sympatric top predators are exploring the ecosystem with some intra and interspecific niche separation or resource partitioning, which brings advantage to their populations by minimizing resources competition.

Key words: diet, resource competition, marine mammals, *Otaria flavescens*, *Tursiops truncatus*

Introduction

Evaluating the feeding habits of marine mammals is important to determine their position in the food chain and define their ecological role in the ecosystem (Pauly et al. 1998). These ecological traits, however, might vary within components of the population due to different resources utilization. Intra and interpopulational variation in diet might bring advantages to the population by minimizing both intraspecific and interspecific effects of competition with sympatric species/populations (Schoener 1974, Ford et al. 1998, Saulitis et al. 2000, Bizzarro et al. 2007).

The South American sea lion (*Otaria flavescens* – here in referred as sea lion) and the common bottlenose dolphin (*Tursiops truncatus*– here in referred as bottlenose dolphin) are defined as generalists, but have shown a particular diet in each place where they occur, reflecting plastic trophic habits according to prey abundance and seasonality in their home range (George-Nascimento et al. 1985 off Central Chile; Koen- Alonso et al. 2000, off northern Patagonia coast; Szteren et al. 2004 off Uruguay; Soto et al. 2006 off Peru; Barros e Wells 1998 off southeastern United States; Barros et al. 2000 off the South China Sea; Cockcroft and Ross 1990 off South Africa). The sea lion occurs in both the Pacific and Atlantic Oceans from Peru to southern Brazil (Vaz-Ferreira 1981, Cappozzo 2002). The bottlenose dolphin, on the other hand, is a wide-range species inhabiting both coastal and oceanic areas of tropical and temperate zones (Kenney 1990), of all oceans, sometimes entering estuaries and rivers (Wells and Scott 1999).

The sea lion feeds on a wide variety of prey, including fish, cephalopods, crustaceans and occasionally seabirds (George-Nascimento et al. 1985, Koen- Alonso et al. 2000, Suarez et al. 2005, Soto et al. 2006, Raya Rey et al. 2012). Although there are ontogenetic and gender-related variation in diet at different spatial and temporal scales, sea lions seem to prey mostly on demersal or benthic species, off both coasts of South America (Siefield 1999, Naya et al. 2000, Suarez et al. 2005). Some of these studies have reported intraspecific differences in food habits, attributing them, at least partially, to the different use of foraging areas between reproductive classes or sex (Koen-Alonso et al. 2000, Campagna et al. 2001, Drago et al. 2009). The species shows a marked sexual dimorphism and a polyginous breeding system with female parental care (Beck and Austin 2009). Differences in foraging ground, therefore, might be attributed to both the reproductive strategy, which limits the range of females foraging ground (Vaz Ferreira 1981, Campagna et al. 2001) and the sexual dimorphism, which gives higher physiological potential for males to perform longer and deeper dives and longer fasting period that favors dispersion to distant feeding sites (Boyd 2002).

Previous studies on the diet of bottlenose dolphins showed that they prey upon a wide variety of species including pelagic and demersal fish, cephalopods and crustaceans in different locations (Norris and Prescott 1961, Pate and McFee 2012 off southwestern United States and Mexican waters; Barros and Odell 1990, Barros and Wells 1998 off the southeastern United States; Barros et al. 2000 off the South China Sea; Blanco et al. 2001, Santos et al. 2007 off Spain; van Waerebeek et al. 1990 off Peru; Cockcroft and Ross 1990 off South Africa). This has led some authors to consider bottlenose dolphins as opportunistic feeders according to their different environments (Leatherwood et al. 1975, Barros and Odell 1990, Blanco et al. 2001). Furthermore, ontogenetic and gender-

related differences in diet have been observed. Cockcroft and Ross (1990) found that adult males consume a greater proportion of larger fish than did adult females, and also took species either not consumed at all. Santos et al. (2007) observed that larger animals take more and bigger fish of certain species. Blanco et al. (2001) found that adult bottlenose dolphins feed upon a greater variety of prey sizes than juveniles. Pate and McFee (2012), on the other hand, found that immature males prey predominantly upon shoaling fish. A trend towards greater consumption of squid by mature female was observed in some regions (Blanco et al. 2001, Gannon 2003, Pate and McFee 2012). The requirement for a higher quality diet of mature females might be related to energetic costs of reproduction.

It has been suggested that both the availability of resources and the nutritional value (size and proximal composition of the prey, such as content of fat, carbohydrate, protein and water), influence the choice of prey and hence the predator-prey relationship (Gurevitch and Hedges 1999, Costa 2002, Reid et al. 2005). Animals routinely adjust their physiology and behavior when faced with changes in diet and ecosystem conditions (Boyd 2002, McNab 2002). However, there are limits on the adjustments that an animal is capable of doing and efforts may be insufficient to compensate significant declines in energy intake (Jeanniard du Dot et al. 2008). Changes in quantity and quality of prey affect the amount of lipid sand proteins catabolized by animals to attempt energy demands, which, in turn, can affect the survival and reproduction of marine mammals (Rosen and Trites 2004, 2005; Wolf et al. 2006; Trites et al. 2007; Österblom et al. 2008).

Just as there is variation in energy composition of preys, there is a seasonal variation in the need for calories consumption by marine mammals. The total energy requirement is

considered higher in winter than in summer, due to higher energy costs associated with lower temperatures, as pointed out in a study of the northern sea lion, *Eumetopias jubatus* (Winship et al. 2002). Nevertheless, it can be argued that, at least mature or lactating females will consume higher energetic prey or increase food consumption during gestation or lactation, regardless of the season (Cockcroft and Ross 1990, Kastelein et al. 2002). Although the ontogenetic or gender-related variation in diet might exist because of either differences in energetic demands or physiological fitness/behavioral skills to catch some sorts of prey, it is probable that all components of the predator population will benefit by minimizing both intra and interspecific trophic overlap. Likewise, temporal differences in diet, due to seasonal variation on energetic demand or prey availability, represent an optimal niche adaptation to maximize local resource utilization. Prey availability might vary naturally due to stochastic effects on survival and reproductive rates, and hence on recruitment of prey, or due to human-related causes such as overfishing. Competition between marine mammals and fisheries is well documented (Trites et al. 1997, Plagányi and Butterworth 2005, Bearzi et al. 2008). Overfishing can affect marine mammals by reducing the availability of their prey (Plagányi and Butterworth 2005), however, only few studies detected cause-effect relationship between fish stock collapse due to fishing pressure and changes in marine mammal diet (Whitehead and Carscadden 1985, Livingston and Tjelmeland 2000, Politi and Bearzi 2004).

The sea lions and bottlenose dolphins are high trophic level predators with sympatric distribution in parts of their range, such as in the western South Atlantic, between southern Brazil and central Argentina (Bastida et al. 2007). Although there are nobreeding colonies in Brazil, two haul-outs of a few dozens of adult male sea lions

occur along the coast of Rio Grande do Sul state, at Lobos Island (29°20´S, 52°06´W), and at the jetties of the Rio Grande port, in the Patos Lagoon estuary (32°11´S, 52°04´W) (Vaz-Ferreira 1981, Rosas et al. 1994). This subtropical estuary is an important spawning and nursing habitat of several fish and crustaceans (Castello and Möller 1978, Chao 1985, Vieira et al. 1998) that sustains commercial fisheries and top predators in the adjacent continental shelf (Pinedo 1997, Vooren 1998, Haimovici et al. 2006). The Patos Lagoon estuary is also home of a resident population of bottlenose dolphins, recently estimated in 87 individuals (Fruet et al. 2011). This population is part of a metapopulation that includes groups occurring along the adjacent marine coastal zones (Genoves 2013, Fruet et al. in press). The sex ratio of the estuary-resident population is female biased (2:1), while the sex distribution dolphins washed ashore along the coast is highly skewed towards males, mostly juveniles (Fruet et al. 2012, in press). This suggests that some degree of habitat partitioning is likely to exist as a mean to minimize trophic overlap with conspecifics as well as with the sympatric sea lion population. The sea lions observed in southern Brazil come from breeding colonies of Uruguay, from where they perform seasonal migrations in search for food during the non-breeding period (Castello and Pinedo 1977, Artico et al. 2010). These seasonal movements are performed mostly by adult and subadult males, perhaps to minimize resource competition with females near the colonies (Castello and Pinedo 1977, Pavanato et al. in press). Females foraging movements are more restricted to adjacencies of the colonies as they are involved in parental care (Vaz- Ferreira 1981 Campagna et al. 2001). Strandings of this species occur throughout the year all along the coast of Rio Grande do Sul, with lower frequency during austral summer (December to February) (Kinas et al. 2005, Pavanato et al. in press), when most reproductively

active individuals return to their breeding colonies on the Uruguayan coast (Campagna 1985, Silva 2004). Studies on the feeding ecology of these two species in this area of sympatry are mostly descriptive and unpublished. It has been demonstrated that teleost demersal fish predominate in the diet of both species (Pinedo 1982, Pinedo and Barros 1983, Rosas 1989, Falco 2008, Lopez 2009). It has also been shown that bottlenose dolphins feed exclusively on teleost fish (Lopez 2009) while sea lions might consume elasmobranchs, cephalopods, crustaceans as well as teleost fish (Falco 2008) including discards from fishing boats (Bozzeti 2007, Cardoso pers. Commn[3]). Though, no attempt to assess intra and interspecific trophic overlap has been made. Similarities in prey composition and length range (Falco 2008, Lopez 2009) suggests a potential interspecific competition.

The objective of this study was to investigate the feeding ecology of two sympatric predators inhabiting a productive area in the inner continental shelf of the western South Atlantic. The hypotheses to be tested were that: i) there are seasonal differences in the diet of both predators due to temporal patterns of prey availability; ii) the sexual dimorphism and reproductive strategy of sea lions reflect gender-related and ontogenetic differences in their diet; iii) the sex-biased distribution leads to differences in the diet of adult bottlenose dolphins; and iv) intra and interspecific differences in diet occurs to minimize trophic overlap.

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Materials and methods

Study area and data collection

The coast of Rio Grande do Sul, southern Brazil, is characterized by the 618 km long sandy beach that is interrupted by the Tramandai river and Peixe Lagoon bar, to the north portion and by the mouth of Patos Lagoon estuary to the south (Seeliger et al. 2004). The southern portion of this coastline (355 km), bounded to the north by the Peixe lagoon bar (31°21'S – 51° 02'W) and to the south by Chui (33°45'S-53° 22'W) (Figure1), is systematically monitored since 1979, except between 1987 and 1991 to record the occurrence and collect biological samples from stranded marine mammals. The bottlenose dolphin and sea lion samples were obtained in the periods 2002-2012 and 2008-2012, respectively.

Total length and sex were determined and stomachs were collected from sea lion and bottlenose dolphin carcasses of decomposition state up to code 4 (*sensu* Geraci and Lounsbury 2005). The stomachs were removed by cutting at the end of the esophagus and beginning of small intestine tying at both ends to avoid losing contents.

Stomach contents were gently washed with running water over a 200µm mesh sieve. Otoliths were separated, washed, dried and stored. Cephalopods beaks, crustaceans and elasmobranchs were preserved in 70% alcohol. Otoliths and beaks were separated into right and left and upper and lower, respectively. For each stomach, the maximum number of right or left otoliths and upper or lower beaks was considered as the minimum number of fish and cephalopods intake (Barros and Odell 1990).

All otoliths and beaks were identified under a stereoscopic microscope and compared with the reference collection of *Laboratório de Recursos Demersais e Cefalópodes*

(*Universidade Federal de Rio Grande- FURG*). In order to minimize underestimation of size and biomass of consumed prey, measurements were taken only for whole or little worn otoliths. Worn or broken otoliths had their measurements assigned based on length of entire or slightly worn otolith of the same species randomly sampled withing the same stomach (Koen-Alonso et al. 2000). No measure was considered for very worn or broken otoliths when there was no other otolith of the same species in the same stomach that could be measured.

Otolith total length was measured as the longest longitudinal distance. In the case of otoliths with broken ends, the width, defined as the greatest distance perpendicular to the longitudinal axis, was used. All measurements were taken using a digital caliper, with resolution between 0.005 and 0.01mm.

Identification of elasmobranchs was very limited due to the degree of digestion of the material. The quantification was also limited because cartilaginous fish do not possess structures resistant to digestion. Only the whole or slightly digested fish could be identified and used for quantitative purposes.

Data analysis

The values obtained for the dimensions of the otoliths and beaks were used to estimate the total length (TL) of teleost, mantle length (ML) of cephalopods and their biomass. These values were calculated using specific regression equations (available from the *Laboratório de Recursos Demersais e Cefalópodes- FURG*). Empty stomachs were excluded from the analyses. The frequency of occurrence (%FO): number of stomachs in which a particular taxon occurs divided by the total number of stomachs with food items; numerical frequency (%N): Total number of individuals of a taxon divided by the

total number of prey consumed; biomass (%W): contribution of each prey biomass divided by total biomass. The Index of Relative Importance (IRI): was calculated as IRI= (%N+%W) %FO (Pinkas et al. 1971).

Seasonality

Within year variation in the diet was evaluated by clumping months into warm and cold seasons according to mean Patos Lagoon estuary surface water temperature from 2002 to 2011 (Brazilian Long Term Ecological Research – Site 8: Patos Lagoon Estuary and Adjacent Coast – Istituto de Oceanografia, Universidade Federal do Rio Grande). Cold and warm seasons ranged from May to October, and from November to April, respectively. Mann-Whitney was used to test for differences between total length and total biomass of food items found in stomachs collected during these two seasons.

Maturity classes and sex

Detailed information on the growth and on the age or length at which bottlenose dolphins and sea lions attain sexual maturity in the region is lacking. Carcasses were classified according to two classes: adults (sexually mature) and juvenile (sexually immature). Females of marine mammals are considered sexually mature when they reach *ca.* 85% of its asymptotic lengths (Laws 1956, Chivers 2002). Therefore, the criterion used to define sexual maturity was based on studies of the same species, but from different locations.

For dolphins, we used the same approach as Fruet et al. (2012), based on the estimates of Sergeant et al. (1973) for a population from the east coast of Florida, United States. In this region, males and females over 245cm and 225cm, respectively, are sexually mature, corresponding to 82.4% and 81.8% of their maximum recorded lengths

(Sergeant et al. 1973). For those carcasses whose sex determination was not possible, length at sexual maturity was assumed to be the midpoint between males and females estimated lengths. According to these criteria, the classes were defined as follow (see Fruet et al. 2012): i) adults: males and females measuring over 318cm and 278cm, respectively, and individuals of undetermined sex larger than 298cm; ii) juveniles: males measuring up to 318 cm, females up to than 278 cm and individuals of undetermined sex with total length up to 298 cm.

For sea lions, the criteria were based on lengths at which males and females reach sexual maturity in Patagonia, Argentina (Grandi et al. 2010). According to these authors, females and males reach sexual maturity at a mean length of 147cm and 183.5 cm, respectively. For carcasses of undetermined sex, the midpoint (165.5 cm) between the estimated lengths of males and females was used.

The relationship between the size of both predators and their preys were assessed through Spearman's correlation tests. For both predators differences in the mean length of each of the main prey species (% IRI >1) were tested between males and females and between adults and juveniles using Student-t test or equivalent non-parametric Mann-Whitney. Normality was verified with Kolmogorov-Smirnov test. Differences in biomass and number of prey consumed by predators of different maturity classes, gender and period of year were tested using Mann-Whitney, after Kolmogorov-Smirnov test.

Interdecadal periods

Temporal changes in the diet of both predators were assessed using data on stomach contents from 1977-1983, for sea lions (n=66) (Falco 2008), and from 1976-1980, for

bottlenose dolphins (n=12) (Pinedo 1982). These data referred as “period I” were compared to the results of the present study, referred as “period II”.

Niche Overlap Indexes

The existence of intraspecific dietary overlap between maturity classes, sexes, seasons and periods, as well as between the two predator species were evaluated with Specific Overlap Index (SO) and General Overlap Index (GO) (Petraitis 1979, Ludwig and Reynolds 1988). Both indexes contain values between 0 and 1. SO can be described as the probability of one curve of niche utilization be explained by the other. In this case, it is tested whether the utilization curve of a subgroup (male, for example) completely overlaps with the utilization curve of other subgroup (females) and vice- versa. Because they are asymmetrical curves, it means that curve 1 may explain curve 2, but not necessarily curve 2 explains curve 1 (Petraitis 1979). The GO, on the other hand, evaluates the probability of obtaining the utilization curve of each subgroup from the common utilization curve of all groups (Petraitis 1979). In order to calculate the GO and SO, the number of occurrences of prey species in the different subgroups is required (see Ludwig and Reynolds 1988).

The SO value is calculated by the equation:

$SO_{1,2} = e^{E1,2}$

Where,

$E_{1,2} = \sum_j^r .(p_{1j} ln r_j p_{2j}) - \sum_j^r .(p_{1j} ln r_j p_{1j})$

Since:

p_{1j}= probability of occurrence of the food item j in subgroup 1;

p_{2j}= probability of occurrence of the food item j in subgroup 2;

r= groups of food items with values of IRI higher than 1%.

The null hypothesis of complete specific overlap of the curve 1 on curve 2 is tested through statistic U test, defined as: U = -2 * N_i * ln ($SO_{1,\ 2}$) and that follows a chi-square distribution with degrees of freedom r - 1 (Ludwig and Reynolds 1988).

The GO value is given by: GO= e^E

Where,

$E = \sum_j^s . \sum_j^r . \frac{(nij\ (lncj - lnpij))}{T}$

Since:

n_{ij}= number of occurrences of the food item j in subgroup i;

c_j = combined proportion of food item j;

p_{ij} = probability of occurrence of the food item j in sub group i;

r= groups of food items with values of IRI higher than 1%.

T= total occurrences of food items in all subgroups.

The hypothesis of complete general overlap between subgroups (GO =1), is verified by the statistic V test, defined as: V=-2*T*ln (GO). It follows a chi-square distribution with degrees of freedom (s -1) *(r -1) (Ludwig and Reynolds 1988), as U test and V test, both are known by the name "G test", which according to Zar (1984), is described as: G= $2 * \sum_j^r . O_j *$ln ($O_j E_j$)

Where,

O_j= observed value;

E_j= expected value.

In the case of $SO_{1,2}$, for example, where the goal is to evaluate whether the amplitude curve 1 explains the utilization curve 2, the expected value becomes the subgroup 1 data, while the observed becomes the second subgroup data. In the case of GO, G test is a test for homogeneity of the two distributions.

Statistical analyzes were performed using the BioStat 5.3. To calculate the index of overlap (SO and GO), we used the software of Microsoft Office, Excel 2010. For all tests a significance level of 5% was adopted.

Energetic analysis of the main prey species

The proximate composition and energy content were determined for the main prey of both marine mammal predators. The species were collected during research expeditions or obtained from local fishing industries between 2011 and 2012. The sampled species were selected according to those in previous diet studies of bottlenose dolphin and sea lion in the region (Falco 2008, Lopez 2009). Whenever possible, three sizes of fish were sampled: near the mean length of that species as a prey of adult and juvenile predators and an intermediate length. The proximate composition of prey was determined according to official methods (AOAC 1995) for quantification of protein, moisture, lipid and ash in triplicate for each analysis.

Samples were homogenized using a blender. For analysis of moisture, a 5 g sample was dried at 105° C until a constant weight (Method 950.46). Lipids were extracted from a 5g sample with a Soxhlet (Method 960.39). For ash determination a 1.5 g sample was incinerated in a muffle furnace at 600°C until constant weight (Method 920.153). The proteins were determined by micro Kjeldahl from a 0.2 g sample (Method 928.08). The amount of carbohydrates was not measured because its energy value is near to zero in fish (Payne et al. 1999). The energy value was obtained indirectly using the Rubner's

coefficient for aquatic organisms: 9.5 kcal g^{-1} for lipids, 5.65 kcal g^{-1} for proteins (Winberg 1971), expressed in kJ g^{-1} (wet weight).

Results

Otaria flavescens

Most of the specimens were males (n= 48), followed by females (n= 15) and individuals for which the sex could not be determined (n= 9). Sixty-one sea lions were adults and eleven were juveniles. Samples were collected more frequently during cold (n= 47) than during warm months (n= 25). The length of sea lions ranged from 106.5 to 264 cm (Figure 2).

Stomachs of 72 sea lions were analyzed, among which food remains were found in 51 sea lions and included otoliths of 3372 teleosts (39 could not be identified due to advanced digestion), structures of 18 elasmobranches, nine cephalopods and four crustaceans. These items encompassed at least 27 species, including 20 teleosts, two elasmobranchs, two cephalopods and three crustaceans (Table 1). Nine teleost species belonged to the family Sciaenidae and the remaining represented 11 different families (Table 1).

The number of prey items per stomach varied from 1 to 556 (mean= 68.8, SD= 123), and the diversity of taxa found in individual sea lion ranged from 1 to 9 (mean= 3.9, SD= 2.2). The mean estimated weight of stomach contents was 5713.6 g (SD= 8224.8). Size of prey ranged from 25.7 mm to 1229 mm (mean= 180.6 mm, SD= 116.8). The banded croaker, *Paralonchurus brasiliensis*, and the southern king weakfish, *Macrodon atricauda*, were the most numerically important (63.6%, 7.8%) and frequent (64.7%, 45%) prey. The whitemouth croaker, *Micropogonias furnieri*, and *P. brasiliensis* were

the most representative by weight (27.2%, 24.9%) and relative importance (IRI= 14.1% and 61%) (Table 1).

Comparative analyses

Sex

Thirty-five stomachs of males and 10 of females contained solid food remains. Males consume 26 taxa, while females ingested 13 (Table 2). The mean biomass ingested by male sea lions (6719.7 g, SD = 9422.3) were not significantly different than that consumed by females (3380.2 g, SD = 2670.6) (U=149, p=0.9).

For males, *P. brasiliensis* and *M. atricauda* were the most important prey by number (59.7%, 9.1%) and occurrence (82.8%, 48.5%), while the higher contribution in biomass came from *M. furnieri* (29.5%) and *P. brasiliensis* (23.6%). The most important prey according to %IRI were *P. brasiliensis* (61.9%) and *M. furnieri* (15.3%) (Table 2, Figure 3).

For females the most numerically important prey were *P. brasiliensis* (21%) and the stripped weakfish, *Cynoscion guatucupa* (20%). *Macrodon atricauda* and *C. guatucupa* (both 40%) were the most frequent. By weight, the cutless fish, *Trichiurus lepturus* (31.3%) and *M. furnieri* (21%) were most important, while *T. lepturus* and *C. guatucupa* showed the highest IRI (26.1%, 23.4%) (Table 2, Figure 3). No elasmobranchs or crustaceans and only one squid, *Loligo sanpaulensis*, were found in the diet of females (Table 2). The length of the most important prey except (*M. atricauda*) ingested by females were significantly larger than that ingested by males ($p < 0.05$, table 3 a).

Maturity classes

Forty-four adults (30 males and 9 females) and seven juveniles (5 males and 1 female) presented prey items in their stomach. There were no significant differences in the mean number (75.67 g, SD = 129.96 *vs* 19.0 g, SD = 9.66, U = 112.5, p = 0.86) and biomass (6116.07 g, SD = 8705.37 *vs* 2723.80 g, SD =1318.47, U = 108, p = 0.98) of ingested prey between adult and juvenile sea lions.

For adults, *P. brasiliensis* and *M. atricauda* were, numerically, the most important prey (65.3%, 7.9%). The former was also the most frequent (65.9%) in the diet of this predator, followed by *M. atricauda* and *U. brasiliensis* (45.4% each). *Paralonchurus brasiliensis* and *M. furnieri* were the most representative species by weight (25.7%, 29%) and according to IRI (61.4%, 15.0%) (Table 4, Figure 3).

Among juveniles, *Cynoscion guatucupa* and *Porichthys porosissimus* were the most important prey in number (31%, 18.4%), biomass (34.9%, 18.5%) and IRI (31.8%, 17.8%). The most frequent prey, however was *P. brasiliensis* (71.4%) (Table 4, Figure 3). There was no correlation between the sizes of the predators and their ingested preys (r_s = 0.03, p= 0.86) for males (r_s = 0.46, p= 0.20) for females (Figures 4 and 5). The lengths of *U. brasiliensis*, *C. guatucupa* and *M. furnieri* ingested by juveniles was significantly larger than those ingested by adults ($p < 0.05$, see Table 3 b).

Seasonality

Thirty stomachs contained identifiable prey remains during cold and 21 in warm months, 17 stomachs were empty during cold and four during warm months. During cold months 20 taxa were found and the mean number of prey items consumed was 82 (SD = 152), while in the warm months 19 taxa were found and the mean number of prey

ingested was 49.6 (SD = 59) (Table 5). This difference was non-significant (U = 307.5, p = 0.72). The biomass ingested during cold months (mean = 5724.4g, SD = 8923.2) was not significantly different than that ingested at warm months either (mean = 5697.9g, SD = 7318.2) (U = 317, p = 0.58).

During cold months *P. brasiliensis* and *M. atricauda,* were the most important in number (76.9%, 7.5%), frequency of occurrence (60%, 56.6%) and relative importance (70.4%, 11.4%). In terms of biomass the contribution of *P. brasiliensis* (34.4%) was the most important, followed by *M. furnieri* (22.5%) (Table 5).

During warm months, *P. brasiliensis* (33%) and tonguefish, *Symphurus jenynsi* (20.1%) were the species, numerically, most important. *Paralonchurus brasiliensis and M. furnieri* (71.4% and 57.1%) were the most frequent and showed the highest relative importance (37.4%, 29.2%). The contribution of *M. furnieri* was highest in biomass (35%) followed by *T. lepturus* (19%) (Table 5).

Tursiops truncatus

Stomachs of 46 bottlenose dolphins were analyzed, including 29 males, 14 females and three animals for which the sex could not be determined. Most of the animals were collected during warm months (n = 35), while only 11 were sampled in cold months. Seventeen dolphins were classified as adults and 29 as juveniles. The length of dolphins ranged from 134 to 362 cm (Figure 6).

Food remains were found in only 31 stomachs and included otoliths of at least 587 teleosts, structures of one cephalopod and three crustaceans (Table 6). Fish found in the dolphins' stomachs represented at least 13 taxa, seven of which (53.8%) belonged to Sciaenidae and the other six to one family each. The only cephalopod beak found

belonged to the order Octopoda. Crustaceans were represented by two specimens of Anomura and one unidentified shrimp.

The number of prey per stomach varied from 1 to 89 (mean = 19.2, SD = 23.8) and the diversity of taxa found in individual dolphins ranged from 1 to 7 (mean = 2.7, SD = 1.7). Mean weight of stomach contents was 5108.6g (SD = 7548) and size of prey varied from 29.2 mm to 1072.8 mm (mean = 291.3, SD = 206).

Micropogonias furnieri and *P. brasiliensis,* were the most important preys in number (35.3%, 19.9%) and IRI (70.5%, 8.9%). *Micropogonias furnieri* and *Menticirrhus* sp. were the most frequent (54.8%, 35.4%), while in terms of biomass, *M. furnieri* (68.7%) and *T. lepturus* (14%) were the most representative (Table 6).

Comparative analyses

Sex

Twenty males and ten females had identifiable prey remains in their stomachs. Sixteen taxa were found in male stomachs, while nine were found in females. The mean biomass ingested by male (5195.7g, SD = 5989.4) was not significantly different from that consumed by females bottlenose dolphins (5386.1g, SD = 11060.6) ($U = 57$, $p = 0.40$). There was no significant difference in the mean number of teleosts found in the stomach of individual males (22.7, SD = 27.4) and females (14.3, SD= 15.1) ($U = 78.5$, $p = 0.44$).

For males, *M. furnieri* and *P. brasiliensis* were the most important prey by number (32.6%, 24%), frequency of occurrence (55%, 35%) and IRI (70.3%, 12.2%). The

greatest contribution in biomass came from *M. furnieri* (67.2%) and *T. lepturus* (17.2%) (Table 7, Figure 7).

For females, on the other hand, *M. furnieri* and *Menticirrhus* sp. were the most important prey in number (43.8%, 26.7%) and frequency of occurrence (60% both). The most representative prey by weight was *M. furnieri* (78.8%), followed by *M. liza* (9.2%) and *Menticirrhus* sp. (8.9%). According to IRI, *M. furnieri* (67.4%) and *Menticirrhus* sp. (20.4%) were the most relevant species (Table 7, Figure 7).There was no significant difference in the mean length of the ingested main preys between male and female bottlenose dolphins ($p > 0.05$ for all comparisons, see Table 3 c).

Maturity class

Fifteen stomachs of adults and 16 of juveniles contained solid remains. Juveniles consumed a broader trophic spectrum (14 taxa) than adults (10 taxa) (Table 8). The mean biomass consumed by adults (6890.7, SD = 9562.6) and juveniles (3683.0g, SD = 5390.7) was not significantly different ($U = 85$, $p = 0.56$). The mean number of teleosts found in stomachs of individual adults (10.2, SD = 10.4) was not significantly different than that of juveniles (mean = 27.0, SD = 29.4) ($U = 76.5$, $p = 0.14$).

For adults, *M. furnieri* and *T. lepturus* were the most important prey in number (57.6%, 19.8%), weight (77.4%, 13%) and IRI (84.4%, 6.8%), though *M. furnieri* (60%) and *M. liza* (33.3%) were the most frequently preyed species (Table 8, Figure 7).

For juveniles *M. furnieri* and *P. brasiliensis* were more representative by number (27.5%, 26.1%), occurrence (50%, both) and IRI (53.5%, 21%). The most important preys by weight were *M. furnieri* (54.6%) and *T. lepturus* (15.3%) (Table 8, Figure 7).

There was no correlation between sizes of predators and mean size of their ingested preys (rs = 0.11 p = 0.57) (Figure 8). Nevertheless, *M. furnieri* and *Menticirrhus* sp. ingested by adults were significantly larger than that consumed by juveniles ($p < 0.05$, see Table 3d).

Seasonality

Only eight stomachs collected during cold months and 23 collected in warm season contained prey items. Twelve and 16 prey species were recorded in stomachs from cold and warm months, respectively (Table 9). The mean number of teleosts found per stomach collected in warm (20.2, SD = 25.5) and cold (16.5, SD = 19.5) months was not significantly different (U = 85.5, p = 0.9).

The mean biomass ingested by bottlenose dolphins during warm months (6349.4g, SD = 8168.8) was significantly higher than that consumed in cold months (996.2g, SD =758.5) (U = 29, p = 0.01).

During cold months, *Menticirrhus* sp. and *P. brasiliensis* were the most important prey by number (23.3%, 37.9%), occurrence (50%, 37.5%) and IRI (48.5%, 28.5%). *Menticirrhus* sp. (41.3%) and *T. lepturus* (16.1%) were the most representative by weight (Table 9). In warm months, the most ingested prey were *M. furnieri* (41%) and Engraulidae (18.1%). *Micropogonias furnieri* (65.2%) followed by, *T. lepturus* and *M. liza* (34.7% both) were the most frequently ingested prey. These three species were also the most important prey in biomass (72.1%, 13.8% and 8.4%) and relative importance (77.4%, 8.6% and 5.7%) (Table 9).

Intra and interspecific analysis of trophic overlap

Otaria flavescens

Considering the GO, no differences in *O. flavescens* diet were found between sexes, seasons, maturity classes or periods (Table 10). The SO, on the other hand, indicates differences in the resource utilization curve between sexes (males-females), stages of maturity (adults-juveniles), seasons (warm-cold months and cold-warm months) and periods (period I-period II and period II-period I) (Table 10).

The differences found between the sexes were mainly due to the higher occurrence of *P. brasiliensis* and *M. furnieri* in stomachs of male, especially adults in the case of the former (Figure 3).

The differences found between the stages of maturity were mainly due the absence of *T. lepturus* in the diet of juveniles, and the higher occurrence of *U. brasiliensis* and *T. lepturus* in the stomach of adult sea lions (Figure 3).

The occurrence of all main prey varied between seasons, reflecting the differences in both SO analyses (warm-cold months and cold-warm months). *Macrodon atricauda* and *U. brasiliensis* presented higher occurrence during cold months, while *C. guatucupa, P. brasiliensis*, *M. furnieri* and *T. lepturus* occurred more frequently during warm months (Table 5).

The most important species were the same in both periods, but their frequency of occurrence varied, and some species changed their importance. Species such as *M. atricauda*, *M. furnieri* and *U. canosai* that were very important during period I, had their importance replaced by *P. brasiliensis* and *U. brasilinesis* in period II (Figure 9).

Tursiops truncatus

Between sexes of dolphins, no differences were found in the GO and the SO (Table 11). Even though the GO did not indicate differences in the resource utilization curve between maturity classes, some differences were detected in SO (juvenile-adult) (Table 11). The differences were mainly due the higher occurrence of *P. brasiliensis* and *T. lepturus* in stomachs of juveniles (Figure 7).

There were no differences in the diet of dolphins between the two seasons and periods, according to the GO. However, the null hypothesis of complete overlap in resource utilization was rejected according to the SO for seasonal comparison (warm-cold months) and periods (period I-period II and period II-period I), indicating that there are some seasonal and interdecadal differences in the diet of bottlenose dolphins inhabiting the Patos Lagoon estuary and the adjacent marine coast (Table 11).These differences in SO (warm-cold months) were probably mainly due the higher occurrence of *M. furnieri*, *T. lepturus* and *M. liza* during warm months (Table 9).

As observed for sea lions, the composition of dolphins diet is not very different from around 30 years ago. However, the differences found in SO might be explained mainly by the decline in frequency of occurrence of *M. furnieri* and an increase of some species as *T. lepturus* and *P. brasiliensis*. Moreover, during the first period *Menticirrhus* sp. was absent, while in the period II it was an important prey (Figure 10).

Sea lions appeared to feed on a more diversified diet (27 taxa) than bottlenose dolphins (16 taxa). But, more than 80% of the dolphins prey (at least 13 taxa) was found in the diet of the sea lions. Significant differences were found in the resource utilization curve between the two predators according to both, GO and SO. The null hypothesis of

complete overlap between the diets of sea lions and dolphins was rejected (Table 10). Some species such as *M. atricauda, U. brasiliensis, P. brasiliensis* and C. *guatucupa* occurred much more frequently in the diet of sea lions, while *M. furnieri*, *M. liza* and *Menticirrhus* sp. occurred more often in dolphins diet.

Energy analysis of the main preys

Only slight differences were found in the energy value of the main preys consumed by the predators. The most energetic prey was *M. liza* (7.3 KJ/g) followed by *M. furnieri* (6.7 KJ/g) and *Menticirrhus* sp. (6 KJ/g), while the majority of the preys presented energy values around 4 kJ/g (Table 12). More energetic preys as *M. liza* (7.3 KJ/g) and *M. furnieri* (6.7 KJ/g) occurred more frequently during warm months in the diet of both predators.

DISCUSSION

Otaria flavescens

The predominance of adult male sea lions in the analyses was probably due to the existence of a non-breeding rookery within the study area composed mostly of adult males. Furthermore, some other adult and sub-adult males may have displaced from the neighboring breeding colonies in Uruguay in search for alternative feeding grounds (Castello and Pinedo 1977, Pavanato et al. in press). Females have their feeding grounds more restricted to areas surrounding the breeding colonies for parental care, splitting their time between foraging trips and fasting periods for nursing their pups (Vaz-Ferreira 1981, Campagna et al. 2001). *Otaria flavescens* consumed a wide variety of prey in southern Brazil. Although some demersal--benthic and pelagic fish, cephalopods and crustaceans were consumed, demersal and demersal-pelagic teleost fish

predominated (Figure 11). This pattern corroborates previous studies carried out in this region (Pinedo and Barros 1983, Rosas 1989, Falco 2008). A diet composed mainly of teleost was also found in sea lions sampled along the Uruguayan (Szteren et al. 2004, 2013); northern and central Argentinian Patagonia coasts (Koen-Alonso et al. 2000, Suarez et al. 2005, Bustos et al. 2012), Chile (George-Nascimento et al. 1985, Sielfeld 1999) and at the Malvinas/Falkland Islands (Thompson et al. 1998).

Although the cephalopods appear not to be important for sea lions, they were an important prey for South American fur seals, *Arctophoca australis*, found washed ashore in southern Brazil in recent years (Albernaz 2013). This is coincident with the pattern observed in sympatric populations of these pinnipeds in Uruguay (Szteren et al. 2004). The low occurrence of crustaceans was similar to other studies in neighbouring areas of Uruguay and Argentina (Naya et al. 2000, Bustos et al. 2012, Szteren et al. 2013). Nevertheless, in the southern most areas of the species distribution, such as the Malvinas/Falkland Islands (Thompson et al. 1998) and in the eastern South Pacific (Soto et al. 2006) crustaceans were considered important preys.

All preys found in this study are typically coastal species distributed over the southern Brazilian continental shelf (Haimovici 1997, Fischer et al. 2011), which reflects the near shore foraging ground of the sea lion. Studies of foraging activity suggest that, although sea lions are capable of traveling hundreds of kilometers, it is uncommon to observe them beyond the wide continental shelf off Argentinian Patagonia (Campagna et al. 2001, Riet-Sapiza et al. 2011). The main species of teleost preyed upon by the sea lion, such as the sciaenids, are abundant and widely distributed over the inner continental shelf as well as in the Patos Lagoon estuary (Haimovici et al. 1996, Garcia et al. 2003). According to the former authors, sciaenids represent more than 80% of the catch per

unit effort in the area during scientific fishing cruises. With the exception of *P. brasiliensis*, the main teleost species preyed upon by *O. flavescens* have commercial value and represent more than 50% of the local fishing landings. Although the catch of *P. brasiliensis* is considerable, it is usually discarded because of its small size and low commercial value (Haimovici et al. 2005, Fisher et al. 2011). Therefore, it is possible that the discarded fish are opportunistically consumed by sea lions that often follow trawlers operating in the area (Carvalho et al. 1996, L.G. Cardoso, pers. commn[4]).

Comparative analyses

Sexual

Demersal species (e.g. *Paralonchurus brasiliensis*, *M. atricauda* and *M. furnieri*) predominate in the diet of male sea lions, while females also consumed demersal-pelagic fish (e.g. *T. lepturus* and *C. guatucupa*). In Argentinian Patagonia, preys of female are more evenly distributed within ecological groups than preys of males. The latter consumed mostly benthic and demersal–pelagic species (Koen-Alonso et al. 2000). Considering the specific overlap index (SO), amplitude of trophic niche of females is completely overlapped by that of males but not the other way round, indicating that males have a broader trophic niche, preying upon a wider variety of prey than females. The differences in diet might be due to gender-related variation in foraging areas, behavior as well as physiological diving limits and may minimize intraspecific resource competition. Differences in food habits between males and females from the breeding colonies of the Argentinian Patagonia were attributed, at least partially, to a variation in foraging areas (Koen-Alonso et al. 2000). Since adult

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females have to nurse their pups for several months after parturition (Bastida et al. 2007), the range of their foraging bouts are limited to the adjacencies of the colony, while males can explore wider areas (Koen- Alonso et al. 2000, Campagna et al. 2001, Drago et al. 2010).

Furthermore, in southern Brazil, *O. flavescens*, especially males, take advantage of discards from trawlers (L. G. Cardoso pers. commn[5]), which might explain the dominance of *P. brasiliensis* in their stomachs. Male sea lions also often steal the catch from gillnets (Carvalho et al. 1996, Bozzeti 2007), showing that both passive and active fisheries offer to sea lions easy food opportunities with minimum metabolic expense compared with pursuing and catch free ranging prey. This depredation sometimes leads to their death due to incidental entanglement or retaliation by fishermen (Rosas 1989, Bozzetti 2007). Rosas (1989) estimated that at least 30% of sea lions found stranded in the area were killed by fishermen, especially in winter and spring, when fishing is more intense. In fact, gun bullets were found in skulls of several male sea lions found dead along the coast (*Laboratório de Ecologia e Conservação da Megafauna Marinha – EcoMega-FURG* unpubl. data) and large amounts of recently ingested *P. brasiliensis* were found in the stomachs of some individuals, suggesting that healthy animals were killed after interacting with fisheries. The higher frequency of adult males interacting with fisheries has been described elsewhere (Goetz 2008 in Chile; Crespo et al. 1997 in Argentina). In Uruguay, however, both adult males and females, as well as sub- adults take fish from gillnets and longline hooks (Szteren and Paez 2002). In the present study, the sizes of the most important prey, except *M. atricauda,* ingested by females were

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significantly larger than those ingested by males. The reason for this might be the large number of small discarded fishes being ingested by males.

Status of maturity

Paralonchurus brasiliensis was the most important item in the diet among adult sea lions, while for juveniles, *C. guatucupa* was the most representative prey. The feeding of *O. flavescens* juveniles does not explain the feeding of adults. On the other hand, the juvenile's amplitude of trophic niche is completely overlapped by the adults, indicating that adults have a broader trophic niche. As stated earlier, differences in the diet were probably due to interaction of adult males with trawling fisheries. *Cynoscion guatucupa* is the most abundant teleost on the continental shelf of southern Brazil (Haimovici et al. 1996) and also the most important fish in the diet of *Pontoporia blainvillei*, other inner continental shelf predator (Bassoi 2005). This fish was also very important for adult sea lion females. This similarity strengthens the evidence that interactions with fisheries are restricted to adult males (Bozzetti 2007), which leads to important differences in the diet composition in comparison to adult females and juveniles of both sexes. For example, the larger sizes of *M. furnieri* and *Menticirrhus* sp. ingested by juveniles might be due to the high number of small fishes from discards ingested by adult males.

Ontogenetic changes in sea lions diet might be explained either by the gradual improvement of diving skills or as an opportunistic commensal behavior of adult males on fisheries. Diving skills in pinnipeds are progressively acquired through time until they become adults. Juveniles have less physiological capabilities of diving than adults due their small body size and inexperience (Costa 1991, Horning and Trillmich 1997, Costa 2004, Rodrígues et al. 2013). Better diving skills are expected to enhance

forager´s access to the seabed and the diving time as their body mass increase, allowing for a higher contribution of benthic prey to their diet (Le Boeuf et al. 1996). It was also verified that the consumption of benthic prey is higher as sea lions body mass increase (Drago et al. 2009). In our study, demersal-benthic preys were more frequent in stomachs of adult males. Although the demersal-benthic preys were found only in the diet of adults (i.e. Jenyn`s tonguefish, *Symphurus jenynsi* and Patagonian flounder, *Paralichthys patagonicus*), they were consumed just by a few individuals. The ingestion of, at least *S. jenynsi*, however, might have derived from discards of trawling fisheries targeting shrimps (Duarte 2012).

Seasonal

The most important species in the diet of sea lions (i.e. *Paralonchurus brasiliensis*, *M. atricauda* and *M. furnieri*) occur year round and use the region for spawning and development (Hamovici 1996), what explains their high importance both in warm and cold periods. The frequency and abundance of *T. lepturus* (also the most important food item in biomass during warm months), *P. paru*, *Menticirrhus* sp. and *Ctenosciaena gracilirrhus* from spring to autumn is explained by their association with warm waters carried by the Brazil current (Haimovici 1996, Martin 2000). In contrast, the Brazilian flathead, *Percophis brasiliensis,* and the anchovy, *Engraulis anchoita,* occurred only during cold months and were absent during warm months. In southern Brazil these species are more frequent in winter or associated to subantarctic water masses (Lima and Castello 1995, Haimovici 1996). The seasonal differences in the diet of sea lions were due to variation in niche breadth between warm and cold months, demonstrating the opportunistic feeding behavior of this predator.

Tursiops truncatus

Most of dolphins collected were juvenile males stranded in warm months, which is coincident with the bottlenose dolphin stranding patterns in the area (Fruet et al. 2012). Artisanal gillnetting operates year round in Patos Lagoon estuary and adjacent marine area, though effort during spring and summer is more intense and has been considered the main cause of by-catch of bottlenose dolphins in the region (Fruet et al. 2012). Bottlenose dolphins appear to be preferentially ichthyophagous, preying largely upon demersal teleost fish, in southern Rio Grande do Sul. Three crustaceans and one octopus beak were also found, but were not important in the diet of this population. These results corroborate with previous studies conducted in the region (Pinedo 1982, Lopez 2009), though no cephalopod had been registered in the past. The predominance of fish, but with the occurrence of some cephalopods, was also observed in the diet of bottlenose dolphins from the adjacent northern Rio Grande do Sul coast (De Carvalho 2011); Rio de Janeiro, southeastern Brazil (Di Benedito et al. 2001); southeastern United States (Barros and Odell 1990, Dunshea et al. 2013); Scotland (Santos et al. 2001) and northwestern Spain (Santos et al. 2007).

As described for *O. flavescens*, all preys of bottlenose dolphins in southern Brazil are coastal species (Fischer et al. 2011). This bottlenose dolphin population is restricted to the coastal zone, with more than 90% of sightings happening in the estuary or along the adjacent marine coast, within 2 km from shore, at any time of the year (Di Tullio 2009). An offshore ecotype of bottlenose dolphins is found beyond the shelf break (*ca.* 150 km from shore - *Laboratório de Ecologia e Conservação da Megafauna Marinha – EcoMega - FURG*, unpubl. data) though none individual from this ecotype was sampled (they can be differentiated based on skull morphology – Barreto, 2000).

Sciaenidae was the most important family in the diet of bottlenose dolphins, occurring in 83.8 % of the stomachs analyzed in this work. This family was also important in bottlenose dolphins diet off Southeastern United States, where it appeared in 60.5 % of the stomachs analyzed (Barros and Odell 1990). As stated earlier, the high occurrence of sciaenids can be explained by its high availability in the area (Haimovici et al. 1996). Species of this family are important resources for regional fisheries and *M. furnieri* (the most important prey), is one of the most abundant and commercially important fish in southern (Vasconcellos and Haimovici 2006) as well as southeastern Brazil (Valentine 1991, Haimovici 2006), where its presence was also reported in the diet of bottlenose dolphins (Di Benedito et al. 2001). The genus *Micropogonias* (*M. undulatus*) is also important in the diet of bottlenose dolphin in other parts of its distribution range (e.g. southeastern and northeastern United States - Leatherwood et al. 1978, Barros and Odell 1990, Mead and Potter 1990).

The presence of *Paralonchurus brasiliensis* in the diet of dolphins was not be linked to fishery interactions as suggested for sea lions. Despite the high mortality of dolphins due to entanglement in fishing nets (Fruet et al. 2012), there is no record of dolphins eating discarded fish or stealing the catch from fishing gear as occur in some regions (e.g. northern Gulf of Mexico- Leatherwood 1975, Greece-Raitsos et al. 2003).

Comparative analyses

Sexual

For males, *M. furnieri*, *P. brasiliensis* and *T. lepturus* were the most important prey. For females, *M. furnieri* was also the most important prey though followed by *Menticirrhus* sp. and *Mugil liza*. No differences were found regarding the GO and the SO. This lack

of variation in resources utilization between sexes might indicate that competition between males and females might exist. Despite lack of significant differences, the second and third most important prey of males and females were not the same. The importance of *Menticirrhus* sp. and *Mugil liza* in females diet might be due the differences in habitat use patterns. Females are twice as more frequent in the sheltered and more productive estuarial waters than males based on random sampling for genetic sex ratio (Fruet et al. in press). As in South Africa it seems that more sheltered or shallow areas are favored for females (Cockcroft and Ross 1990).

Status of maturity

Micropogonias furnieri was the most important prey for both adults and juveniles. *Trichiurus lepturus* and *M. liza*, however, were more important for adults while *P. brasiliensis* was for juveniles. The adults' amplitude of trophic niche is completely overlapped by the juveniles. On the other hand, the feeding of juveniles is not explained by the feeding of adults indicating that juveniles have a broader niche. It might suggest that juveniles compensate their lower experience in catching and selecting preys, by feeding opportunistically upon a wider variety of prey. As dolphins gain experience higher quality prey may gain importance in their diet (e.g. Santos et al. 2007). In fact, we found that larger individuals of energetic prey (*M furnieri* and *Menticirrhus* sp.) were consumed by adults. This might indicate some ontogenetic shifts in the diet, with larger animals eating larger fishes of certain species. In South Africa, Cockcroft and Ross (1990) found that adults consume significantly larger preys than juveniles. Blanco et al. (2001) observed that adult bottlenose dolphins ingested a wider range of hake size than juveniles off the Mediterranean coast of Spain. They suggest that these differences are probably more related to increase experience, improvement of diving and skills to

catch the prey rather than anatomical related differences as suggested by some authors (e.g. Santos et al. 2007).

Seasonal

There was an overlap in the diet of dolphins between the two periods of the year, according to the GO. However, according to the SO (warm-cold months), there are some differences in the resources utilization by bottlenose dolphins inhabiting the Patos Lagoon and the adjacent coast throughout the year. As stated earlier, seasonal variations in niche bread this likely due to seasonal changes in oceanographic conditions that lead to variation in the abundance of species associated to warm and cold waters (Hamovici et al. 1996). *Micropogonias furnieri, T. lepturus* and *M. liza* were the most important prey during warm months. As stated earlier, species such as *T. lepturus* and *Umbrina canosai* (observed only during warm months), are characteristic of warm water thus their availability increases during warm months (Haimovici 1996, Martins 2000), suggesting that bottlenose dolphins are opportunistic feeders preying upon the available prey.

Mugil liza is considered an estuarine-dependent species that uses the Patos Lagoon estuary to develop until reaching maturation, when they migrate to spawn in the sea (Fischer et al. 2011). By April/May, large shoals of mullet concentrate at the mouth of estuaries prior to migration (Vieira and Scalabrin 1991). The mean size of *M. liza* preyed by bottlenose dolphins is 46.7 cm, thus considered sexually mature (Gonzáles-Castro et al. 2011). The greatest abundance during the warm months in the diet can be explained by the greater abundance of mature individuals in the estuary, adjacent coast

and especially its higher density near the estuary mouth where dolphins concentrate (Mattos et al. 2007, Di Tullio 2009).

During cold months *Menticirrhus* sp. and *P. brasiliensis* were the most important prey by occurrence, number and %IRI, while *T. lepturus* was important by weight. The high importance of *Menticirrhus* sp. and *T. lepturus* during this period was not expected. Although these species occur throughout the year, their abundance and frequency is associated to warm waters of the Brazil current (Haimovici 1996). *Paralonchurus brasiliensis* and *M. furnieri* uses the region all year round and are abundant in both periods (Haimovici 1996). However, in the diet of *T. truncatus,* the importance of *P. brasiliensis* increased during cold months, while the importance of *M. furnieri* dropped in this period.

Although the mean number of ingested prey was similar between periods, the biomass ingested by dolphins during warm months was significantly greater than in cold months. This might be explained by the greater biomass of some species consumed more often during this period, such as *M. liza* and *M. furnieri*. It is probably advantageous to the predator to consume larger prey if the tradeoff between chasing cost and energy return compensates, especially during the breeding period when cost for reproduction leads to higher energetic requirements. In fact, these two prey species where mostly ingested by females.

Interdecadal periods

The diet composition of both predators is not very different from around 30 years ago. However, the frequency of occurrence of the main preys varied, and some species changed their position in importance. For sea lions, differences found in SO between the

periods were mainly due the variation in frequency of occurrence of species such *M. atricauda*, *M. furnieri* and *U. canosai* that used to be more important during period I, while *P. brasiliensis* and *U. brasiliensis* became more important in the period II.

For dolphins the differences found in SO might be explained mainly by the decline in frequency of occurrence of *M. furnieri* and an increase of species such *T. lepturus* and *P. brasiliensis*. Moreover, during the first period *Menticirrhus* sp. was absent, while in the period II it was an important prey. This decrease in the occurrence of *M. furnieri*, *M. atricauda* and *U. canosai* coincides with the period when there was a sharp decline in the landings of these species in the region (Reis 1992, Haimovici 1998, Cardoso and Haimovici 2011). These data also corroborate studies on the status of stocks of croaker in southern Brazil (Haimovici 1997). According to this author, the croaker was overexploited between the 1980s and 1990s. On the other hand, species that are not so important commercially, as *P. brasiliensis* and *T. lepturus* (in the case of dolphins), have become more important with the reduced availability of commercially exploited species. The increased consumption of *U. brasiliensis* and *Menticirrhus* sp. is difficult to interpret due to the lack of information about their standing stocks. The same trend of decrease in the occurrence of *M. furnieri* and *M. atricauda* and increased importance of *T. lepturus* was observed in the diet of *P. blainvillei* in this region (Bassoi 1997, 2005; Secchi et al. 2003). This suggests that fluctuations in abundance of commercially important species affect the foraging ecology of local high trophic level marine mammal predators.

Micropogonias furnieri, *C. guatucupa*, *U. brasiliensis* and *Mugil liza* are targeted by fisheries operating off southern Brazil (Haimovici 1997, Haimovici et al. 2006). Sea

lions and dolphins eat these species at both landed and discarded sizes (Figure 13, 14). These results indicate some overlap between these two predators and the fishery, rising concerns about the potential negative effect of uncontrolled fishing pressures on their feeding ecology.

Comparison of South American sea lion and bottlenose dolphin diets

Both predators are considered generalist-opportunist feeders since their diets are constituted by a few dominant items in the environment and a relatively high number of other less abundant preys. The comparison of their diets suggests that these predators share the same prey profiles, with demersal prey being the most important, complemented with some demersal-benthic, demersal-pelagic and pelagic species. Predators foraging patterns reflect the abundance and distribution of prey and, in situation of sympatry, local environmental conditions might lead to similarities in feeding behavior of the species (Robinson et al. 2002). Several prey and their mean sizes are common in the diet of the two predators, such as *P. brasiliensis*, *M. furnieri* and *T. lepturus*, are very similar.

The dietary results suggest that the two predators show partial overlap over major dimensions of the foraging niche: prey profile, foraging habitats, prey species and size range. However, significant differences were found for the GO and the SO. The null hypothesis of complete overlap between the diets of sea lions and dolphins was rejected; pointing out that the feeding of these species has some differences in the studied area. Species such as *M. atricauda*, *U. brasiliensis*, *P. brasiliensis* and *C. guatucupa* occurred much more frequently in the diet of sea lions, while *M. furnieri*, *M. liza* and *Menticirrhus* sp. occurred more often in dolphins diet.

Otaria flavescens seems to have broader trophic niche, showing a more diverse diet. This can be explained, at least in part, by their interaction with fisheries, which provide them access to preys in different proportions that are naturally available. Furthermore, the home range of coastal bottlenose dolphins is much more restricted to very shallow waters than that of sea lions in western South Atlantic (e.g. Campagna et al. 2001, Fruet et al. 2012). Even at relatively low population density, these two sympatric populations are exploring the ecosystem with some niche separation or resource partitioning, which brings advantage to both predators by minimizing resources competition. This is especially relevant for populations (or part of) inhabiting spatially restricted coastal areas.

Energetic analysis

The hypothesis that predators ingest more energetic preys during cold months was not confirmed. The results did not show that dolphins or sea lions consume more caloric preys in cold months. More energetic preys as *M. liza* (7.3 KJ/g) and *M. furnieri* (6.7 KJ/g) occurred more frequently during warm months in the diet of both predators.

According to Fruet et al. (2012) this bottlenose dolphin population has a well-defined birth season, from December to early March with a peak in January/February. The higher ingestion of more energetic preys during warm months coincides with a period when females of bottlenose dolphins give birth and need more energy for suckling the calf. Lactating females of bottlenose dolphins loose much energy through milk (Ridgway et al. 1995). According to Kastelein et al. (2002), captive bottlenose dolphins increase their caloric consumption by 52-97% during lactation, but do not increase during gestation. Since these dolphins must satisfy an increased energy demand during

this time, it is not surprising that females consume more caloric prey, such as *M. liza* during this period. Whether females select *M. liza* because of their caloric value or prey upon most abundant species remains unclear, though if the latter, it would be expected a similar increase in consumption by males.

The stocks of *M. furnieri* have decreased due to extensive exploitation by fisheries (Vasconcellos and Haimovici 2006) while abundance of *Mugil liza* varies interannually both because of fishing pressures and environmental stochasticity (Garcia et al. 2003, Miranda et al. 2006) making them less available to these predators, at least during some years. If changes in diet composition from caloric to low energy prey occur, it might have implications on reproductive potential and survival of the predators. Trites and Donelly (2003) have shown strong evidence for a relationship between the decline of Steller sea lions, *Eumetopias jubatus*, in the Gulf of Alaska and Aleutian Islands and the reduced availability of suitable prey, which may be caused by a reduced abundance of key species of high nutritional quality. Trites et al. (2007) have also suggested that an outbreak of epidemic disease in sea lions could have been related to increase oxidative stress due to poor diet and thus increase susceptibility to disease.

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LIST OF TABLES

Table 1. Number (n), percent frequency of occurrence (% FO), percent number (% N), percent estimated wet weight (% W), and percent index of relative importance (% IRI) of prey of the South American sea lions from southern Brazil. P= pelagic, D= demersal, DB= demersal- benthic DP= demersal-pelagic, P= pelagic. Ecological groups were assigned following Fischer et al., 2011; Haimovici, 1997; Magro et al., 2000, Bond-Buckup and Buckup, 1999.

Prey	Common name	Family	Ecological group	n	%N	%FO	W%	%IRI
Teleosts								
Macrodon atricauda	Southern King Weakfish	Sciaenidae	D	263	7.89	45.09	14.09	10.54
Cynoscion guatucupa	Stripped weakfish	Sciaenidae	DP	197	5.91	35.29	7.88	5.17
Paralonchurus brasiliensis	Banded croaker	Sciaenidae	D	2121	63.65	64.70	24.99	61.0
Umbrina canosai	Argentine croaker	Sciaenidae	D	18	0.54	15.68	1.15	0.28
Cynoscion jamaicensis	Jamaica weakfish	Sciaenidae	D	1	0.03	1.96	0.0008	0.0006
Ctenosciaena gracilicirrhus	Barbel drum	Sciaenidae	D	38	1.14	1.96	0.14	0.02
Stellifer rastrifer	Rakestar drum	Sciaenidae	D	3	0.09	1.96	0.01	0.002
Micropogonias furnieri	Whitemouth croaker	Sciaenidae	D	226	6.78	39.21	27.26	14.19
Menticirrhus sp.	Southern king croaker	Sciaenidae	D	44	1.32	17.64	3.78	0.95
Urophycis brasiliensis	Brazilian codling	Phycidae	D	69	2.07	43.13	3.84	2.71
Pomatomus saltatrix	Blue fish	Pomatomidae	DP	9	0.27	7.84	0.57	0.07
Trichiurus lepturus	Cutless fish	Trichiuridae	DP	73	2.19	25.49	12.35	3.94
Symphurus jenynsi	Jenyn's tongue fish	Cynoglossidae	DB	196	5.88	7.84	0.15	0.50
Paralichthys patagonicus	Patagonian flounder	Paralichthyidae	DB	18	0.54	7.84	1.35	0.15
Porichthys porosissimus	Midshipman	Batrachoididae	D	30	0.90	11.76	1.39	0.28
Peprilus paru	American harvest fish	Stromateidae	P	13	0.39	9.80	0.60	0.10
Percophis brasiliensis	Brazilian flathead	Percophidae	D	1	0.03	1.96	0.037	0.001
Engraulis anchoita	Argentine anchovy	Engraulidae	P	3	0.09	1.96	0.007	0.002
Mugil liza	Lebranche mullet	Mugilidae	DP	2	0.06	1.96	0.26	0.006
Helicolenus lahillei		Sebastidae	D	7	0.21	1.96	0.07	0.005
Elasmobranchs								
Sympterygia acuta	Bignosefanskate	Arhynchobatidae	D	6	-	-	-	-
Subordem Rajoidei			D	12	-	-	-	-
Cephalopods								
Loligo sanpaulensis	Sao Paulo squid	Loliginidae	P	8	-	-	-	-
Octopoda			DB	1	-	-	-	-
Crustaceans								
Anomura			-	1	-	-	-	-
Pleoticus muelleri	Argentine redshrimp	Solenoceridae	P	2	-	-	-	-
Artemesia longinaris	Argentine stilettoshrimp	Penaeidae	P	1	-	-	-	-

Table 2. Number (n), percent frequency of occurrence (% FO), percent number (% N), percent estimated wet weight (% W), and percent index of relative importance (% IRI) of prey of the South American sea lion from southern Brazil.

Prey	Males					Females				
	N	%N	%FO	W%	%IRI	n	%N	%FO	%W	%IRI
Teleosts										
Macrodon atricauda	251	9.18	48.57	17.34	11.53	8	8.42	40	2.65	8.14
Cynoscion guatucupa	168	6.14	31.42	7.27	3.77	19	20	40	11.87	23.43
Paralonchurus brasiliensis	1634	59.78	82.85	23.63	61.91	20	21.05	20	4.13	9.26
Umbrina canosai	11	0.40	14.28	1.07	0.18	1	1.05	10	0.41	0.26
Cynoscion jamaicensis	1	0.03	2.85	0.001	0.0009	-	-	-	-	-
Ctenosciaena gracilicirrhus	38	1.39	2.85	0.18	0.04	-	-	-	-	-
Stellifer rastrifer	-					3	3.15	10	0.16	0.61
Micropogonias furnieri	217	7.93	45.71	29.59	15.36	5	5.26	20	21.09	9.68
Menticirrhus sp.	43	1.57	22.85	4.42	1.22	1	1.05	10	0.74	0.33
Urophycis brasiliensis	50	1.82	45.71	1.39	1.31	8	8.4	30	17.3	14.2
Pomatomus saltatrix	6	0.2	5.7	0.1	0.01	3	3.15	20	3.27	2.36
Trichiurus lepturus	58	2.12	28.57	11.17	3.40	15	15.78	30	31.39	26.01
Symphurus jenynsi	196	7.17	11.42	0.19	0.75	-	-	-	-	-
Paralichthys patagonicus	17	0.62	8.57	1.59	0.17	-	-	-	-	-
Porichthys porosissimus	24	0.87	11.42	1.29	0.22	5	5.26	10	2.96	1.51
Peprilus paru	6	0.21	8.57	0.19	0.03	7	7.36	20	3.90	4.14
Percophis brasiliensis	1	0.03	2.85	0.04	0.002	-	-	-	-	-
Engraulis anchoita	3	0.10	2.85	0.009	0.003	-	-	-	-	-
Mugil liza	2	0.07	2.85	0.33	0.01	-	-	-	-	-
Helicolenus lahillei	7	0.25	2.85	0.08	0.008	-	-	-	-	-
Elasmobranchs										
Sympterygia acuta	6	33.3	11.1	-	-	-	-	-	-	-
Subordem Rajoidei	12	66.6	5.5	-	-	-	-	-	-	-
Cephalopods										
Loligo sanpaulensis	7	-	-	-	-	1	-	-	-	-
Octopoda	1	-	-	-	-	-	-	-	-	-
Crustaceans										
Anomura	1	-	-	-	-	-	-	-	-	-
Pleoticus muelleri	2	-	-	-	-	-	-	-	-	-
Artemesia longinaris	1	-	-	-	-	-	-	-	-	-

Table 3. Mann- Whitney (U) and t Student (t) testes of the length of the main preys ingested by South American sea lions and bottlenose dolphins.

a- Sea lion

	Males		Females		U/t	p
	mean	SD	mean	SD		
M. atricauda	250.5	67.1	252.5	83.1	U= 584	0.4
U. brasiliensis	149.5	104.6	252.5	83.1	U=29	0.005
P. brasiliensis	155.2	29	186	31.5	U = 6847	< 0.001
C. guatucupa	178.6	89.5	236.3	94.5	U= 989	0.003
M. furnieri	244.4	87.9	449	21.2	t= -18.2	< 0.001
T. lepturus	758.1	171.2	861.2	152.2	t= -2.1	0.03

b- Sea lion

	Adults		Juveniles		U/t	P
	mean	SD	mean	SD		
M. atricauda	249.3	66.7	294.7	62.7	U= 460	0.05
U. brasiliensis	181.2	141.6	274.3	35.7	U= 49	0.009
P. brasiliensis	153.1	28.9	158.2	38.3	U= 24608	0.12
C. guatucupa	169.2	90.5	273.7	32.8	U=1080.5	< 0.0001
M. furnieri	253.2	99.7	312.5	44.8	U= 326	0.01
T. lepturus	779.9	171.6	-	-	-	-

c. Bottlenose dolphin

	Males		Females		U/t	p
	mean	SD	mean	SD		
P. brasiliensis	147.5	36.4	164.7	50.7	t= -0.38	0.70
M. furnieri	284	105.1	278.1	137.7	U= 4260.5	0.31
T. lepturus	812.7	76.1	766.3	54.2	t= 1.49	0.14
Menticirrhus sp.	210.6	47.4	186.5	71.7	t= 1.40	0.16
Mugil liza	453.5	64.1	437.0	94.5	t= 0.59	0.55

d. Bottlenose dolphin

	Adults		Juveniles		U/t	p
	mean	SD	Mean	SD		
P. brasiliensis	121.3	61.6	145.0	37.34	t=-1.21	0.22
M. furnieri	333.3	131.6	243.3	85.03	U= 2900.5	< 0.0001
T. lepturus	787.7	117.6	820.1	92.1	t= -0.92	0.35
Menticirrhus sp.	242.6	67.6	176.7	58.4	t= 116.5	0.0015
Mugil liza	442	97.45	450.33	64.40	t= -0.29	0.77

Table 4. Number (n), percent frequency of occurrence (% FO), percent number (% N), percent estimated wet weight (% W), and percent index of relative importance (% IRI) of prey of the South American sea lion from southern Brazil.

Prey	Adults					Juveniles				
	n	%N	%FO	%W	%IRI	n	%N	%FO	%W	%IRI
Teleosts										
Macrodon atricauda	255	7.9	45.4	14.3	10.3	8	6.7	42.8	8.4	7.3
Urophycis brasiliensis	64	1.9	45.4	3.4	2.6	5	4.2	28.5	3.2	2.3
Cynoscion guatucupa	160	4.9	34	5.3	3.6	37	31	42.8	34.9	31.8
Paralonchurus brasiliensis	2103	65.3	65.9	25.7	61.4	18	15.1	71.4	6.7	17.5
Umbrina canosai	6	0.1	11.3	0.4	0.07	12	10	42.8	12	10.7
Cynoscion jamaicensis	1	0.03	2.2	0.0009	0.0007	-	-	-	-	-
Ctenosciaena gracilicirrhus	38	1.1	2.2	0.1	0.03	-	-	-	-	-
Stellifer rastrifer	-		-	-	-	3	2.5	14.2	0.3	0.4
Micropogonias furnieri	220	6.8	40.9	29	15	9	7.5	42.8	15.1	10.9
Menticirrhus sp.	44	1.3	20.4	3.3	0.9	-	-	-	-	-
Pomatomus saltatrix	9	0.2	9	0.5	0.08	-	-	-	-	-
Trichiurus lepturus	73	2.2	29.5	13.8	4.8	-	-	-	-	-
Symphurus jenynsi	196	6	9	0.1	0.5	-	-	-	-	-
Paralichthys patagonicus	18	0.5	9	1.4	0.1	-	-	-	-	-
Porichthys porosissimus	8	0.2	6.8	0.3	0.03	22	18.4	42.8	18.5	17.8
Peprilus paru	11	0.3	9	0.6	0.08	2	1.6	14.2	0.4	0.3
Percophis brasiliensis	1	0.03	2.2	0.03	0.001	-	-	-	-	-
Engraulis anchoita	-		-	-	-	3	2.5	14.2	0.1	0.4
Mugil liza	2	0.06	2.2	0.56	0.01	-	-	-	-	-
Helicolenus lahillei	7	0.2	2.2	0.07	0.006	-	-	-	-	-
Elasmobranchs										
Sympterygia acuta	6	-	-	-	-	-	-	-	-	-
Subordem Rajoidei	12	-	-	-	-		-	-	-	-
Cephalopods										
Loligo sanpaulensis	7	-	-	-	-	1	-	-	-	-
Octopoda	1	-	-	-	-	-	-	-	-	-
Crustaceans										
Anomura	1	-	-	-	-	-	-	-	-	-
Pleoticus muelleri	2	-	-	-	-	-	-	-	-	-
Artemesia longinaris	1	-	-	-	-	-	-	-	-	-

Table 5. Number (n), percent frequency of occurrence (% FO), percent number (% N), percent estimated wet weight (% W), and percent index of relative importance (% IRI) of prey of the South American sea lion of southern Brazil.

Prey	Cold months					Warm months				
	N	%N	%FO	%W	%IRI	N	%N	%FO	%W	%IRI
Teleosts										
Macrodon atricauda	175	7.5	56.6	11.6	11.4	84	8.6	23.8	18.1	7.5
Urophycis brasiliensis	37	1.5	50	5.8	3.9	32	3.2	38	0.7	1.8
Cynoscion guatucupa	97	4.1	26.6	10.2	4.0	93	9.5	47.6	0.9	5.9
Paralonchurus brasiliensis	1786	76.9	60	34.4	70.4	321	33	71.4	11.1	37.4
Umbrina canosai	10	0.4	13.3	1.0	0.2	8	0.8	19	1.6	0.5
Cynoscion jamaicensis	-	-	-	-	-	1	0.1	4.7	2.2	0.1
Ctenosciaena gracilicirrhus	-	-	-	-	-	38	3.9	4.7	0.3	0.2
Stellifer rastrifer	3	0.1	3.3	0.03	0.005	-	-	-	-	-
Micropogonias furnieri	145	6.2	23.3	22.5	7.0	78	8	57.1	35	29.2
Menticirrhus sp.	10	0.4	10	2.4	0.3	33	3.3	23.8	5.8	2.6
Pomatomus saltatrix	9	0.3	13.3	0.9	0.1	-	-	-	-	-
Trichiurus lepturus	21	0.9	20	8.0	1.8	49	5	28.5	19	8.1
Symphurus jenynsi	-	-	-	-	-	196	20.1	19	0.3	4.6
Paralichthys patagonicus	18	0.7	13.3	1.7	0.3	-	-	-	-	-
Porichthys porosissimus	6	0.2	6.6	0.6	0.06	24	2.4	19	2.6	1.1
Peprilus paru	1	0.04	3.3	0.3	0.01	6	0.6	14.2	0.9	0.2
Percophis brasiliensis	1	0.04	3.3	0.06	0.003	-	-	-	-	-
Engraulis anchoita	3	0.1	3.3	0.01	0.004	-	-	-	-	-
Mugil liza	-	-	-	-	-	2	0.2	4.7	0.6	0.04
Helicolenus lahillei	-	-	-	-	-	7	0.7	4.7	0.1	0.05
Elasmobranchs										
Sympterygia acuta	6	-	-	-	-	-	-	-	-	-
Subordem Rajoidei	12	-	-	-	-					
Cephalopods						-	-	-	-	-
Loligo sanpaulensis	3	-	-	-	-	5				-
Octopoda	-			-	-	1	-	-	-	-
Crustaceans	-	-	-	-	-					
Anomura	1			-	-	-	-	-	-	-
Pleoticus muelleri	1	-	-	-	-	1	-	-	-	-
Artemesia longinaris	-	-	-	-	-	1	-	-	-	-

Table 6. Number (n), percent frequency of occurrence (%FO), percent number (%N), percent estimated wet weight (%W), and percent index of relative importance (%IRI) of prey of bottlenose dolphins from southern Brazil. P= pelagic, D= demersal, DB= demersal-benthic DP= demersal-pelagic, P= pelagic. Ecological groups were assigned following Fischer et al. 2011, Haimovici 1997, Magro et al. 2000, Bond-Buckup and Buckup 1999.

Prey	Common name	Family	Ecological group	N	%N	%FO	%W	%IRI
Teleosts								
Macrodon atricauda	Southern King Weakfish	Sciaenidae	D	7	1.2	12.9	0.2	0.2
Cynoscion guatucupa	Strippedweakfish	Sciaenidae	DP	4	1.2	9.6	0.3	0.1
Paralonchurus brasiliensis	Bandedcroaker	Sciaenidae	D	115	19.9	32.2	2.5	8.9
Umbrina canosai	Argentinecroaker	Sciaenidae	D	2	0.3	6.4	0.3	0.05
Stellifer rastrifer	Rakestardrum	Sciaenidae	D	8	1.3	6.4	0.03	0.1
Micropogonias furnieri	Whitemouthcroaker	Sciaenidae	D	204	35.3	54.8	68.7	70.5
Menticirrhus sp.	Southern kingcroaker	Sciaenidae	D	54	9.3	35.4	4	5.8
Urophycis brasiliensis	Braziliancodling	Phycidae	D	10	1.7	9.6	0.6	0.2
Trichiurus lepturus	Cutlessfish	Trichiuridae	DP	46	7.9	29	14	7.8
Paralichthys patagonicus	Patagonianflounder	Paralichthyidae	DB	2	0.3	3.2	0.2	0.02
Peprilus paru	American harvestfish	Stromateidae	P	4	0.6	6.4	0.1	0.07
-	-	Engraulidae	P	83	14.3	9.6	-	-
Mugil liza	Lebranchemullet	Mugilidae	DP	35	6	32.2	8.5	5.8
Cephalopods								
Octopoda	-	-	DB	1	-	-	-	-
Crustaceans								
Anomura	-	-	-	2	-	-	-	-
Shrimp	-	-	P	1	-	-	-	-

Table 7. Number (n), percent frequency of occurrence (%FO), percent number (%N), percent estimated wet weight (%W), and percent index of relative importance (%IRI) of prey of the bottlenose dolphin from southern Brazil.

	Males					Females				
Prey	n	%N	%FO	%W	%IRI	N	%N	%FO	%W	%IRI
Teleosts										
Macrodon atricauda	6	1.3	15	0.1	0.3	1	0.6	10	0.4	0.1
Cynoscion guatucupa	4	1.3	10	0.09	0.1	1	0.6	10	0.7	0.1
Paralonchurus brasiliensis	103	24	35	3.3	12.2	12	8.2	30	0.9	2.6
Umbrina canosai	2	0.4	10	0.5	0.1	-	-	-	-	-
Stellifer rastrifer	1	0.2	5	0.02	0.01	7	4.7	10	0.04	0.4
Micropogonias furnieri	140	32.6	55	67.2	70.3	64	43.8	60	73.8	67.4
Menticirrhus sp.	15	3.4	25	1.6	1.6	39	26.7	60	8.9	20.4
Urophycis brasiliensis	10	2.3	15	1.0	0.6	-	-	-	-	-
Trichiurus lepturus	37	8.6	30	17.2	9.9	8	5.4	20	4.7	1.9
Paralichthys patagonicus	-	-	-	-	-	2	1.3	10	0.9	0.2
Peprilus paru	4	0.9	10	0.2	0.1	-	-	-	-	-
Engraulidae	82	19.1	10	-	-	-	-	-	-	-
Mugil liza	23	5.3	25	8.2	4.3	12	8.2	40	9.2	6.6
Cephalopods										
Octopoda	1	-	4.7	-	-	-	-	-	-	-
Crustaceans										
Anomura	2	66.6	9.5	-	-	-	-	-	-	-
Shrimp	1	33.3	4.7	-	-	-	-	-	-	-

Table 8. Number (n), percent frequency of occurrence (%FO), percent number (%N), percent estimated wet weight (%W), and percent index of relative importance (%IRI) of prey of the bottlenose dolphin from southern Brazil.

Prey	Adults					Juveniles				
	n	%N	%FO	%W	%IRI	N	%N	%FO	%W	%IRI
Teleosts										
Macrodon atricauda	-	-	-	-	-	7	1.6	25	0.6	0.7
Cynoscion guatucupa	-	-	-	-	-	7	1.6	18.7	0.7	0.5
Paralonchurus brasiliensis	4	2.6	13.3	0.1	0.3	111	26.1	50	6.2	21
Umbrina canosai	1	0.6	6.6	0.3	0.07	1	0.2	6.2	0.4	0.05
Stellifer rastrifer	-	-	-	-	-	8	1.8	12.5	0.07	0.3
Micropogonias furnieri	87	57.6	60	77.4	84.4	117	27.5	50	54.6	53.3
Menticirrhus sp.	13	8.6	26.6	3.2	3.3	40	9.4	37.5	5.3	7.1
Urophycis brasiliensis	-	-	-	-	-	10	2.3	18.7	1.7	0.9
Trichiurus lepturus	30	19.8	20	13	6.8	16	3.7	37.5	15.3	9.3
Paralichthys patagonicus	2	1.3	6.6	0.4	0.1	-	-	-	-	-
Peprilus paru	1	0.6	6.6	0.2	0.06	3	0.7	6.2	0.1	0.06
Engraulidae	-	-	-	-	-	82	19.3	12.5	-	-
Mugil liza	13	8.6	33.3	5	4.7	22	5.1	25	14.5	6.3
Cephalopods										
Octopoda	1	-	-	-	-	-	-	-	-	-
Crustaceans										
Anomura	-	-	-	-	-	2	-	-	-	-
Shrimp	1	-	-	-	-	-	-	-	-	-

Table 9. Number (n), percent frequency of occurrence (%FO), percent number (%N), percent estimated wet weight (%W), and percent index of relative importance (%IRI) of prey of the bottlenose dolphin from southern Brazil.

Prey	Cold months					Warm months				
	n	%N	%FO	%W	%IRI	n	%N	%FO	%W	%IRI
Teleosts										
Macrodon atricauda	4	3.2	12.5	-	-	3	0.6	13	0.2	0.1
Cynoscion guatucupa	6	4.8	25	1.2	2.2	1	0.2	4.3	0.2	0.02
Paralonchurus brasiliensis	47	37.9	37.5	12.9	28.5	68	15	30.4	1.9	5.4
Umbrina canosai	-	-	-	-	-	2	0.4	8.6	0.4	0.07
Stellifer rastrifer	7	5.6	12.5	0.3	1.1	1	0.2	4.3	0.01	0.01
Micropogonias furnieri	18	14.5	25	4.1	6.9	186	41	65.2	72.1	77.4
Menticirrhus sp.	29	23.3	50	41.3	48.5	25	5.5	30.4	2.0	2.4
Urophycis brasiliensis	5	4	25	12.4	6.1	5	1.1	4.3	0.06	0.05
Trichiurus lepturus	2	1.6	12.5	16.1	3.3	44	9.7	34.7	13.8	8.6
Paralichthys patagonicus	-	-	-	-	-	2	0.4	4.3	0.3	0.03
Peprilus paru	3	2.4	12.5	1.2	0.6	1	0.2	4.3	0.1	0.01
Engraulidae	1	0.8	12.5	-	-	82	18.1	8.6	-	-
Mugil liza	2	1.6	12.5	10.1	2.2	33	7.2	34.7	8.4	5.7
Cephalopods										
Octopoda	-	-	-	-	-	1	-	-	-	-
Crustaceans										
Anomura	-	-	-	-	-	2	-	-	-	-
Shrimp	-	-	-	-	-	1	-	-	-	-

Table 10. Diet overlap analyses between the major sources of variation in the sample of the South American sea lion and the bottlenose dolphin from southern Brazil studied. GO= general overlap index; V= the statistic to test the null hypothesis the GO= 1; df = degrees of freedom; P= probability of the statistic; SO_{ik} = specific overlap of group *i* onto group *k*; U= statistic to test the null hypothesis that $SO_{ik} = 1$.

SA sea lion		General overlap index				
Source of variation		GO	V	Df		P
Sex		0. 981	4.605	5		0. 465
Season		0. 965	9.132	5		0. 103
Stage of maturity		0. 984	4.189	5		0. 522
Period		0. 986	9.168	6		0.164
Between species		0. 915	36.641	7		5.48519E-06
		Specific overlap index				
Source of variation	*I*	*K*	SO	U	df	P
Sex	males	females	0.846	33.200	5	2.34348E-06
	females	males	0.860	5. 421	5	0.366
Seasons	Warm months	Cold months	0.865	16.214	5	0.00625787
	Cold months	Warm months	0.855	22. 213	5	0.00047689
Stage of maturity	adults	juveniles	0.165	414. 851	5	1.86691E-87
	juveniles	adults	0.868	4.536	5	0.475
Periods	Period I	Period II	0.942	21.780	6	0.001
	Period II	Period I	0.942	16.109	6	0.01
Between species	SA sea lion	B. dolphin	0.680	106.587	7	4.68279E-20
	B. dolphin	SA sea lion	0.591	70.375	7	1.24104E-12

Table 11. Diet overlap analyses between the major sources of variation in the sample studied. GO= general overlap index; V= the statistic to test the null hypothesis the GO= 1; df= degrees of freedom; P= probability of the statistic; SO_{ik}= specific overlap of group *i* onto group *k*; U= statistic to test the null hypothesis that $SO_{ik} = 1$.

B. dolphin		General overlap index				
Source of variation		GO	V	df		P
Sex		0.979	2.332	4		0.675
Period of the year		0.965	3.975	4		0.409
Stage of maturity		0.965	3.968	4		0.410
Periods		0.947	8.294	4		0.081
		Specific overlap index				
Source of variation	*I*	*k*	SO	U	df	P
Sex	Males	females	0.915	6.024	4	0.197383
	Females	males	0.912	3.888	4	0.421369
Period of the year	Warm months	Cold months	0.802	19.897	4	0.000523
	Cold months	Warm months	0.795	5.055	4	0.281722
Stage of maturity	Adults	juveniles	0.866	6.595	4	0.15891
	Juveniles	adults	0.848	10.559	4	0.031995
Periods	Period I	Period II	0.067	10.095	4	0.038851
	Period II	Period I	0.040	368.085	4	2.18055E-78

Table 12. Water content, dry mass, proximate- composition (protein, lipid and ashes) and energetic (E) mean values for main preys of the South American sea lion and bottlenose dolphin from southern Brazil.

Species	Mean length in the diet (cm)	Length (cm)	Water content (%WM)	Dry mass (%DM)	Protein (%DM)	Lipid (%DM)	Ashes (%DM)	Energy value (KJ/g)
Macrodon atricauda		14.7	81.68	19.29	16.25	0.47	2.57	4.03
Sea lion	22.4	18.6*	80.62	18.87	15.60	1.20	2.07	4.16
Urophycis brasiliensis		12*	80.30	18.79	15.59	0.78	2.42	4.03
Sea lion	18.9	28	80.38	20.22	16.79	1.23	2.20	4.46
		39.5	81.06	18.61	16.07	0.50	2.04	4.00
Paralonchurus brasiliensis		12	79.66	21.12	16.46	1.31	3.35	4.41
Sea lion	15.3	14**	78.49	22.06	17.22	1.28	3.56	4.58
Dolphin	14.4	19.5	76.98	24.38	17.69	3.52	3.17	5.58
Micropogonias furnieri		13	73.25	24.36	14.13	4.15	6.08	4.99
Sea lion	25.4	22	73.72	26.5	17.09	5.15	4.26	6.09
Dolphin	28.1	26.5**	73.33	27.78	17.36	6.65	3.77	6.75
		35.5	73.23	24.25	16.44	4.72	3.09	5.7
Menticirrhus sp.		25**	73.50	25.83	18.71	3.98	3.14	6.00
Sea lion	25.8	31.5	72.52	27.61	18.03	6.23	3.35	6.74
Dolphin	19.2							
Trichiurus lepturus		59.5	77.92	22.08	17.16	1.29	3.63	4.57
Sea lion	77.9	76**	78.00	22.38	17.45	1.33	3.60	4.65
Dolphin	80.4	105	78.28	23.28	16.26	2.86	4.16	4.98
Cynoscion guatucupa								
Sea lion	18.8	13.6	77.08	22.42	17.59	0.87	3.96	4.50
Mugil liza								
Dolphin	44.7	41	70.17	29.07	18.06	7.83	3.18	7.38

*The sample with the length closer to the mean length of the preys in the diet of the sea lions and dolphins.

LIST OF FIGURES

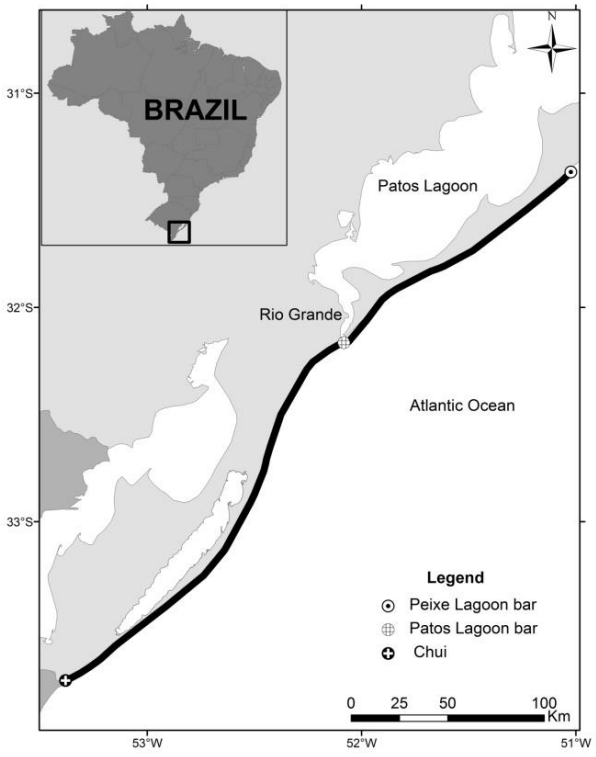

Figure 1. Study area comprises a 350 km river long stretch of a sandy beach from Chui river to Peixe Lagoon bar.

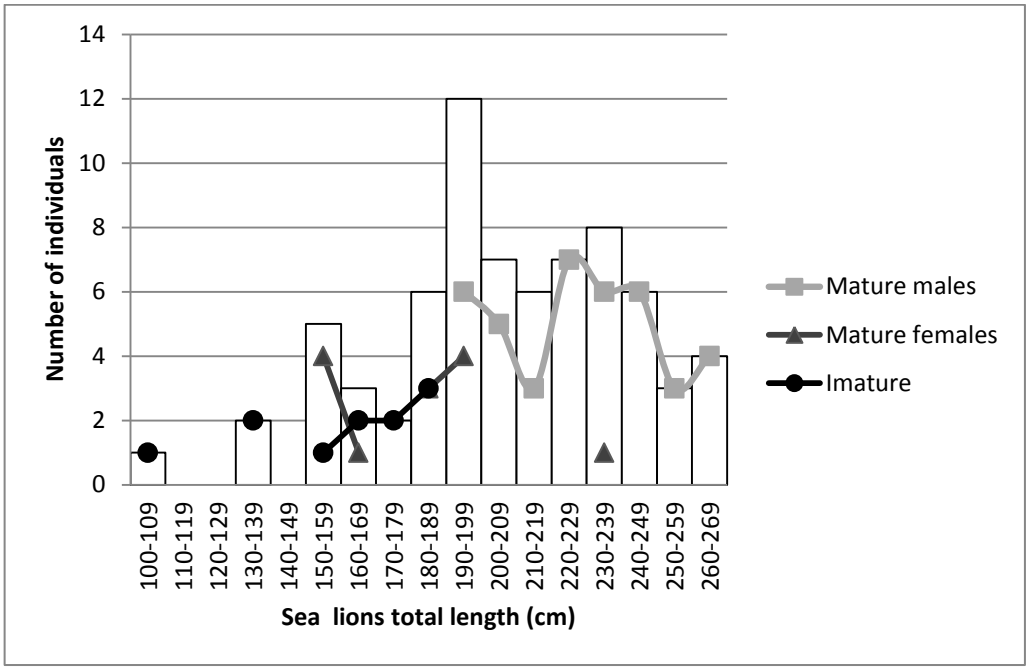

Figure 2.Length frequency distribution of the pooled sample of South American sea lion analyzed in this study and the length frequency distribution by trophic groups (mature males, mature females and immature individuals). Bars are pooled samples.

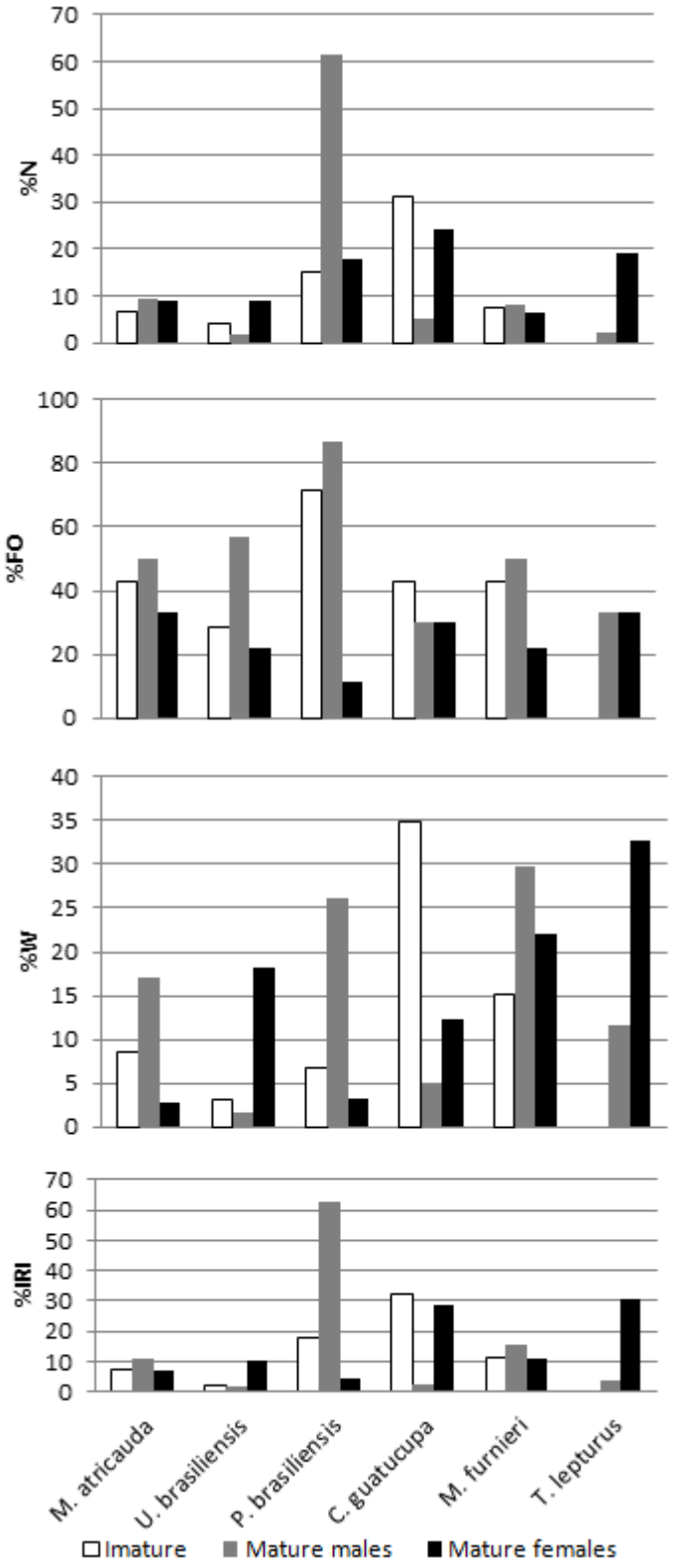

Figure 3. Main prey species in the diet of South American sea lions. %N = percentage by number, %W = percentage by regression-estimated weight, %FO= percent frequency of occurrence, and %IRI = Percent Index of Relative importance.

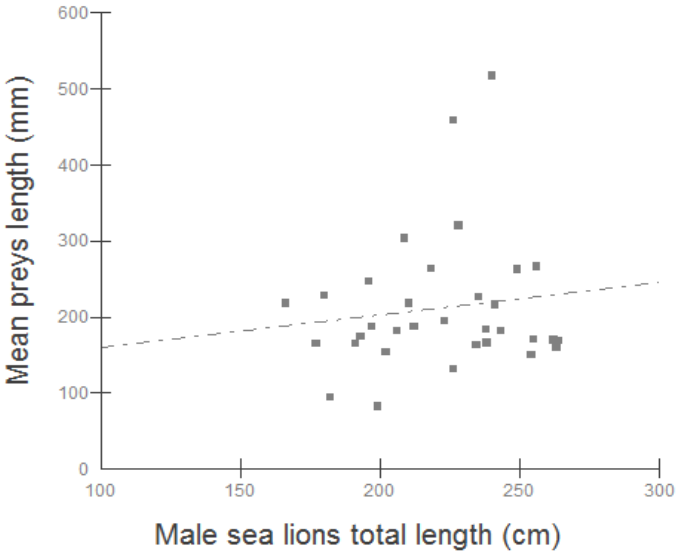

Figure 4. Correlation between average length of preys and male SA sea lions total length. rs= 0.031, p= 0.86.

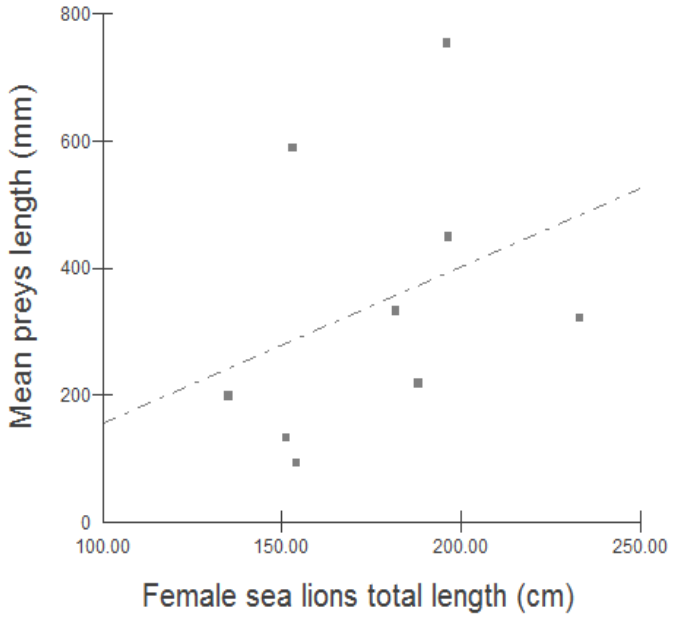

Figure 5. Correlation between average length of preys and female SA sea lions total length. rs= 0.46, p= 0.20.

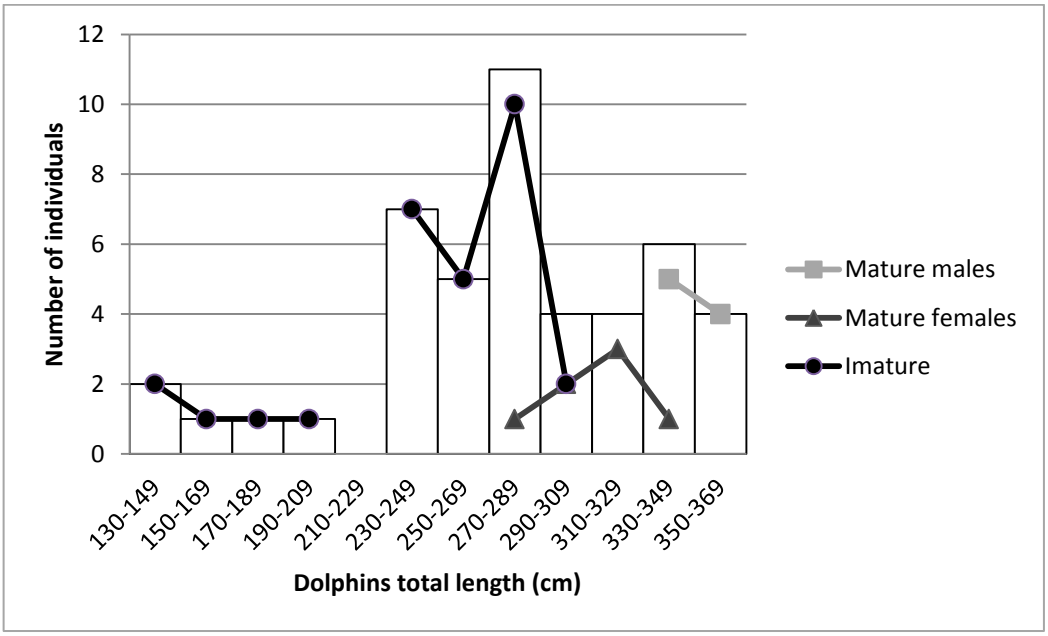

Figure 6. Length frequency distribution of the pooled sample of bottlenose dolphins analyzed in this study and the length frequency distribution by trophic groups (mature males, mature females and immature individuals). Bars are pooled samples.

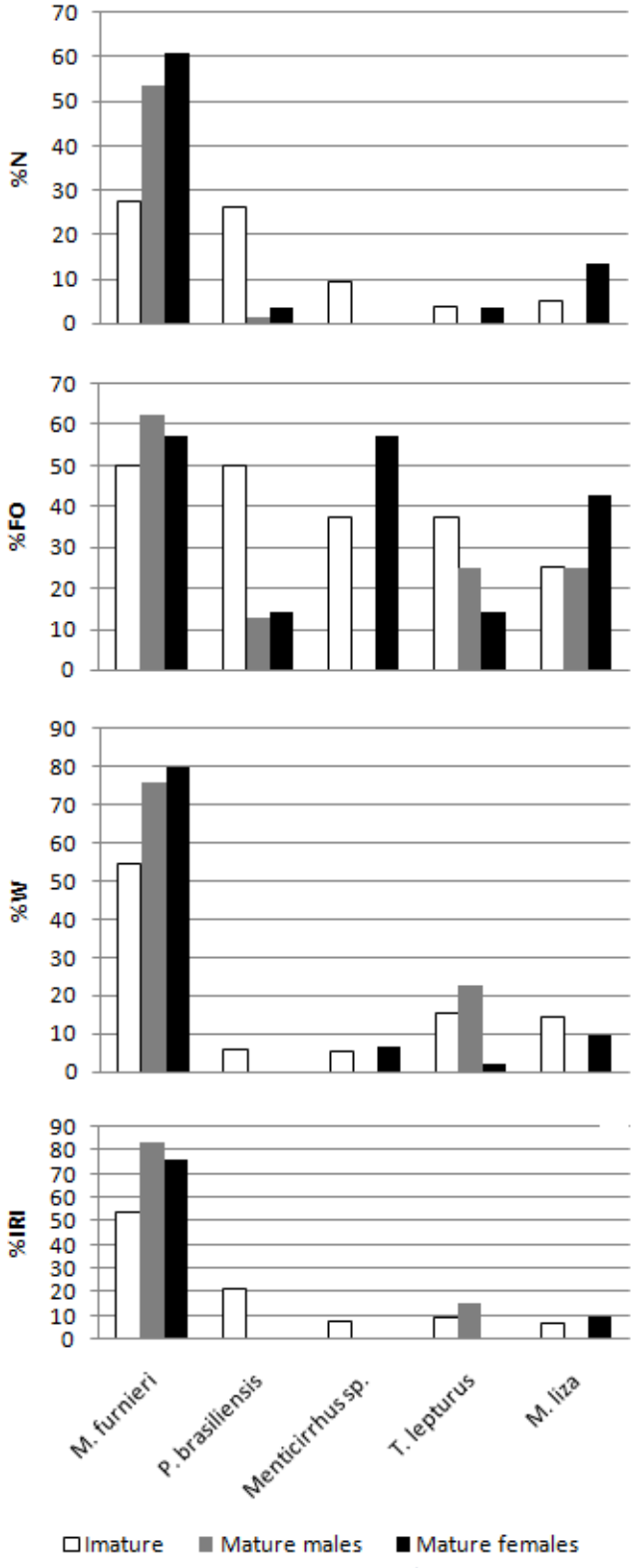

Figure 7. Main prey species in the diet of bottlenose dolphins: %N = percentage by number, %W= percentage by regression- estimated weight, %FO= percent frequency of occurrence, and %IRI= percent Index of Relative Importance.

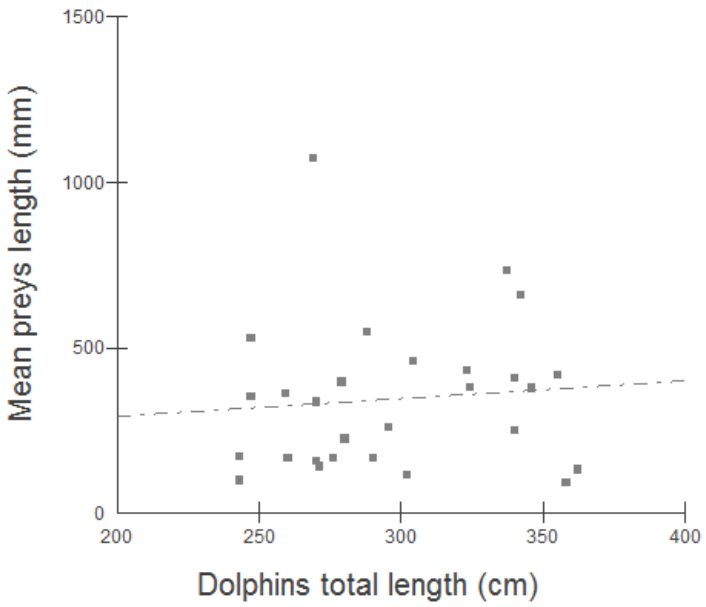

Figure 8. Correlation between average lengths of preys and dolphins total length. rs= 0.11, p=0.57.

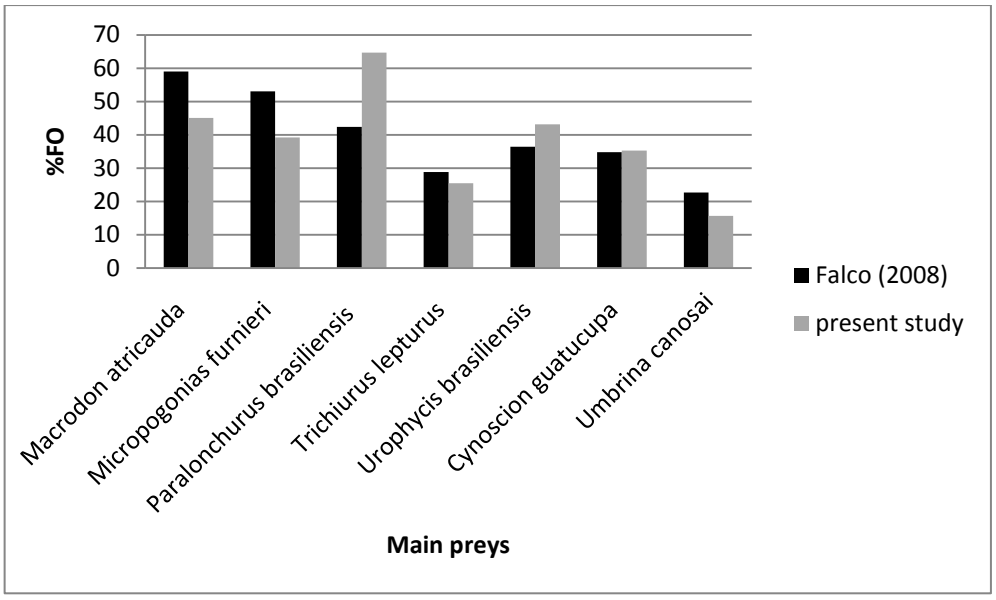

Figure 9. Comparison of frequencies of occurrence of the main species predated by South American sea lions in this study (2008-2012) and by Falco, 2008 (1977-1983).

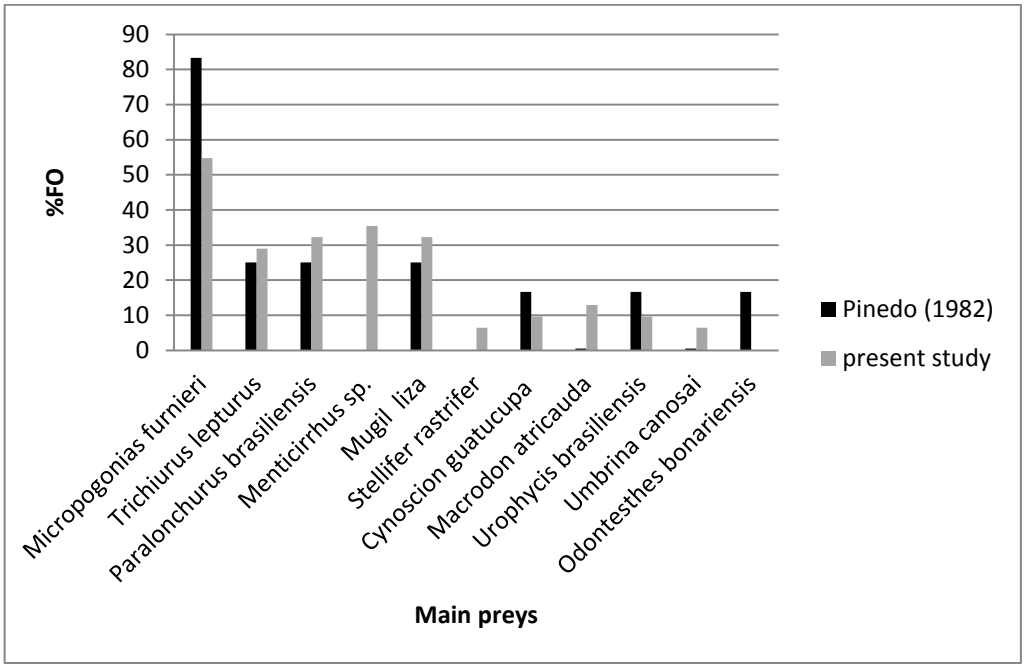

Figure 10.Comparison of frequencies of occurrence of the main species predated by bottlenose dolphins in this study (2002-2012) and by Pinedo, 1982 (1976-1980).

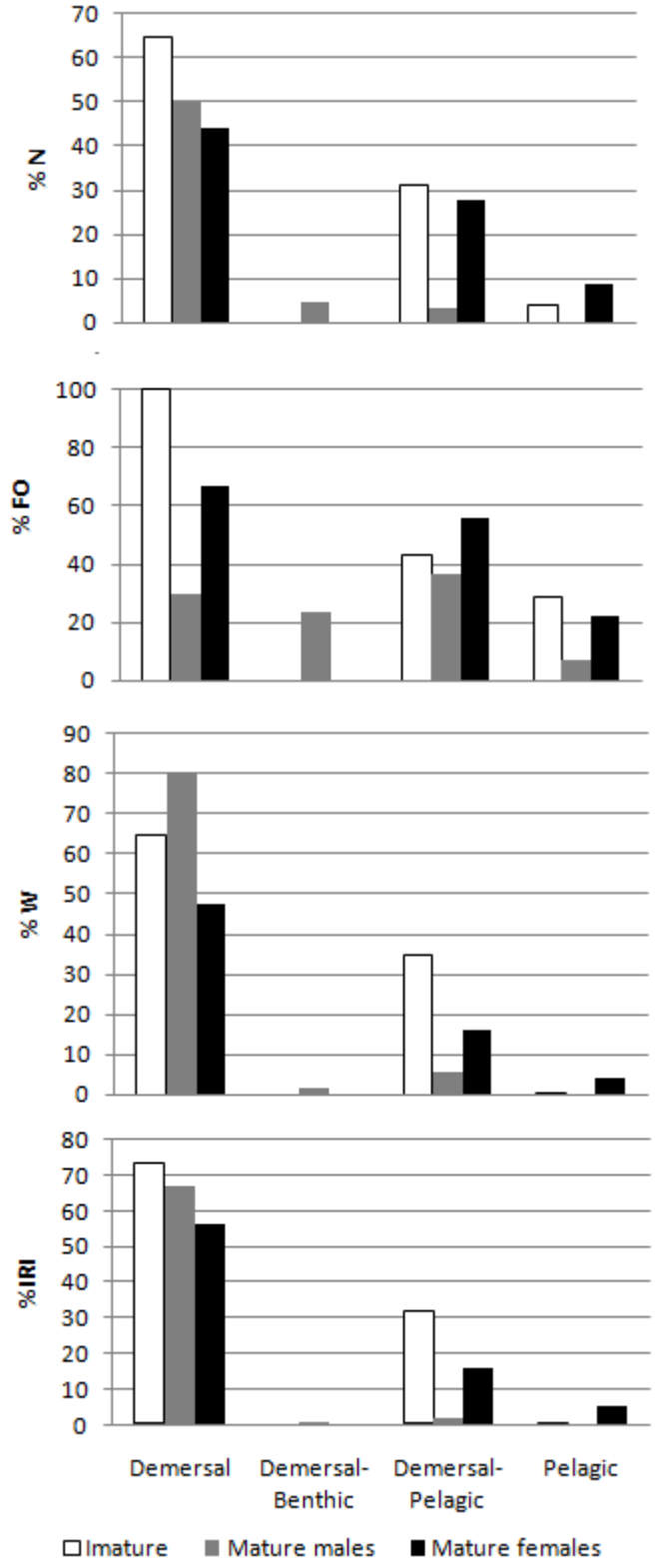

Figure 11. Diet composition for South American sea lion trophic groups based on the ecological environment of prey. %N = percentage by number, %W= percentage by regression-estimated weight, %FO= percent frequency of occurrence, and %IRI= percent index of relative importance.

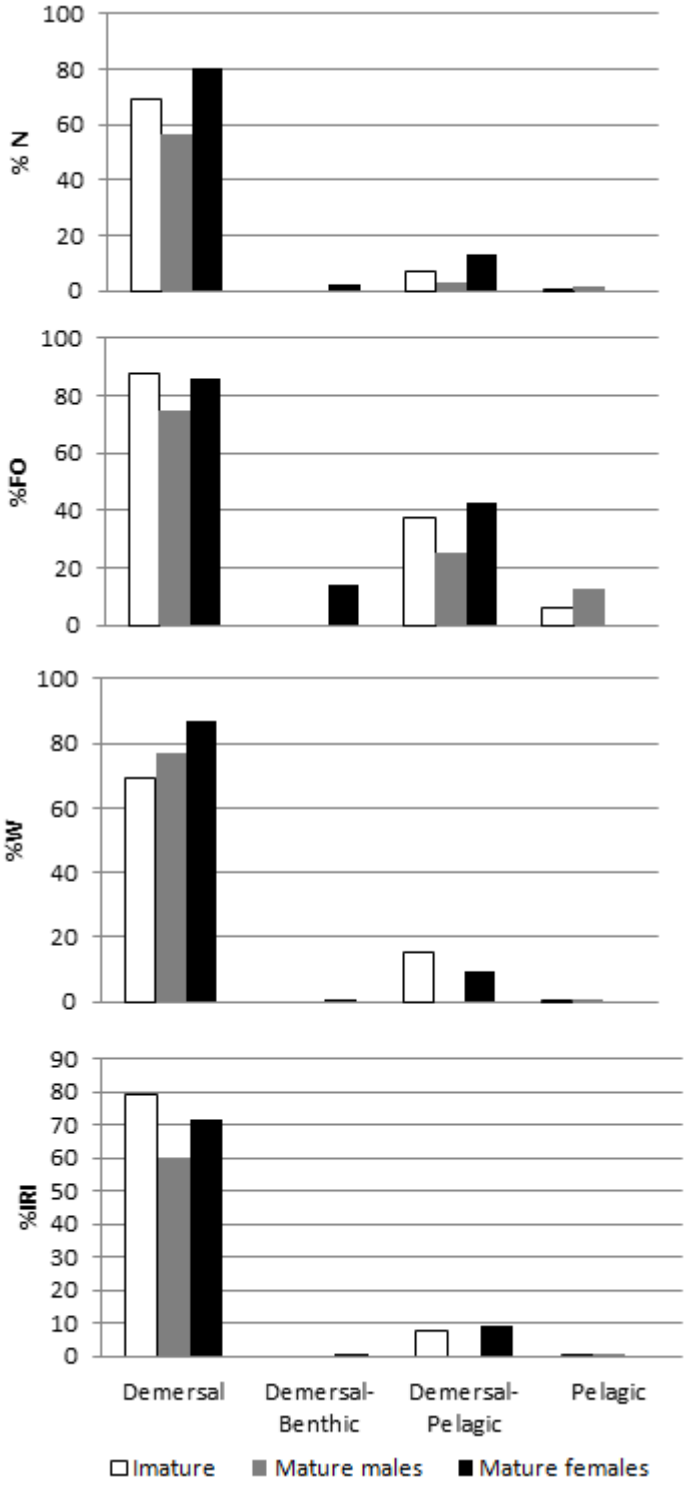

Figure 12. Diet composition for bottlenose dolphins trophic groups based on the ecological environment of prey. %N = percentage by number, %W= percentage by regression- estimated weight, %FO= percent frequency of occurrence, and %IRI= percent index of relative importance.

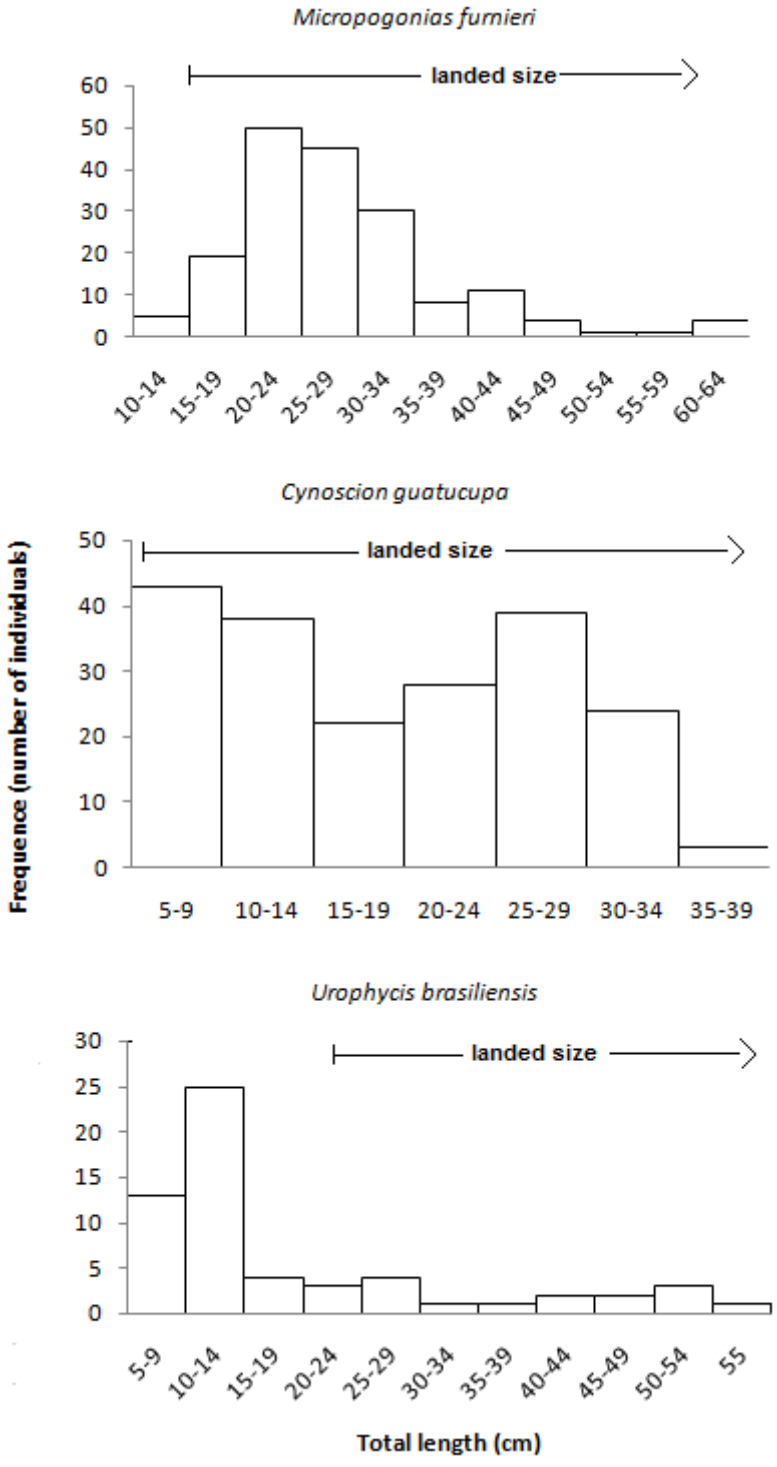

Figure 13. Regression-estimated size-frequency distribution of *M. furnieri*, *C. guatucupa* and *U. brasiliensis* consumed by South American sea lions off southern Brazil collected in our study. The arrows indicate the landed size of the fishes (Source: Haimovici and Ignácio 2005, Haimovici and Miranda 2005, Haimovici and Mendonça 1996).

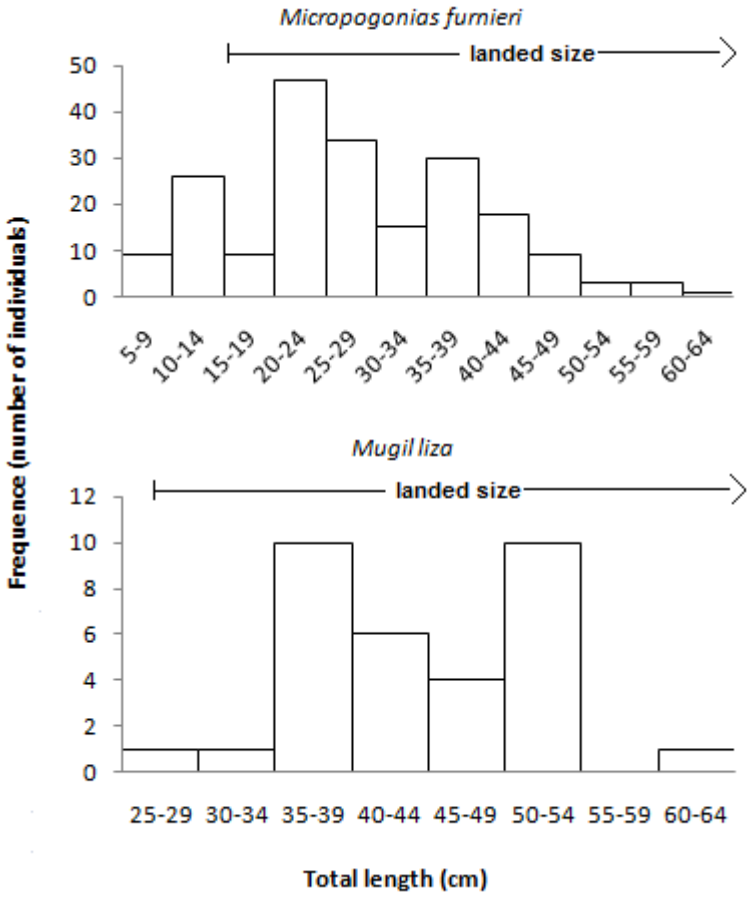

Figure14. Regression-estimated size-frequency distribution of *M. furnieri* and *M. liza* consumed by bottlenose dolphins off southern Brazil collected in our study. The arrows indicate the landed size of the fishes (Source: Haimovici and Ignácio 2005, Miranda et al. 2006).