UNIVERSIDADE FEDERAL DE PERNAMBUCO
DEPARTAMENTO DE OCEANOGRAFIA
PROGRAMA DE PÓS-GRADUAÇÃO EM OCEANOGRAFIA

Ecologia comportamental do golfinho-rotador (*Stenella longirostris*) em Fernando de Noronha

José Martins da Silva Júnior

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Tese apresentada ao Curso de Doutorado do Programa de Pós-Graduação em Oceanografia Biológica da Universidade Federal de Pernambuco, como requisito para obtenção do título de Doutor em Oceanografia.

Orientador: Dr. José Arlindo Pereira da Silva

Recife, 2005.

S586e **Silva Júnior, José Martins da**

Ecologia comportamental do golfinho-rotador (*Stenella longirostris*) em Fernando de Noronha / José Martins da Silva Júnior . – Recife : O Autor, 2005.

120 folhas. : il. ; tab, fig.

Tese (doutorado) – Universidade Federal de Pernambuco. CTG. Oceanografia. Área Oceanografia Biológica, 2005.

Inclui bibliografia e anexos.

1. Oceanografia biológica. 2. Ecologia comportamental - golfinhos-rotadores 3. Cetáceos I. Título.

551.46 **CDD (22.ed)** **BCTG/2005-20**

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Vive-se por merecimento.

AGRADECIMENTOS

Ao término de mais um capítulo do meu “darma” Projeto Golfinho Rotador, continuo agradecendo aos entes que o viabilizam.

Aos rotadores de Noronha, por me permitir estar com eles.

Aos meus pais, José e Marta, pelas minhas qualidades e por me trazerem até aqui.

Ao meu orientador, Arlindo Pereira, por mais uma vez ter viabilizado minha pós-graduação.

Aos meus colegas de pesquisa, Flávio Lima e Ivan Sazima, por me ajudarem a divulgar o que percebo.

Aos funcionários e professores do Departamento de Oceanografia da UFPE, em especial, Fernando e Myrna, pela ajuda nos trâmites burocráticos do curso.

Aos ex e atuais pesquisadores, funcionários e estagiários no Projeto Golfinho Rotador, em especial, Fabiana Cava.

Aos funcionários do Parque Nacional Marinho de Fernando de Noronha, em especial, Marcos Aurélio, pelo empenho na conservação da casa dos rotadores.

Ao IBAMA, por nos permitir estudar e conviver com os golfinhos, em especial Rômulo Mello e Ricardo Soawinski.

Aos membros do Centro Golfinho Rotador, Flávio, Amália, Andrea, Maria Dulce, Fátima, Marisa, Ivan, Marcos Aurélio, Régis e Arlindo (in memória).

Ao Jacques Mayol, pela inspiração e pelo apoio (in memória).

Aos amigos dos golfinhos-rotadores de Fernando de Noronha: Ana Paula Prates, Carlos Minc, Ciro Girard, Fernando Gabeira, José Truda Palazzo, Leonardo Boff e Tania Tavares.

A todas as mulheres da minha vida, em especial Andrea, Cíntia, Erika, Márcia, Marisa e Rachel.

Às instituições que financiaram o Projeto Golfinho Rotador, PETROBRAS, FNMA, IBAMA, CAPES, UNESCO, Fundação Banco do Brasil, Fundação AVINA, Banco Real, Fundação O Boticário e Atalaia Turismo.

À Administração do Distrito Estadual de Fernando de Noronha.

Aos Sócios Colaboradores do Centro Golfinho Rotador.

A todas as muitas pessoas e instituições que de alguma forma me ajudaram, muito obrigado.

RESUMO

Golfinhos-rotadores (*Stenella longirostris* - Delphinidae) congregam-se regularmente em grandes grupos ao redor do Arquipélago de Fernando de Noronha, principalmente na Baía dos Golfinhos, enseada com elevada transparência da água. É apresentada aqui uma visão ordenada sobre a atividade subaquática diurna dos golfinhos-rotadores. Em mergulho livre na Baía dos Golfinhos, o comportamento dos golfinhos foi observado, fotografado, filmado em vídeo e registrado qualitativa e quantitativamente com uso dos métodos de amostragens "animal focal" e "todas as ocorrências". A foto-identificação dos golfinhos foi usada para algumas das análises em que foi necessário individualizar os animais. A coleta de dados foi feita de maio de 1994 a maio de 1995 e de junho de 1998 a junho de 2004, totalizando 243 dias de mergulho e 204 horas/homem de observações. Além de comportamentos descritos em outros estudos para outras populações, como descanso, acasalamento e jogo, são aqui descritos comportamentos pouco conhecidos, como amamentação, defecação e regurgitação. Também, é descrito e ilustrado o comportamento de regurgitação dos golfinhos-rotadores, detalhando as fases do processo, o conteúdo dos regurgito e uma hipótese causal. Todos os regurgitos eram compostos por pedaços do corpo e bicos de lulas, estes últimos presumivelmente irritantes ao tubo digestório. São também relatadas interações e associações heteroespecíficas dos golfinhos-rotadores. São registrados aqui dois tipos de interações agonísticas, com golfinhos-pintados (*Stenella attenuata* - Delphinidae) e com tubarões-de-recifes (*Carcharhinus perezi* - Carcharhinidae). Ainda, foram registrados dois tipos de associações entre peixes e golfinhos-rotadores, aproveitamento alimentar de dejetos dos golfinhos por peixes planctófagos e acompanhamento dos golfinhos por rêmoras. Doze espécies de peixes de sete famílias foram observadas alimentando-se de fezes e vômitos dos golfinhos. Como todas as espécies observadas se alimentando de dejetos dos golfinhos alimentam-se de plâncton ou algas à deriva na coluna d'água, alimentar-se dos restos de cetáceos pode ser considerado como uma mudança oportunista no comportamento de forrageio. Esta relação entre peixes e golfinhos é aqui considerada como uma nova função ecológica para cetáceos, a de provedor de alimento para peixes recifais. Outra associação registrada foi a fixação de rêmoras (*Remora australis* - Echeneidae) ao corpo dos golfinhos. Foram feitos registros múltiplos de duas rêmoras (uma delas com marcas naturais) agarradas a um golfinho durante 47 dias e de outro par de rêmoras (ambas com marcas naturais) agarrado ao mesmo golfinho durante 87 dias. Provavelmente, a fidelidade de associação ao mesmo golfinho hospedeiro aumente a possibilidade da rêmora se reproduzir, assim como a natureza altamente social dos golfinhos-rotadores propicie o encontro entre parceiros de rêmoras para reprodução. O comportamento do golfinho-rotador de Fernando de Noronha é similar, em diversos aspectos, ao descrito para outras populações, especialmente no que se refere às categorias de descanso, cópula e jogo. Entretanto, em Fernando de Noronha foram registradas categorias de comportamentos até então inéditas, confirmando a elevada diversidade do repertório comportamental do golfinho-rotador. É provável que o registro, em Fernando de Noronha, de comportamentos pouco conhecidos para golfinhos esteja relacionado às condições oceanográficas e comportamentais excepcionalmente favoráveis para observações subaquáticas dos golfinhos-rotadores na Baía dos Golfinhos.

ABSTRACT

Spinner dolphins (*Stenella longirostris* – Delphinidae) usually congregate in large schools around Fernando de Noronha Archipelago, mainly at the Dolphins Bay, where the water is very clear. The diurnal underwater activity of these dolphins is presented here. Through snorkeling at the Dolphins Bay, the behavior of the animals was observed, photographed, video-taped and recorded qualitatively and quantitatively with use of the “focal animal” and “all occurrences” samplings. When individual identification was needed, photo-identification data was used. Data was collected during 243 snorkeling days and 204 hours/man of observations, from May/2004 to May/2005, and from June/1998 to June/2004. Besides behaviors already described in other studies on other dolphin populations, such as resting, mating and playing, some poorly known behaviors like suckling, defecating and vomiting are here described. A description and illustration of the spinner dolphins’ vomiting behavior, including the process, the vomit contents and one causal hypothesis are presented here. Vomits contained squid remains including their beaks, the latter presumably irritating to the dolphins’ digestive tract. There are also presented here heterospecific interactions and associations of the spinner dolphins. Two types of agonistic interactions were here recorded: one with spotted dolphins (*Stenella attenuata* - Delphinidae), and the other with reef sharks (*Carcharhinus perezi* - Carcharhinidae). Two types of fish associations with the spinner dolphins were recorded: feeding on dolphins’ offal by plankton-eating fishes, and using dolphins for attachment by whalesuckers. Thirteen fish species in seven families were recorded feeding on the dolphins’ feces and vomits. Since all offal-eating species feed on plankton or drifting algae to some extent, feeding on cetacean feces and vomits may be regarded as an opportunistic shift in the fishes’ foraging behavior. Due to this relationship, a new ecological role is here proposed for cetaceans: that of a food provider to reef fishes. The other recorded association related to whalesuckers (*Remora australis* - Echeneidae) attached to the bodies of the dolphins. There were made multiple records of two whalesuckers (one of them with natural marks) attached to a dolphin during 47 days and another pair of whalesuckers (both with natural marks) attached to the same dolphin during 87 days. The attachment fidelity to the same host probably increases the whalesucker’s chance to mate and the highly social nature of the spinner dolphins may facilitate meetings between potential mating fish partners. The behavior of spinner dolphins from Fernando de Noronha is similar, in several aspects, to that registered to other populations, mainly in relation to resting, mating and playing. However, in Fernando de Noronha there were records of behavior types poorly known or even unheard-of, which strengthen the view of high diversity of the spinner dolphins’ behavioral repertoire. The records of dolphins’ poorly known behaviors are probably related to the extremely favorable oceanographic and behavioral conditions for underwater observations of spinner dolphins at the Dolphins Bay.

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INTRODUÇÃO

Apresentação

O objetivo desta Tese de Doutorado é apresentar aspectos da ecologia comportamental do golfinho-rotador no Arquipélago de Fernando de Noronha, com o intuito de reunir subsídios para a conservação desta população de cetáceos.

A presente Tese é constituída por uma introdução, quatro capítulos e considerações finais. Na introdução, são apresentadas informações sobre o golfinho-rotador, *Stenella longirostris*, o Arquipélago de Fernando de Noronha e a metodologia de pesquisa utilizada. Os quatro capítulos são independentes e correspondem a quatro artigos científicos, sendo que o artigo do Capítulo I foi aceito para publicação e os outros três já foram publicados em periódicos internacionais indexados.

No Capítulo 1, “Rest, nurture, sex, release, and play: diurnal underwater behaviour of the spinner dolphin at Fernando de Noronha Archipelago, SW Atlantic” (SILVA-JR., SILVA & SAZIMA, no prelo), são descritas as atividades subaquáticas dos golfinhos-rotadores na Baía dos Golfinhos. Os dados quantitativos de tamanho dos grupos de descanso, tempo de submersão durante o comportamento de descanso, tempo de amamentação, tamanho dos grupos de cópula e tempo de penetração durante a cópula já haviam sido utilizados na dissertação de mestrado de José Martins da Silva Júnior (SILVA-JR., 1996).

No Capítulo 2, “Vomiting behavior of the spinner dolphin (*Stenella longirostris*) and squid meals” (SILVA-JR., PANDOLFO & SAZIMA, 2004), é descrito e ilustrado o comportamento de regurgitação do golfinho-rotador, comportamento pouco conhecido para cetáceos na natureza.

No Capítulo 3, “The cetacean offal connection: feces and vomits of spinner dolphins as a food source for reef fishes” (SAZIMA, SAZIMA & SILVA-JR., 2003), é descrita a associação de doze espécies de peixes que se alimentam das fezes e dos vômitos dos golfinhos-rotadores.

No Capítulo 4, “Whalesuckers and a spinner dolphin bonded for weeks: does host fidelity pay off?” (SILVA-JR. & SAZIMA, 2003), é registrado o acompanhamento de um golfinho-rotador por dois pares de rêmoras distintos, durante 47 dias e 87 dias, respectivamente.

Informações prévias sobre golfinho-rotador

Atualmente, são reconhecidas para a espécie *Stenella longirostris* – Delphinidae (Gray, 1828) as seguintes subespécies *Stenella longirostris longirostris*, *S. l. orientalis*, *S. l. centroamericana* e *S. l. roseiventris*. O golfinho-rotador que ocorre em Fernando de Noronha pertence à sub-espécie *S. l. longirostris*, conhecida como pantropical (PERRIN, 1990; PERRIN, AKIN & KASHIWADA, 1991; PERRIN, DOLAR, & ROBINEAU, 1999).

Quanto à distribuição, sabe-se que o golfinho-rotador *Stenella longirostris longirostris* é um cosmopolita, que ocorre em águas oceânicas tropicais nos Oceanos Atlântico, Pacífico e Índico (REEVES et al., 2002). Este golfinho apresenta hábitos pelágicos, prefere águas profundas, mas se aproxima de ilhas, bancos e atóis, como ocorre no Havaí (PERRIN & GILPATRICK, 1994) e em Fernando de Noronha (SILVA-JR., SILVA & PEREIRA, 1996).

A população de *S. longirostris* que ocorre ao longo de todo o Arquipélago do Havaí (EUA) freqüenta, preferencialmente, as águas calmas da enseada Kealakeakua Bay, localizada a sotavento da Ilha do Havaí, realizando atividades relacionadas a repouso, reprodução e cuidado de filhotes (NORRIS & DOHL, 1980).

No Brasil, há registro da ocorrência dessa espécie desde o Arquipélago de São Pedro e São Paulo (SILVA-JR., SILVA & PEREIRA, 1996) até o Rio Grande do Sul (ZERBINI & KOTAS, 1998), com registros para o Arquipélago de Fernando de Noronha desde 1556 (SILVA, 1992).

Em relação à organização social, sabe-se que os golfinhos oceânicos tendem a viver em grandes agrupamentos, como forma de reduzir os riscos de predação, facilitar a captura de alimento e aumentar as oportunidades de reprodução (MANN et al., 2000). Em contrapartida, a vida em grupos facilita a transmissão de hospedeiros externos, como rêmoras-de-baleias, *Remora australis* (KATONA & WHITEHEAD, 1988) e parasitas (AZNAR et al., 1994; RUOPPOLO et al., 2002).

A estrutura social do golfinho-rotador é considerada como fluída e transitória, com grupos se fundindo e se separando continuamente, formando os chamados grupos “fissão-fusão” (LAMMERS, 2004) em que as funções se alternam entre indivíduos e coligações ou grupos (JOHNSON & NORRIS, 1994).

Quanto à possibilidade de comunicação intra-específica, Brownlee e Norris (1994) relatam que os golfinhos-rotadores emitem basicamente três tipos de sons (estalidos, assobios e sinais pulsados), assim como descrevem a variação dos sinais sonoros em relação aos comportamentos exibidos por um agrupamento de golfinhos-rotadores no Havaí, sugerindo que cada estado comportamental pode ser identificado pelo tipo de som. Estudos relatam a existência de padrões particulares de emissões sonoras relacionados a agrupamentos específicos do golfinho-nariz-de-garrafa (*Tursiops truncatus*, Delpninidae), como mães e filhotes (MCCOWAN & REISS, 1995) e machos e fêmeas durante a corte (CONNOR & SMOLKER, 1996).

As atividades aéreas, saltos ou batidas com parte do corpo realizadas acima do nível do mar, são indicadoras do grau de agitação dos golfinhos e estão relacionadas com padrões comportamentais como deslocamento e agrupamento, podendo ser entendidas como forma de comunicação (NORRIS, 1994; SILVA-JR., 1996).

Estudos dos aspectos do comportamento de repouso utilizando a técnica “de ponto fixo” foram desenvolvidos com *Stenella longirostris* no Havaí (WÜRSIG et al., 1994) e com *Lagenorhynchus obscurus* (Delpninidae) na Patagônia (WÜRSIG & WURSIG, 1980). Esses estudos, assim como o de *L. obliquidens* em cativeiro (GOLEY, 1999), descrevem que a formação e o comportamento de repouso de golfinhos são sincronizados, lentos e com movimentos ascendentes e descendentes na coluna d’água.

Würsig, Wells e Norris (1994) estudaram o tempo de submersão do golfinho-rotador havaiano enquanto descansa, que é de 120 segundos, e Bearzi, Politie e Di Sciara (1999) estudaram o tempo de submersão em deslocamentos lentos do golfinho-nariz-de-garrafa no mar Adriático, que apresentou média de 121,2 segundos (SD±65,1; N=298).

Quanto às características morfológicas e de crescimento, pode-se afirmar que o comprimento médio dos golfinhos-rotadores do Oceano Pacífico ao nascerem é de 77 cm e o comprimento estimado para um ano de idade é de 133 cm. O crescimento dos filhotes é rápido até a puberdade. Em média, as fêmeas chegam à maturidade sexual entre 4 e 7 anos, com comprimento total entre 165 e 170 centímetros. Os machos atingem a idade de reprodução entre 7 e 10 anos, com comprimento total entre 160 a 180 cm (PERRIN & GILPATRICK-JR., 1994). A idade de desmame dos filhotes se dá entre 11 e 34 meses, conforme a população e as subespécies (MARTIN, 1990). A idade máxima de vida, estimada através das camadas dos dentes para *Stenella longirostris*, é de 20 anos (NORRIS & DOHL, 1980).

Os laços mãe-filhote são persistentes entre os golfinhos-rotadores (NORRIS & DOHL, 1980), mas, em caso de falta da mãe, Würsig, Cipriano e Würsig (1991) sugerem que possa ocorrer adoção de filhotes. A existência de agrupamentos constituídos exclusivamente ou com grande predomínio de pares mãe-filho, observada por Norris e Dohl (1980) para *Stenella longirostris*, também é relatada por Pryor e Shallenberger (1991) para *S. attenuata* e por Wells (1991) para *Tursiops truncatus*.

Em relação aos aspectos reprodutivos, estudos relatam que na população de golfinhos-rotadores do Oceano Pacífico a razão sexual é de aproximadamente 1:1 e a reprodução ocorre uma vez, no fim da primavera e início do verão, ou duas vezes por ano, uma na primavera e outra no outono. A taxa anual de gravidez é de 30 a 35%, correspondendo a intervalos entre partos de 3,3 a 3,9 anos e a taxa de nascimento anual é de 6,7 a 9,4% da população (MARTIN, 1990). Norris e Dohl (1980) estimam que o período médio de gestação de golfinhos-rotadores é de 10,5 meses.

Resultados de Benirschke e Benirschke (1980) indicam que a ovulação pode ser espontânea para golfinhos-rotadores. Segundo Barlow (1984), a taxa de ovulação em golfinhos-rotadores varia com a idade e com a população, mas na maioria dos casos é de uma vez por ano em animais sexualmente maturos. A reprodução é sazonal e é mais definida em algumas regiões do que em outras.

Animais que formam agrupamentos com dezenas de indivíduos tendem a apresentar estratégia reprodutiva poligâmica promíscua, como relatado por Maier (1998) para chimpanzés (*Pan troglodytes*, Hominidea) e por Scott, Wells e Irvine (1990) para golfinhos.

Wells e Norris (1994) sugerem como provável sistema de acasalamento de golfinhos-rotadores a poliginandria, na qual os parceiros da cópula reprodutiva não são definidos, com machos e fêmeas copulando com parceiros distintos. Os golfinhos-rotadores formam grupos de cópula muito coesos e agitados, embora também sejam observadas cópulas fora desses grupos, por escolha dos machos e das fêmeas. Johnson e Norris (1994) levantam a hipótese de que a fêmea possa escolher a paternidade de seus filhos internamente, limitando o acesso à vagina por meio de um tampão.

Johnson e Norris (1994) afirmam que não ocorre seleção de machos na cópula de golfinhos-rotadores, pois definem o sistema de acasalamento como sendo do tipo promíscuo.

Östman (1991) relaciona a agressividade entre os machos adultos de golfinhos durante o comportamento reprodutivo e os toques do rostro do macho na genitália da fêmea como sendo indícios de dominância no relacionamento. Cadwell e Cadwell (1967) observaram, em cativeiro, um filhote de *Tursiops truncatus* de dois dias de idade ter ereção quando era tocado por sua mãe. Knudtson (1996) registrou a ocorrência de postura de cópula entre dois machos de *Orcinus orca* (Delpninidae) em ambiente natural.

Segundo Wells e Norris (1994), comportamentos com orientação homossexual, como toques com o rostro na fenda genital entre fêmeas ou cópula entre machos, pode ser visto como uma opção sexual e social de competição entre golfinhos. Silva-Jr. (1996) concorda com Norris e Dohl (1980), quando esses afirmam que a utilização de padrões sexuais faz parte do desenvolvimento ligado ao relacionamento e comportamento interativo entre os indivíduos de um grupo e não que esses comportamentos possam ser classificados como homossexuais ou que ocorra cópula com indivíduos imaturos.

Quanto ao comportamento trófico, sabe-se que os golfinhos-rotadores alimentam-se preferencialmente de presas com tamanho inferior a 20 centímetros, capturados em mergulho de até 300 metros de profundidade. No Havaí, muitos desses organismos tornam-se acessíveis aos rotadores à noite, quando a camada de dispersão profunda ascende à superfície (NORRIS & DOHL, 1980).

Silva-Jr. (1996) relata que foram observados, no conteúdo estomacal de golfinho-rotador de Fernando de Noronha, otólitos de peixes da família Carangidae, bicos de lulas

(*Loligus sp.)* e pedaços de camarões vermelhos. No conteúdo estomacal de albacoras-de-nadadeiras-amarelas *Thunnus albacares* (Tunidae), encontradas com golfinhos-rotadores em comportamento de alimentação, havia lulas (*Loligus sp.*), peixes-voador (Exocoetidae), garapaus *Decapterus sp.* (Carangidae), agulhinhas (*Synentognathi*) e camarões vermelhos não identificados.

O comportamento de excreção, defecação e regurgito é pouco registrado para golfinhos-rotadores, como também para outros cetáceos, particularmente na natureza. Shinohara, Kishida e Kawa (1999) descrevem que, quando um o golfinho-nariz-de-garrafa vai defecar, mergulha um pouco além dos demais indivíduos do grupo e assim raramente borrifa suas fezes sobre outros golfinhos.

Em relação às interações sociais, são conhecidas associações de golfinhos-rotadores com golfinhos-pintados-pantropical (*Stenella attenuata*), atuns-de-nadadeira-amarela e várias espécies de aves e de peixes no Oceano Pacífico. A provável função dessas associações é a de proteção contra predadores aos indivíduos das diferentes espécies (NORRIS, 1994).

Jonson e Norris (1994) e Bel`Kovich (1991) relatam a prática de comportamentos típicos de indivíduos adultos pelos filhotes, entre golfinhos-rotadores selvagens e outras espécies de golfinhos. Golfinhos selvagens interagindo com objetos, como algas, foi observado em *Stenella longirostris* (JOHNSON & NORRIS, 1994) e *Lagenorhynchus obscurus* (WÜRSIG, 2002).

Würsig (2002) descreve que golfinhos-dusky (*Lagenorhynchus obscurus*) interagem com gaivotas *Larus dominicanus* e *L. maculipennis* (Laridae), mordendo-as e puxando-as para baixo, mas, aparentemente, sem machucá-las. Bel`kovich (1991) descreve que golfinhos-nariz-de-garrafa realizam o arremesso no ar de peixes dos quais se alimentam. Würsig (2002) relata que algumas espécies de golfinhos são conhecidas por interagir com tartarugas, puxando sua cauda ou pernas, e com tubarões, imitando seus movimentos.

Norris e Dohl (1980) referem-se à alta freqüência de mordidas de grandes tubarões e de o pequeno tubarão-charuto *Isistius spp.* (Dalaitiidae), que retira pedaços em forma de disco do tecido adiposo dos rotadores. Relatam também que os rotadores, ao se confrontarem com tubarões, ficam com o corpo todo curvado, em forma da letra “S” em vista lateral, para aumentar o poder de golpe da cabeçada, caso necessitem atacar.

Silva-Jr. (1996) registra relação entre a saída da Baía dos Golfinhos de golfinhos-rotadores em alta velocidade e a presença de tubarões na enseada. Também relata a observação de um grupo com cerca de três tubarões capturarem e se alimentarem de um golfinho-rotador.

Há registro da associação de forrageio entre peixes e mamíferos para diversas espécies, como o de Hediger (1953) para hipopótamo (*Hippopotamus amphibius*, Hippopotamidae) e de Sabino e Sazima (1999) para macaco-prego (*Cebus apella*, Cebidae). As associações de peixes com golfinhos incluem formações de grupos mistos de proteção dos predadores e vantagens de forrageio (WÜRSIG, WELLS & NORRIS, 1994), assim como o uso dos mamíferos para deslocamento (FERTL & LANDRY, 1999) e exploração de suas fezes como alimentação.

Alimentar-se de fezes (coprofagia) é um comportamento habitual para uma série de espécies de peixes no Oceano Pacifico. Fezes de peixes são utilizadas como uma fonte rica de alimento (BAILEY & ROBERTSON, 1982; ROBERTSON, 1982). O uso das fezes do golfinho-rotador como alimento foi observado para três espécies de peixes coralinos no Atlântico Sul Ocidental (LODI & FIORI, 1987; LODI, 1998).

As rêmoras se fixam a vários vertebrados marinhos em busca de benefícios como deslocamento, alimentação e proteção contra predadores (STRASBURG, 1959; CRESSEY & LACHNER, 1970; KATONA & WHITEHEAD, 1988). Algumas espécies se anexam a hospedeiros em particular, como a rêmora-de-baleia (*Remora australis*, Echeneidae) que se fixa somente em cetáceos e é pouco conhecida (FOLLETT & DEMPSTER, 1960; RICE & CALDWELL, 1961; RADFORD & KLAWE, 1965).

Quanto à presença de golfinhos em Fernando de Noronha, estudos relatam grande concentração de golfinhos-rotadores na Baía dos Golfinhos (CASTELLO & BARCELLOS, 1986; LODI & FIORI, 1987; SILVA-JR., SILVA & PEREIRA, 1996). Lodi e Fiori (1987) não detectaram a existência de períodos de descanso dos rotadores na Baía dos Golfinhos e sugerem que, provavelmente, a enseada seja uma área de reprodução e cria.

Em cerca de 94% dos dias do ano, entre 1990 e 2004, grupos de 3 a 2046 golfinhos-rotadores ocuparam a Baía dos Golfinhos do Parque Nacional Marinho de Fernando de Noronha (SILVA & SILVA-JR., 2004), usando a área para descansar, reproduzir, cuidar de seus filhotes e refugiar-se de tubarões (SILVA-JR., SILVA & PEREIRA, 1996). A freqüência, o número e o tempo de permanência dos animais no interior da Baía dos Golfinhos apresentaram correlação positiva com a direção e velocidade do vento e correlação negativa com a pluviosidade. O ciclo diário de atividades dos golfinhos-rotadores consiste em: alimentação noturna, movimento matinal em direção à Baía dos Golfinhos, chegada ao nascer do sol e saída à tarde para as áreas de alimentação (SILVA, 2001; SILVA-JR., 1996).

Os golfinhos-rotadores também interagem com as outras espécies de cetáceos mais avistadas em Fernando de Noronha. A segunda espécie de cetáceo mais avistada é o golfinho-pintado (PERRIN et al., 1985). Estas duas espécies de *Stenella* ocorrem associadas nas zonas de alimentação no Oceano Pacífico (LEATHERWOOD et al., 1982), são cosmopolitas oceânicas tropicais e estão incluídas na categoria “insuficientemente conhecida” na lista de espécies de cetáceos do Plano de Ação para Mamíferos Aquáticos do Brasil (IBAMA, 2001). A terceira espécie de cetáceo mais registrada para Fernando de Noronha é a baleia-jubarte (*Megaptera novaeangliae,* Balaenopteridae), que ocorre principalmente entre os meses de julho e outubro (SILVA-JR., 2003a).

No que se refere à interação dos golfinhos-rotadores com os humanos em Fernando de Noronha, a facilidade de se encontrar golfinhos-rotadores e o carisma que despertam nos humanos fizeram da observação de cetáceos um dos principais atrativos turísticos de Fernando de Noronha, dando uma importância também econômica à presença desses animais no Arquipélago. Cerca de 80% dos visitantes do Arquipélago observam golfinhos-rotadores em passeios de barco e 40% no Mirante dos Golfinhos (SILVA-JR., 2003a).

Em 2002, ocorreram 2.474 saídas de barco para observar golfinhos levando 49.938 pessoas para observar golfinhos e realizar mergulho livre no Parnamar-FN, 79% dos visitantes da Ilha naquele ano. Em média, ocorreram 6,9 (DP=2,6) saídas de barcos para observar golfinhos com 140,3 (DP=58,3) visitantes por dia na área do Parnamar-FN. No dia 4 de março de 2002 foi registrado o maior número de visitantes, 365 em 17 saídas. Os passeios de barco para observar golfinhos têm duração média de 3 horas e ocorrem em dois horários: entre oito e dez horas e entre treze e quinze horas. Outros tipos de passeios de barco que eventualmente encontram os golfinhos-rotadores em Fernando de Noronha são: para mergulho rebocado, para mergulho autônomo, de caiaque, de vela e para pesca esportiva (SILVA-JR., 2003b).

É sabido que a recreação em barcos a motor causa efeitos indiretos na vida selvagem, que são difíceis de serem isolados e estudados (KNIGHT & GUTZWILLER, 1995). Norris e Reeves (1978) afirmam que as perturbações antropogênicas que provocam maiores gastos energéticos durante os comportamentos críticos, como reprodução e descanso, podem ter efeitos em longo prazo, reduzindo o bom estado biológico da população de cetáceos afetada.

Norris e Dohl (1980) observaram que os rotadores, quando perseguidos por barcos, nadam para águas profundas ou abandonam a área onde se encontram. Segundo Silva-Jr. (1996), a perseguição dos barcos aos rotadores que entram ou saem da Baía dos Golfinhos vem alterando o comportamento dos golfinhos, provocando a divisão do grupo e aumentando a velocidade do deslocamento. Essas alterações comportamentais foram descritas por Norris e

Reeves (1978), Kruse (1991) e por Shane (1990) como sendo resultantes de molestamento aos cetáceos.

Quando os golfinhos-rotadores encontram um barco de turismo, os animais que estão de guarda nadam na proa da embarcação e o grupo principal aumenta o tempo de submersão, desvia da rota dos barcos e aumenta a velocidade do deslocamento (SILVA-JR., 1996).

Os golfinhos que não acompanham a embarcação estão descansando, reproduzindo, cuidando dos filhotes, são filhotes ou estão em deslocamento de chegada ou saída da área de descanso. Dessa forma, quanto mais barcos ou quanto mais tempo os barcos perseguem os golfinhos, menos tempo os rotadores têm disponível para descansar, reproduzir e cuidar dos filhotes. Como conseqüências dessas alterações comportamentais, pode-se supor que o aumento do turismo de observação de golfinhos em Fernando de Noronha produza estresse nos rotadores e diminua a taxa de reprodução desta população de cetáceos (SILVA-JR., 1996).

Embora a legislação de proteção aos cetáceos (Lei Federal n° 7643/87; Portaria/IBAMA n° 05/95; Portaria/IBAMA n° 117/96; Instrução Normativa/ ADEFN n° 4/99) tenha normas que objetivam diminuir o impacto humano sobre esses animais, o turismo náutico em Fernando de Noronha constitui uma atividade com impacto negativo sobre os golfinhos-rotadores (SILVA-JR. & SILVA, 2000).

Área de Estudo

O Arquipélago de Fernando de Noronha (3°51' Sul de latitude e 32°25' Oeste de longitude) está distante 345 km do Cabo de São Roque no Rio Grande do Norte e situa-se na altura da bifurcação da corrente Sul Equatorial, que corre no sentido oeste com águas caracterizadas pela salinidade elevada, pelas baixas concentrações de sedimentos, matéria orgânica, nutrientes e plâncton (FUNATURA, 1990), pela alta transparência, com profundidade de extinção da luz de 87 m (COSTA, 1991) e por apresentar temperatura em torno de 27^{0}C (LINSKER, 2003).

Fernando de Noronha possui um clima tropical com duas estações pluviométricas bem definidas: período seco, de agosto a fevereiro; e período chuvoso, de março a julho. A precipitação média anual é de 1.300 mm3, oscilando de 500 mm3 a 2.000 mm3 (LINSKER, 2003). A temperatura do ar oscila entre 23,5° C' e 31,5 ° C' e apresenta amplitude térmica média de 4,1°C'. Predominam os ventos alísios de sudeste e leste (FUNATURA, 1990).

O Arquipélago é o que resta do alto de um vasto edifício vulcânico, cuja base repousa no assoalho oceânico, a 4.000 metros de profundidade, com as ilhas secundárias elevando-se de uma rasa plataforma com até 5 km de largura (ALMEIDA, 1958). O Arquipélago é constituído por uma ilha principal, Fernando de Noronha, e 17 ilhas secundárias, totalizando uma área de 26 km2 (FUNATURA, 1990).

A Ilha de Fernando de Noronha possui 17 km2, distribuídos longitudinalmente na direção sudoeste-nordeste, formando duas faces com 11 km de extensão. A face noroeste, denominada de Mar de Dentro, fica protegida dos ventos predominantes. No Mar de Fora, a face sudeste, o mar é mais agitado. Quase todo o litoral da Ilha é rochoso e escarpado, principalmente na face sudeste e na extremidade oeste da face noroeste, onde se localiza a Baía dos Golfinhos (Figura 1).

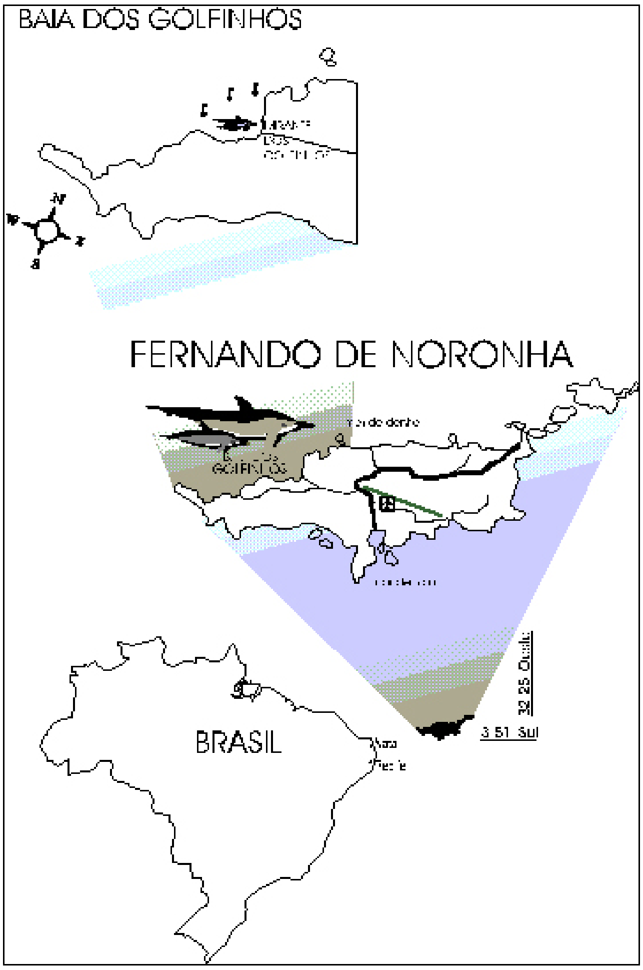

Figura 1 - Localização de Fernando de Noronha e da Baía dos Golfinhos.

A Baía dos Golfinhos (Figura 2) possui o fundo predominantemente coberto por areias vulcânicas com rochas dispersas. A profundidade da Baía vai de 0 a 25 metros, sendo em torno de 15 metros no centro. As encostas são bem íngremes e a enseada não apresenta praias de areias, apenas praias de seixos rolados ou as águas chegam direto no penhasco (ALMEIDA, 1958). A Baía dos Golfinhos é a enseada de águas mais calmas, transparentes e profundas do Arquipélago. Como a borda do penhasco é mais alta que a área adjacente à Baía dos Golfinhos, não existe riacho ou córrego d’água chegando à enseada, pois a água pluvial é carreada para a Baía do Sancho ou para a Praia do Leão. As correntes internas na Baía são fracas e no sentido sudoeste. A face externa da Baía dos Golfinhos é delimitada por cinco bóias, localizadas próximas da isóbata de 25 metros, que sinalizam a área proibida ao acesso dos barcos (SILVA-JR., 1996).

Figura 2 – Vista do Mirante dos Golfinhos

Metodologia

A ecologia comportamental dos golfinhos-rotadores foi estudada por meio de observação direta, fotografia e filmagem em mergulho livre na Baía dos Golfinhos do Parque Nacional Marinho de Fernando de Noronha, como descrito em Pryor e Shallenberger (1991) e Silva-Jr, Silva e Pereira (1996). O período escolhido para as seções de observação foi durante a manhã, uma vez que, à tarde, os golfinhos gradualmente saem da Baía dos Golfinhos (SILVA-JR, SILVA & PEREIRA, 1996).

Os mergulhos seguiram a técnica de mergulho passivo descrita em Mayol et al. (2000), método pouco perturbador e particularmente adequado para estudos de mamíferos marinhos e peixes de águas abertas. Antes do início de cada observação, de 10 – 90 min., foram concedidos de 1 a 3 min para os golfinhos se habituarem ao pesquisador.

Foram utilizados os métodos de amostragens “animal focal” e “todas as ocorrências”. Para observação de ações específicas, como cópula e defecação, os dados foram registrados em intervalos de tempo pré-determinados (ALTMANN, 1974; LEHNER, 1996).

No comportamento de alimentação dos excrementos dos golfinhos pelos peixes, cada evento de alimentação dos restos foi contabilizado apenas uma vez, independente do número de peixes que se alimentavam das fezes e vômitos. Um regurgito foi contabilizado para duas ou três espécies de peixes no caso em que essa eliminação em particular fosse consumida por um grupo misto. Por outro lado, uma espécie de peixe observada alimentando-se de restos em apenas uma sessão de observação foi contabilizada mais de uma vez, conforme o número de vômitos e fezes dos golfinhos de que os peixes se alimentam nessa sessão específica. O tamanho dos peixes foi estimado visualmente e posteriormente checado, comparando espécime de tamanho similar observado na área de estudos ou próximo.

Foram coletados os conteúdos de fezes e regurgitos dos golfinhos-rotadores, incluindo vermes, bem como o conteúdo estomacal de cinco cangulos-pretos (*Melichthys niger*) encontrados alimentando-se de fezes dos golfinhos.

Para algumas observações, como a de por quanto tempo um certo golfinho carrega uma rêmora, os golfinhos foram individualizados. A identificação dos animais deu-se em função da classe etária, sexo e marcas naturais, com o uso de foto-identificação conforme técnicas descritas em Hammond, Mizroch e Donovan (1990).

A caracterização sexual foi baseada nas características morfológicas externas: os machos possuem uma protuberância genital e as fêmeas apresentam duas fendas mamárias evidentes (NORRIS et al., 1994). A idade dos golfinhos foi avaliada pelo tamanho proporcional, tendo sido considerados filhotes os golfinhos com menos de 2/3 do tamanho do adulto. Os golfinhos com mais de 2/3 do tamanho total estimado para a espécie foram classificados como adultos (SILVA-JR, SILVA & PEREIRA, 1996).

Para a identificação por marcas naturais, foram utilizadas formas das nadadeiras, padrões de pigmentação e cicatrizes resultantes de mordidas de tubarões e outros peixes ou de acidentes com redes ou linhas de pesca, conforme relatado em Silva-Jr., Silva e Pereira (1996), Norris et al. (1994) e Würsig e Jefferson (1990).

As fotografias e as filmagens estão arquivadas no Centro Golfinho Rotador em Fernando de Noronha, e amostras de vídeos e fotos escaneadas estão arquivadas no Museu de História Natural da Universidade Estadual de Campinas (ZUEC record collection).

Para alguns comportamentos foram gravados e analisados os sons emitidos pelos golfinhos-rotadores. Os sons foram gravados com um gravador subaquático digital profissional (SONY DSR – PD15 3CCD DVCAM) armazenado em um AMPHIBICO com um hidrofone de alumínio à prova d`água, com freqüência limite de 24kHz. Os sonogramas foram produzidos por um computador Macintosh acoplado ao MacRecorder Sound System @.0.5, usando uma resolução de 8 bit, 22 kHz de freqüência e FFT com 256 pontos.

Os dados utilizados nesta tese foram coletados em dois períodos. Entre maio de 1994 e maio de 1995, em 41 dias de mergulhos e 31 horas/homem de observações diretas. Registros comportamentais adicionais e foto-identificação foram realizados entre junho de 1998 e junho de 2004, em 202 dias de mergulho e 173 horas/ homem. O esforço amostral total foi de 243 dias de mergulho e 204 horas/homem de observação. Também foram analisadas 8 horas de filmagens e cerca de 10 mil fotografias do catálogo fotográfico do Projeto Golfinho Rotador, registradas durante os mesmos períodos.

CAPÍTULO 1

Rest, nurture, sex, release, and play: diurnal underwater behaviour of the spinner dolphin at Fernando de Noronha Archipelago, SW Atlantic

Rest, nurture, sex, release, and play: diurnal underwater behaviour of the spinner dolphin at Fernando de Noronha Archipelago, SW Atlantic

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Key words: Delphinidae, *Stenella longirostris,* social behaviour, eliminative behaviour, heterospecific associations, reef fishes, new role for cetaceans, tropical West Atlantic

Aceito para publicação no Journal of Ichthyology and Aquatic Biology

Abstract

At Fernando de Noronha Archipelago in the South West Atlantic, spinner dolphins (*Stenella longirostris*) regularly congregate in large groups in a clear water, shallow bay, allowing their behaviour to be observed and recorded at close quarters. We present na overview of the diurnal underwater activity of the Noronha spinners while in the bay. Apart from well known types of behaviour such as resting, mating, and playing, we present and illustrate others such as suckling, defaecating, and vomiting which are less well-known and documented. Heterospecific interactions and associations are also discussed. Na ecologically new role for cetaceans, as a food supplier for reef fishes, is here proposed for the Noronha spinners

Resumo

No Arquipélago de Fernando de Noronha, Atlântico Sul Ocidental, golfinhos-rotadores (*Stenella longirostris*) congregam-se regularmente em grandes grupos numa baía rasa com água de boa visibilidade, o que permite sua observação a curta distância. Apresentamos aqui uma síntese sobre a atividade subaquática diurna dos rotadores de Noronha na baía. Ao lado de comportamentos bem conhecidos, como descanso, acasalamento e jogo, apresentamos e ilustramos alguns comportamentos pouco conhecidos ou documentados, como amamentar, defecar e vomitar. Interações e associações heteroespecíficas são também relatadas. Uma nova função ecológica para cetáceos, a de provedor de alimento para peixes recifais, é aqui proposta para os rotadores de Noronha.

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Introduction

From the behavioural viewpoint, spinner dolphins (*Stenella longirostris*, Delphinidae) are among the best studied cetacean species. However, most of the current knowledge of these marine mammals derives from studies on the Pacific populations in Hawaii (review in Norris *et al.*, 1994). Studies of the behaviour of West Atlantic populations are scarce and published in local journals (e.g., Lodi & Fiori, 1987; Silva Jr. *et al.*, 1996). These last deal mostly with the behaviour of surfacing dolphins, as well as providing data on their frequency and permanence in the bay, as observed from the land. In addition, the above mentioned studies are published in Portuguese, which limits their accessibility.

At Fernando de Noronha Archipelago, off north-east Brazil in the equatorial West Atlantic, great concentrations of spinner dolphins are found at the site known as the Baía dos Golfinhos (Dolphins' Bay). The site is regularly visited by groups of up to about 2000 spinners which include adults of both sexes, and juveniles (Silva Jr. *et al.*, 1996). In the bay, the dolphins exhibit different types of behaviour such as aerial display and resting, as well as social interaction which include copulation and nursing (Lodi & Fiori, 1987; Silva Jr. *Et al.*, 1996). The clarity of the water and the fact that large numbers of spinners enter the bay all year round (Silva Jr. *et al.*, 1996) favour observation of their underwater behaviour at close quarters. Groups of spinner dolphins congregate in the bay during the morning and early afternoon, the first individuals arriving mostly between 0600-0700 h to rest and socialise. The last dolphins leave between 1300 and 1600 h to feed in the open sea (Silva Jr. *et al.*, 1996). Dolphins' Bay is a reserve and is part of the Fernando de Noronha National Marine Park: People and boats are not allowed and researchers are only permitted to enter the bay under strict regulation.

Herein we present an account of the diurnal underwater activity of Noronha spinners in the bay. We record a general, qualitative (sometimes quantitative) view of their behaviour, and also touch on three topics which relate to other animals which occur in the bay: 1) Reaction to other similar-sized or larger marine vertebrates; 2) Association between reef fish and the dolphins. 3) The role played by the spinners in the behaviour of these fishes.

Methods

All observations were made in the south-west Atlantic in the Fernando de Noronha National Marine Park off north-east Brazil. Fernando de Noronha Archipelago (03°50'S, 32°25'W) lies about 345 km east of the São Roque Cape in north-eastern Brazil (see Maida & Ferreira, 1997 and Carleton & Olson, 1999, for map and description). Observation sessions were mostly carried out at the Baía dos Golfinhos, a 15-25 m deep bay about 3 km wide (Lodi & Fiori, 1987; Silva Jr. *et al.*, 1996). The bottom of the bay is an open sandy area dotted with patchy reef formations similar to those found in Kealakeakua Bay, Hawaii, another place where spinner dolphins congregate and rest (Norris & Dohl, 1980; Wells & Norris, 1994).

The dolphins' behaviour was observed directly, photographed, and videotaped while snorkelling and skin diving (e.g., Pryor & Shallenberger, 1991; Silva Jr. *et al.*, 1996). The dolphins were given 1-3 min to get used to the divers before starting observation. The sessions lasted from 10 to 90 min. Focal animal and all occurrence samplings were used for direct observations: all instances of specific actions such as copulating or defaecating were recorded over a given period (Altmann, 1974; Lehner, 1996). The best time for observation was in the morning, since during the afternoon the dolphins gradually left the bay (e.g., Silva Jr. *et al.*, 1996; Sazima *et al.*, 2003; see also Lammers, 2004 for Hawaii).

Most of the behavioural records for which we have quantitative data were made between May 1994 and May 1995 and comprised 31 hours of direct observation over a total of 41 diving days. Further behavioural records were made during photo identification and other studies between June 1998 and June 2004, comprising 173 hours of observation (e.g., Sazima *et al.*, 2003; Silva-Jr & Sazima, 2003) over a total of 202 diving days. We also analysed 8 hours of videotapes recorded during the above periods. In some cases it was necessary to identify individual dolphins (e.g., when an observed dolphin carried a diskfish couple – see Silva Jr. & Sazima, 2003). For this we used photo identification, a well known procedure for the study of small cetaceans, making use of natural marks such as fin shapes, nicks, scars, and pigment patterns (Würsig & Jefferson, 1990) used to identify spinners in the Pacific (Norris *et al.*, 1994) and the West Atlantic (Silva Jr. *et al.*, 1996). Dolphins were sexed on their external features: the males have a conspicuous genital protuberance and females possess two obvious mammary slits (Norris *et al.*, 1994). Age groups were assessed by proportional lengths: Individuals measuring up to 2/3 of a fully grown adult's total length were counted as calves (Silva Jr. *et al.*, 1996). Calves were always seen in close proximity to an adult, possibly the mother.

Photographs and video recordings are on file at the Centro Golfinho Rotador in Fernando de Noronha, and video samples and scanned photographs at the Museu de História Natural, Universidade Estadual de Campinas (ZUEC record collection). Sounds were recorded with a SONY® DSR-PD15 3CCD DVCAM professional underwater digital camcorder housed in an AMPHIBICO® dual hydrophone aluminium waterproof case with a 24 kHz upper frequency limit. Sonograms were produced by a Macintosh® computer coupled to the MacRecorder® Sound System 2.0.5, using 8-bit resolution, a 22 kHz sampling frequency, and FFT with 256 points.

Results

Resting behaviour

Groups of dolphins rested while cruising slowly near the bottom, close to each other, mostly in a regular tight formation. Resting groups ranged in size from 3 to 25 individuals (mean 12.6; SD= 4.86; N= 102). From time to time all the members of the small groups ascended together - if small (Fig. 1) – and, if the group was large, rose singly in turn, surfaced to breathe, then descended to the bottom, always in formation and ‘zigzagging’ from the bottom to the surface and vice-versa. Immersion during rest time ranged from seven to 200 sec (mean= 164.67 sec; SD+43.56; N= 193). Resting groups cruised back and forth within the bay, without any obvious route pattern.

Fig. 1. A resting group of spinner dolphins (*Stenella longirostris*) swimming in formation at cruising speed, about to surface for breathing. Note the tongue of one dolphin hanging out from its open mouth. Photo by J .M. Silva-Jr.

Nursing behaviour

Parental care was recorded during most occasions when the dolphins were in the bay. Most of the time the calves remained close to females that were probably their own mothers (Fig. 2). The females frequently touched the calves' back and flippers with their own flippers. Soft noises (burst-pulse signals, cf. Lammers *et al.*, 2003) were habitually emitted by the females in calves' direction, especially when the calves appeared distressed or when they returned from their frolicking (see playing behaviour). These apparently 'soothing' noises were accompanied by touching by the females and the calves.

Fig. 2. A nursing spinner dolphin female and a calf shortly after breathing at surface (above); a female and a still suckling juvenile swimming side by side (below).
Photos by J. M. Silva-Jr. (above) and I. Sazima (below).

Suckling began when a calf would position itself at its mother's underside and whilst nudging the mammary slit with the tip of its beak (Fig. 3). The calf's glottis was seen to move as the milk was taken from the mammary slit by suckling movements. Whilst suckling the calf's eyes remain wide open, the tongue appeared to move and the sternohyoid muscle was contracting. After suckling at one side of the mammary slit, the calf moved to suckle on the opposite side. Suckling lasted between five and twenty sec (mean= 11.25; SD+4.34; N= 16). On rare occasions we recorded the calf taking milk which was squirted from the mammary slit. Once a calf was recorded taking mouthfuls of milk ejected from the mammary slit into the water. Suckling calves ranged from the newborn (identifiable by their neonatal skin folds) to juveniles up to about 130 cm in length.

Fig. 3. A juvenile spinner dolphin about to suckle, nudging the female's mammary slit with its beak. Photo by J .M. Silva-Jr.

Mating behaviour

Mating was recorded year round, copulation being most frequent early in the morning (0800-0930h), as well as before the dolphins left the bay. Although we recorded single males copulating with a female (N= 13), mating subgroups formed by 2-5 mature males were more commonly seen (N= 26). Besides male/ female couples, mating groups of a few males and one female, we also recorded large mating groups comprising up to 20 females and 80 males, with all the males trying to copulate with the females in these very large groups. The large groups were particularly noisy, emitting loud whistles, clicks, and burstpulsed signals (Fig. 4). Before copulating, a male would gently touch the female's flipper or body with his own flippers, and then rubbing, nudging or gently biting with his beak (Fig. 5), and sometimes biting her flippers. A male subgroup would surround a female (Fig. 6) with each male trying to copulate with her in turn. The number of simultaneously courting males ranged between one and ten (mean= 4.48; SD+2.4; N= 64). To copulate, the male positioned himself below the female with his belly up (Fig. 6). During penetration, about half of the penis' length was inserted. Mean penetration time was 16.18 sec (SD+6.66; N=91). A male subgroup would remain with a single female for up to 35 min, with the males copulating repeatedly.

The females avoided the males in about 90% of the records (N= 91) by swimming faster than the male as he positioned himself to copulate, or by rolling her body to assume a lateral or supine posture with belly up, as well as adopting a vertical posture with her beak out of the water. All these tactics proved effective in avoiding penetration. Males within large mating groups were occasionally aggressive towards each other, opening their beaks, biting and bumping each other and leaving distinct scratches on the skin. We recorded no aggressive behaviour amongst males in small mating groups.

In a six male, one female group, one of the males copulated more than the other five, achieving about 50% of the total number of copulations within the group. This particular male nudged the genital slit of the female, copulated, and then nudged her genital slit again after each copulation, behaviour not recorded for any other male in our study. In an eight male, two female group, one male was prevented from copulating with any female by two other males, by interposing themselves between that male and the females, whilst emitting loud clicking and burst-pulses as well as butting it from time to time. This particular male (individual 041) had a laterally twisted, deformed beak.

Pre mating-like behaviour such as nudging or biting the genitals was recorded between males, females, and even juveniles (see playing behaviour). Mating-like behaviour such as belly-to-belly posture and rubbing genitals against each other were recorded for adult males (N= 6). Intromission of the penis of one male into the genital slit of the other male was recorded during this posture (N= 4).

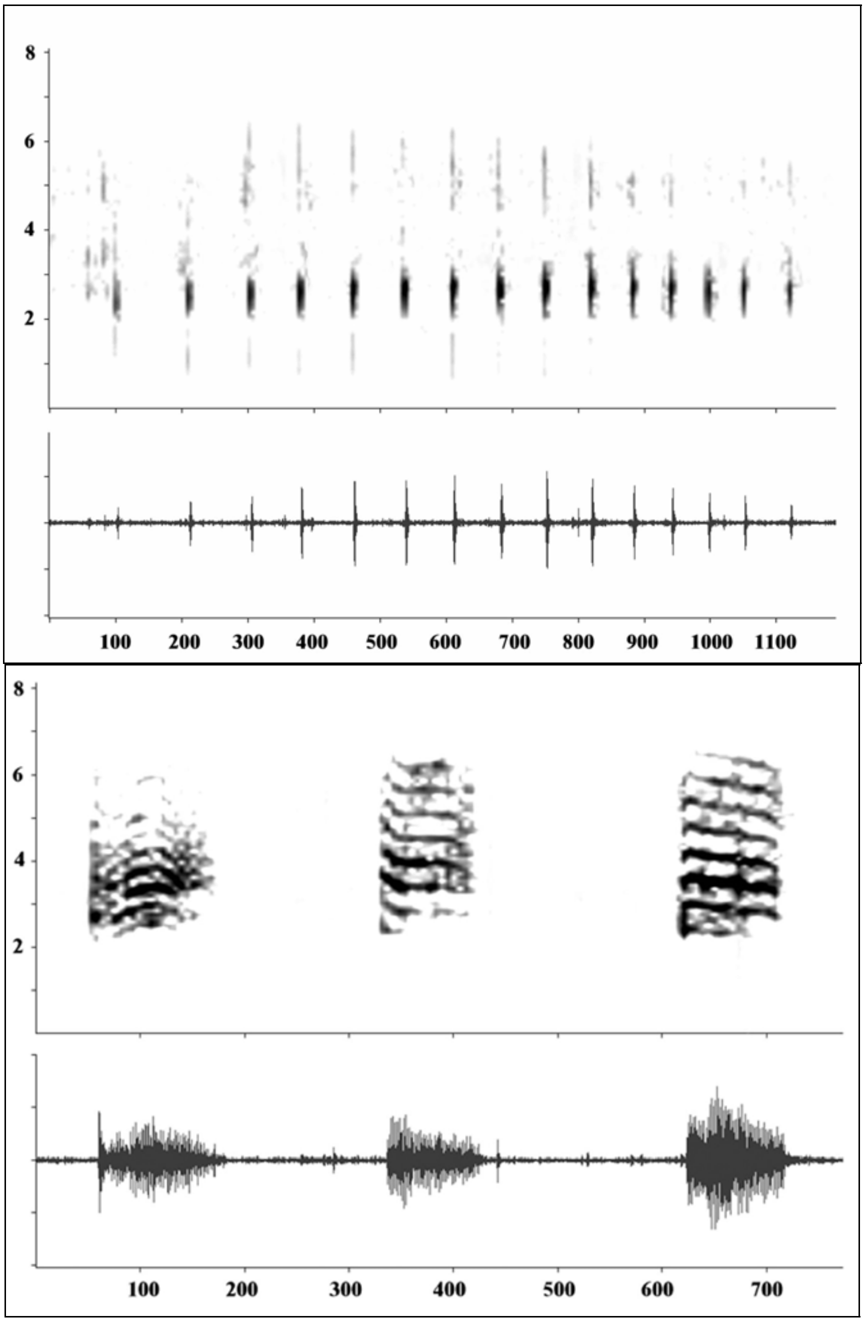

Fig. 4. Underwater-produced sounds of the spinner dolphin, a click (above) and a series of three burst-pulses (below). For each sound a sonogram and an oscillogram are presented. Numbers on vertical axes show frequency (in kHz) and those on horizontal axes show time (in milliseconds) for each sound type. Figures by L. O. Giassom.

Fig. 5. A spinner dolphin male nudging the genital slit of a female with its beak. Photo by J .M. Silva-Jr.

Fig. 6. A group of spinner dolphin males surrounding a female, one male copulating (the upside-down one). Photo by J .M. Silva-Jr.

Eliminative behaviour

We recorded two types of eliminative behaviour: defaecating and vomiting. Defaecating occurred without any regularity during the whole time of the dolphins' stay in the bay. Shortly before defaecating, a dolphin would bend its body into a slight sigmoid curve directed backwards (Fig. 7) and then eliminated a variable amount of faeces which formed a cloud in the water (see Sazima *et al.*, 2003). When the quantity of faeces was small, the dolphin defaecated without noticeable changes in behaviour while cruising or swimming. The faeces were eliminated irrespective of the dolphin's position within the group, i.e., a dolphin about to defaecate did not separate from the rest of the group. As a result the spinner's faeces passed over the individuals behind it in the group. The faeces consisted of a mixture of particulate and amorphous matter, often together with some fluid.

Vomiting was not as common a behaviour as defaecation, the ratio of defaecation to vomiting events varying between 3:1 and 20:1 (see Sazima *et al.*, 2003). Water and rarely air was taken in before vomiting occurred. While swimming with its mouth open, the dolphin took in a mouthful of water (Fig. 8), which caused its throat and mouth floor to bulge. Occasionally the dolphin's tongue hung out of its mouth during the intake of water (Fig. 1). Six distinct phases of vomiting behaviour are described and illustrated by Silva Jr. *et al.* (2004) with the entire sequence lasting about eight to fourteen seconds. Vomiting was generally preceded by a short burst of speed, after which the dolphin usually bent its body in a slight sigmoid curve directed forwards (lateral movements of the hind body might occur at times), and vomited with its mouth wide open. Vomiting apparently was related to a previous night's feeding on squid, as the vomits included pieces of squid and beaks, as well as particulate or amorphous material (see Silva Jr. *et al.*, 2004 for details), and live roundworms (*Anisakis* sp., Anisakidae). We never recorded a vomit consisting only of fish meal. A number of reef fish species fed on faeces and vomit. This behaviour will be discussed later in heterospecific interactions and associations.

Fig. 7. A spinner dolphin voiding a cloud of particulate faeces. Note the sigmoid curve directed backwards formed by the hind-body at the evacuation. Photo by J .M. Silva-Jr.

Fig. 8. A spinner dolphin taking water before vomiting. Note open mouth and distended throat. Photo by J .M. Silva-Jr.

Playing behaviour

The most commonly recorded type of play was when calves practised adult patterns of behaviour such as manoeuvring, leaping, as well as swimming in sudden burst of speed away from adult females (possibly their mothers). The calves practised their playing in open areas, generally circled by some of the individuals of the group including an adult female, possibly the mother. While playing, the calf’s wiggling, tilting, and other movements were exaggerated, and it quickly beat its tail and changed its course repeatedly. The calves also chased each other, touched the other’s body or flippers, and engaged in bouts of which resembled brief sequences of the adult pre mating behaviour, including genital touching with their beaks.

A particular play type was recorded for both juveniles and adults, which consisted of taking a piece of floating seaweed (mostly *Sargassum* sp.). A dolphin would take a piece of seaweed and hold it on its flipper for a while (Fig. 9), then releasing it and placing it on the other flipper, or its tail or beak. A dolphin may play this way with the same seaweed piece repeatedly, or let it drift away after holding it on the flipper for a while or after a tail pass. During the play, the dolphin would not have any problems balancing and holding on to the seaweed irrespective of its manoeuvring within the group. If then dropped, the same seaweed piece may be taken by the following or flanking dolphin, which would play with it for a while in the same way. We also recorded two dolphins playing together with the same seaweed piece, each of them taking its turn, up to about 10 times over the study period. Sometimes two or three dolphins in an observed group carried a seaweed piece each.

A ‘mock’ chasing of fishes was displayed both by juvenile and adult dolphins. One play subject was the black durgon (*Melichthys niger*, Balistidae) which the dolphins chased for short distances (up to 1-2 m), touching it with their beaks and causing the fish to flee. As durgons are the most common associate of spinner dolphins in the bay (see below), they appear to serve as a convenient play object. Only once we recorded a young adult chasing and catching a black durgon, with the fish flapping between its jaw whilst trying to escape, only to release the fish shortly afterwards. On release, the fish escaped unharmed and did not flee away from the dolphin. We also recorded dolphins chasing yellow jacks (*Caranx bartholomaei*, Carangidae), heading towards a single fish and pursuing it for a while before the fish evaded its pursuer. Jack chasing was displayed mostly by young adults.

Fig. 9. Two spinner dolphins playing with a piece of seaweed (*Sargassum* sp.), one of them holding the "toy" on its left fluke. Photo by J .M. Silva-Jr

Heterospecific interactions and associations

We recorded two types of heterospecific interactions, both of them agonistic. Four individuals of the pantropical spotted dolphin (*Stenella attenuata*) entered the bay when it was already occupied by about 350 spinners. The spotted dolphins were closely grouped and swam synchronously with sudden direction changes as they were chased by groups of about 10-15 spinners. The spinners displayed several types of agonistic behaviour towards the spotted dolphins, such as emission of loud echolocation clicks and burst-pulsed signals, sigmoid-shape posture (see Johnson & Norris, 1994), mouth agape and belly bumping the spotted dolphins with their beaks. The spotted dolphins, in turn, as they fled, displayed threatening behaviour as well, including the sigmoid posture.

The second type of agonistic encounters involved reef sharks (*Carcharhinus perezi*, Carcharhinidae) entering the bay. These sharks are common at Fernando de Noronha and display a versatile behavioural repertoire (e.g., Sazima & Moura, 2000). Agonistic encounters between spinners and reef sharks did not occur every time a shark entered the bay, but the dolphins seemed aware of their presence notwithstanding. If a shark swam towards a female with a calf or a group of females with calves, it was almost immediately chased away from the bay. A signal that a group of males was about to chase a shark were emissions of high frequency sounds, perceived by the dolphin's melon vibrating quickly and sometimes its head making short and quick vertical waving. The adoption of a sigmoid posture by one or more dolphins could follow, and the males then swam directly towards the shark (Fig. 10). The shark fled immediately usually out of the bay upon the dolphins' approach without retaliating. Sharks chased by dolphin male groups ranged 80-180 cm in total length. Spinner dolphins appear to be wary of large sharks. Once we recorded all spinner groups (about 350 individuals) suddenly leaving the bay whilst swimming at great speed. Soon after, we saw a large reef shark (in excess of 200 cm in total length) swimming close to the surface. It manoeuvred closely around us (two observers) darting away afterwards and returning again for three times until we approached the shore.

Fig. 10. Two male spinner dolphins chasing a Caribbean reef shark (*Carcharhinus perezi*). Photo by J .M. Silva-Jr.

We recorded two types of fish association with the spinners in the bay. One of them was hitch hiking by the whalesucker (*Remora australis*, Echeneidae), a diskfish commonly attached to the Noronha spinners (Silva Jr. & Sazima, 2003). Whalesuckers were recorded on calves (Fig. 11) as well as on adults. These fish were recorded on spinners year-round, their sizes ranging from 3 to 52 cm in total length and numbers ranging from one to three per dolphin (Fig. 12).

Fig. 11. A juvenile whalesucker (*Remora australis*) attached to the left fluke of a spinner dolphin calf. Note abraded skin on the fluke's upper side. Photo by J .M. Silva-Jr.

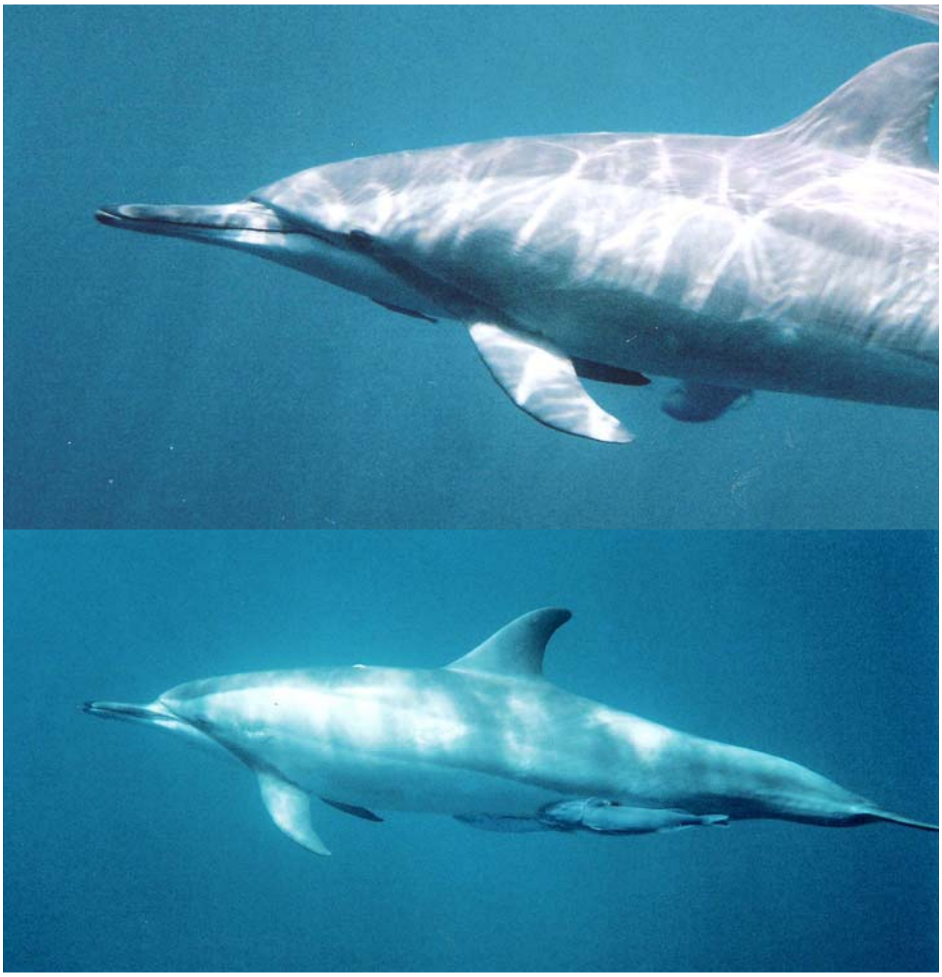

Fig. 12. A recruit-of-the-year whalesucker attached to the throat of a spinner dolphin (above), and two adult fish on the belly and flank of another individual (below). Photos by I. Sazima (above) and J .M. Silva-Jr. (below).

A guild of 12 plankton-eating reef fishes, including the ubiquitous black durgons (*Melichthys niger*) fed on spinner faeces and vomits (Fig. 13). When resting and cruising at low speed the spinners were closely followed by several durgons (Fig. 14), a behaviour probably related to the prospect of the fish being in place when the dolphins would begin defaecating (see Sazima *et al.*, 2003 for details).

Fig. 13. A group of black durgons (*Melichthys niger*) picking up particulate spinner dolphin's faeces. Photo by I. Sazima

Fig. 14. A group of black durgons following a group of resting, low speed cruising spinner dolphins. Photo by J. M. Silva-Jr.

Discussion

Behaviours we recorded for the Noronha spinner dolphin are similar to those recorded in Hawaii (Norris & Dohl, 1980; Norris *et al.*, 1994; Lammers, 2004), such as resting, mating, and playing. Other patterns of behaviour we report here are poorly documented for the Hawaiian spinner but we have no reason to believe that they would differ greatly from those recorded for the Noronha spinner.

Resting behaviour

We are unaware of underwater studies on resting behaviour of spinner dolphins. However, comparisons may be obtained from land based studies on the spinner dolphin and a few other delphinids (e.g., Würsig & Würsig, 1980; Würsig *et al.*, 1994; Goley, 1999). Dive formation and behaviour of resting groups are very similar for spinners both in Hawaii and Fernando de Noronha (Würsig *et al.*, 1994; present study), dusky dolphins (*Lagenorhynchus obscurus*) in Patagonia (Würsig & Würsig, 1980), and Pacific white-sided dolphins (*L. obliquidens*) in captivity (Goley, 1999). Quite probably this similarity indicates a behavioural trait for small to medium-sized dolphin species that live and travel in groups.

Mean submersion time for the Hawaiian spinner while resting is 120 sec (Würsig *et al.*,1994), and the ‘dive/travel slow’ (= resting behaviour) submersion time for the bottlenose dolphin (*Tursiops truncatus*) in Northern Adriatic Sea ranges 31-375 sec (mean= 121.2 sec; SD+65.1; N= 298) (Bearzi *et al.*, 1999), another figure similar to that obtained by Norris *et al.* (1994) and both of them slightly shorter than that we recorded for the Noronha spinner (mean= 164 sec).

Nursing behaviour

The spatial relationship we recorded for calves and females in Noronha seems to be a common behaviour of small to medium sized dolphins, as indicated in the reports on *S.longirostris* and *T. truncatus* in captivity (Tavolga & Essapian, 1957; Johnson & Norris, 1994; Gubbins *et al.*, 1999).

Ours seems to be the first description and documentation of suckling for a free ranging dolphin species (see overview in Whitehead & Mann, 2000). Suckling behaviour of the Noronha spinners does not differ markedly from those reported for captive specimens of the same species from Hawaii (Johnson & Norris, 1994), as well as for the bottlenose dolphin (Cockroft & Ross, 1990). The postures adopted by the calf in relation to the female are very similar, and suckling time for captive spinners ranges 5-20 sec with a mean of 9 sec (Johnson & Norris, 1994), which is almost the same time we recorded. However, suckling time for the bottlenose dolphin seems considerably shorter, as it ranges 3-9 sec with a mean of 5.6 sec, although this behaviour may vary with the calf's growth (Cockroft & Ross, 1990).

Mating behaviour

The mating behaviour of the Noronha spinner, including 'caresses' and copulating postures, is very similar to that reported for the Hawaiian spinner (Wells & Norris, 1994). Thus, average mating groups of the Noronha and Hawaiian spinners are the same (2-6 individuals), although the Noronha spinner may form much larger mating groups of up to about 50-100 individuals. This difference most probably is related to the total number of spinners present in the same place at the same time (up to about 70 in Hawaii and about 2000 in Noronha).

The intromission behaviour of the Noronha spinner (e.g., about half of the penis being inserted in the female's vagina) is similar to that reported for captive *T. truncatus* (Tavolga &

Essapian, 1957). Intromission time reported for the bottlenose dolphin is said as ‘not more than ten seconds’ (Tavolga & Essapian, 1957), which is a little shorter interval than that we recorded for the Noronha spinner (about 16 sec on average).

The high incidence of females behaviourally hampering males’ copulating attempts most probably is related to mate choice by the females. Even if most of the females of gregarious cetacean species have access to a great number of potential mates, there is an evidence for choice of mates by females, which may be an important determinant for reproductive success (Whitehead & Mann, 2000). The dolphins’ great manoeuvrability allows a female to outmanoeuvre males in several ways (Mesnick & Ralls, 2002; present study) and thus to make choices between potential mates. Even the high mating success we recorded for a particular male (see below) seems related mostly to the female’s choice.

The one very successful male within a mating group, and a particular male prevented by others to copulate, even if rare events, raise at least two interesting questions to examine in captive or free-ranging dolphins: 1) certain females would favour particular males whose behaviour is seemingly more stimulating, and thus would increase mating success of these males; 2) males within a group would recognize an odd looking (or behaving) male and would make cooperative efforts to hamper the mating attempt of such individuals.

The male-male mating-like behaviour, including penis intromission, may be na aggressive display of dominance of one individual over the other, as suggested by Psarakos *et al.* (2003), and recorded for the pantropical spotted dolphin (Herzing & Johnson, 1997). Since the social structure of spinner dolphins is regarded as a transitory and fluid one (‘fission-fusion’ groups, see Lammers, 2004) in which roles alternate between individuals and coalitions or groups (Johnson & Norris, 1994), the pre-mating and mating-like behaviours between males and between females may also function to establish some particular bonds, and thus may be more common than our records indicate. Another, very speculative explanation (although one that cannot be entirely ruled out) is that the involved individuals derive some pleasant tactile sensation from this non reproductive, mating-like behaviour.

Eliminative behaviour

Defaecating behaviour in free-ranging dolphins is presently recorded only for the Noronha spinner (Sazima *et al.*, 2003) and the bottlenose dolphin (Shinohara *et al.*, 1999). The major difference between these two species is that spinners commonly eliminate their faeces over individuals at their rear within the group, whereas bottlenose dolphins seldom display this behaviour, the defaecating individual withdrawing a little from other members of the group (Shinohara *et al.*, 1999; Sazima *et al.*, 2003). Thus, for the two most studied delphinid species, this behaviour seems to differ mostly by the position of the defaecating individual within a group.

Vomiting behaviour for free-ranging dolphins was unreported until recently (Silva Jr. *Et al.*, 2004), and thus no comparisons are possible. Vomiting in the Noronha spinners appears to be related to meals rich in squid (Silva *et al.*, 2004), and perhaps its further benefit is to get the dolphin rid of stomach dwelling roundworms. Both the faeces and vomits are fed upon by reef fishes (see below). Durgons' large numbers shown in figure 2 of Sazima *et al.* (2003) may represent the fish feeding on a very rich vomit instead of faeces as originally indicated.

Playing behaviour

The adult-like behaviour practised by calves is already known for free-ranging spinners and other dolphin species (e.g., Johnson & Norris, 1994; Bel'kovich, 1991). Playing with objects such as seaweeds is known for other free ranging dolphin species, including spinners (Johnson & Norris, 1994) and dusky dolphins (Würsig, 2002). Although Würsig

(2002) emphasizes that playing with objects is an activity in which the socialising sense is transferred to the object, the toy trading and apparently interactive playing with seaweed pieces we recorded for the Noronha spinner indicates that the seaweed might be regarded as an instrument for interaction between the dolphins.

We know of no reports of dolphins playing with non food fishes like those recorded here for black durgons, although dusky dolphins play with gulls (*Larus dominicanus* and *L. maculipennis*) which are gently mouthed and dragged shortly underwater, before being released unharmed (Würsig, 2002). However, tossing food fishes into the air is known for the bottlenose dolphin (Bel'kovich, 1991). Mock or play chasing after fishes is apparently unrecorded for spinner dolphins, although some dolphin species are known to interact with turtles (pulling their tail or legs) and sharks (imitating their movements) (Würsig, 2002).

Heterospecific interactions and associations

Agonistic encounters between spinners and pantropical spotted dolphins were described recently, these encounters being behaviourally complex and highly variable (Psarakos *et al.,* 2003), which renders their analyses of limited value until additional data are gathered. Our single record, however, is consistent with the idea that there is a high potential for aggressive interactions between these two dolphin species, especially when one is outnumbered by the other (Psarakos *et al.*, 2003).

Aside from the agonistic encounter between spinners and spotted dolphins reported here, we recorded from a land based observation post a female humpback whale (*Megaptera novaeangliae*) and her calf in front of the Dolphins' Bay escorted by about 50 spinners forming a semicircle that 'closed' the access of the whales to the bay. The spinners escorted the two whales for about 5 min, during which time they reached the open sea. On another occasion three humpbacks arrived at the bay and all the about 500 spinners deserted the area, coming back only after the whales left the bay. These two records indicate a potential for agonistic interactions between spinners and whales in the Dolphins' Bay.

Sharks are known to prey on small to medium sized dolphins, including species of *Stenella* (see reviews in Heithaus, 2001; Maldini, 2003). Dolphins chasing and harassing sharks is a long held view, although there are few documented instances of this behaviour (Wood *et al.*, 1970). Our underwater observations indicate that this is the case indeed, although shark chasing seems to occur under particular circumstances, e.g., defence of calves. Defence against sharks may be related to the apparently high survival rate of dolphins as indicated by healed shark bites on living individuals (e.g., Corkeron *et al.*, 1987; Wells & Scott, 2002). However, Maldini (2003) argues otherwise, i.e., that mutilated and scarred dolphins are survivors of unsuccessful shark attacks. The agonistic sigmoid posture adopted by the Noronha spinner is also recorded for the Hawaiian spinner, and is regarded as mimicking the shark's intraspecific threat posture (Johnson & Norris, 1994). Even if we found the Noronha spinners displaying a similar posture, we have no evidence that the shark perceives the spinner's signal as a threat. Our record of a large reef shark moving close to the water surface and the sudden fleeing of all spinners from the bay indicates that the shark was foraging after dolphins, and possibly due to its large size and position in the water column it was not chased. A similar flight response is recorded for a group of nine bottlenose dolphins approached by a 2.5-3.0 m long great white shark, *Carcharodon carcharias* (Connor, 1996).

Spinner dolphin/reef fish associations are reported for the Dolphins' Bay only (Lodi & Fiori, 1987; Lodi, 1998; Sazima *et al.*, 2003). The whalesucker association with spinners is currently under study, and a brief report on the attachment duration of a diskfish couple to a particular dolphin individual was recently published (Silva Jr. & Sazima, 2003). Besides hitch hiking, the whalesucker probably benefit further from the association by feeding on spinners' offal, increasing its mating chance, and gaining protection from predators (Katona & Whitehead, 1988; Sazima *et al.*, 2003; Silva Jr. & Sazima, 2003).

Spinners' faeces and vomits are a rich and predictable food source in the Dolphins' Bay, and are feed upon by a guild of 12 reef fish species (Sazima *et al.*, 2003). The most ubiquitous offal eater is the black durgon, which probably learned to recognize a dolphin about to eliminate and to follow it (Sazima *et al.*, 2003). Spinner dolphins unquestionably have an ecological role in Dolphin's Bay, that of a rich food source supplier for fish (see below).

Remarks

The water clarity in Dolphin's Bay provided us with exceptionally favourable conditions for underwater observations. We think the behaviours previously unknown and/or poorly documented that we reported here and elsewhere (e.g., Sazima *et al.*, 2003; Silva Jr. & Sazima, 2003; Silva Jr. *et al.*, 2004) most probably occur at other sites occupied by spinner dolphins. However, vomiting behaviour, which we recorded with some frequency at Fernando de Noronha, appears to occur rarely, if at all, in the Hawaiian populations (see Silva Jr. *et al.*, 2004). Nevertheless, other behaviours and/or associations probably are more widespread occurrences. For instance, we predict that dolphins' offal eating by a reef fish guild would be recorded at sites other than Fernando de Noronha Archipelago, provided that adequate conditions are locally available (Sazima *et al.*, 2003), and the same holds for the dolphin/ whalesucker bond (Silva Jr. & Sazima, 2003).

We add here a new role for cetaceans to those already discussed in overviews about the ecological importance of these mammals and their role in aquatic ecosystems (Katona & Whitehead, 1988; Bowen, 1997). The new role is that of a food supplier for reef fishes via faeces and vomits. The Noronha spinners apparently sustain a sizeable population of black durgons in the Dolphins’ Bay, besides supplying additional food for a guild of 11 other, mostly plankton eating reef fish species (Sazima *et al.*, 2003).

As it stands, underwater observation proves a valuable tool to understand some of the behaviours for which a close proximity with the dolphins is needed (see Pryor & Norris, 1991; Norris *et al.*, 1994 for examples and discussion). The Dolphins’ Bay at Fernando de Noronha Archipelago and its spinners still wait for additional, refined and variably focused studies, including sound production related to the behavioural repertoire perceptible while underwater (see Herzing, 1996; Lammers *et al.*, 2003).

Acknowledgements

We thank the student staff of the Centro Golfinho Rotador, as well as the field helpers for logistic support and help in the field; L. Wahba (Canal Azul) and C. Bellini for videorecording several dolphin behaviours here analysed; L. O. M. Giasson and C. F. B. Haddad for working on the sonograms; C. Sazima for help in the field; the Ibama for issuing permits to study spinner dolphins and reef fishes in the Fernando de Noronha National Marine Park; the CAPES, CNPq, FAEP-Unicamp, FAPESP, Fundo Nacional do Meio Ambiente (FNMA/MMA), and Petrobras for essential financial support.

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CAPÍTULO 2

Vomiting Behavior of the Spinner Dolphin (*Stenella longirostris*) and Squid Meals

Vomiting Behavior of the Spinner Dolphin (*Stenella longirostris*) and Squid Meals

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Aquatic Mammals 2004, 30(2), 271-274, DOI 10.1578/AM.30.2.2004.271

Abstract

We describe and illustrate the vomiting behavior of the spinner dolphin (*Stenella longirostris*), na eliminative behavior poorly known for cetaceans in the wild. The vomiting may be conveniently described in six behavioral phases: opening beak, closing beak (water intake), swallowing water, pausing, opening beak about to void, and voiding offal and water. Spinners vomit after a meal rich in squids, and, therefore, we relate this eliminative behavior to the presumably irritating remains of this meal type (squid beaks). The vomits are a rich and predictable food source for plankton-eating reef fishes.

Key Words: *Stenella longirostris*, Delphinidae, eliminative behavior, feeding habits, pelagic squid prey, West Atlantic

Introduction

From a behavioral viewpoint, spinner dolphins (*Stenella longirostris*, Delphinidae) are among the best-studied cetacean species. Most of the current knowledge about these marine mammals originates from studies on the Pacific populations in Hawaii (Norris & Johnson, 1994); however, little is recorded on eliminative behaviors, such as defecating and vomiting, in this species and other cetaceans as well, particularly in the wild (e.g., Sazima et al., 2003; Shinohara et al., 1999).

At Fernando de Noronha Archipelago, off northeast Brazil in the Equatorial West Atlantic, great concentrations of spinner dolphins are found at the site known as the Baía dos Golfinhos (Dolphins' Bay), regularly visited by groups of up to about 2,000 spinners (Sazima et al., 2003; Silva-Jr. et al., 1996). In the bay, the dolphins engage in several behaviors, such as resting, aerial displays, and social interactions (including parental care and copulation), as well as eliminative behaviors. This situation is particularly favorable for underwater behavioral studies due both to the local water's clarity and the large numbers of spinners entering the bay year-round (Sazima et al., 2003; Silva-Jr. et al., 1996).

During medium- and long-term studies on the behavior of spinner dolphins (Sazima et al., 2003; Silva-Jr. et al., 1996), we observed that spinners vomit after a meal rich in squid, a common food of these cetaceans in the area of the Fernando de Noronha Archipelago (Silva-Jr. et al., 1996). Herein we describe, illustrate, and comment on the vomiting, and relate this eliminative behavior to the presumably irritating remains of this meal type (i.e., squid beaks). Additionally, we note that the spinner dolphin vomits are a rich and predictable food source for plankton-eating reef fishes (see Sazima et al., 2003).

Materials and Methods

The observations were made in the Fernando de Noronha National Marine Park (see Maida & Ferreira, 1997, for map and description), off northeast Brazil in the southwest Atlantic. The observational sessions were conducted over 27 days from May to October 2001 and October 2002 at the Baía dos Golfinhos, a 15-25 m deep bay used by spinner dolphins for rest and social interactions (Lodi & Fiori, 1987; Silva-Jr. et al., 1996).

Vomiting behavior was observed directly, photographed, and videotaped during snorkeling. Dolphins were given 1-3 min to habituate to divers before starting observational sessions of 35-70 min (Sazima et al., 2003). Focal animal and all occurrence samplings were used in 1,601 min of direct observation, in which all occurrences of specified actions (e.g., vomiting, offal ingestion by fishes) over a given period were recorded (Altmann, 1974; Lehner, 1979). The best period for the observation of eliminative behaviors, such as vomiting and defecating, was in the morning (Sazima et al., 2003). Photographs and video records of vomiting and defecating spinner dolphins and reef fishes feeding on offal are on file in the Museu de História Natural da Universidade Estadual de Campinas (ZUEC record collection).

Results

Vomiting behavior of the spinner dolphin may be conveniently described in six distinct phases (Figure 1). Additionally, a forward contortion of the body and lateral movements of the hind-body may occur. The vomiting sequence began with the dolphin opening its beak and allowing water to enter its mouth (Figure 1a). During water intake, the fore and hind-body may form exaggerated arches (see Johnson & Norris, 1994, for illustration of habitual swimming movements). The tongue made a few forward and backward undulating movements, as well as lateral ones. Sometimes the tongue hung out of the mouth, but we were unable to perceive whether these movements were voluntary or due to the water flux. After a while, the dolphin closed its beak (Figure 1b) and began to swallow the water mouthful (Figure 1c). Both of these phases bulged the regions of the throat and mouth floor. Throughout the beak closing and water swallowing phases, the pigmented tissue bordering the upper edge of the lower mandible remained stretched (Figures 1b-c). In very few instances (3 of 57 vomiting records), a dolphin raised its beak or head above the water surface and appeared to gulp air along with the water already taken.

Following the three above-mentioned phases, there was a period of no observable changes in the dolphin's habitual swimming or other behaviors (Figure 1d), which we named herein "pausing." Afterwards, the dolphin opened its beak again (Figure 1e) and began to void offal and water (Figure 1f). The whole vomiting sequence lasted about 8 to 14 s (Table 1) and varied according to the number of water intakes (1-4) and the intervals between intakes prior to actual voiding.

The vomits included squid pieces and beaks, as well as particulate or amorphous material, and water. Every vomitus contained at least two to three squid beaks.

Vomiting was not restricted to a single dolphin, and up to nine vomiting dolphins were recorded per session. We recorded no repeat vomiters (i.e., the same individual vomiting more than once). Additionally, no juvenile up to 1 m in total length was ever recorded vomiting. Vomits per observational session ranged from 1 to 9 (mean = 3.8 + 2.1 SD, n = 57). We were unable to assess the frequency of this behavior (number of vomits per number of dolphins). Squids' beaks identified from vomits belonged mostly to species of Ommastrephidae and Cranchiidae.

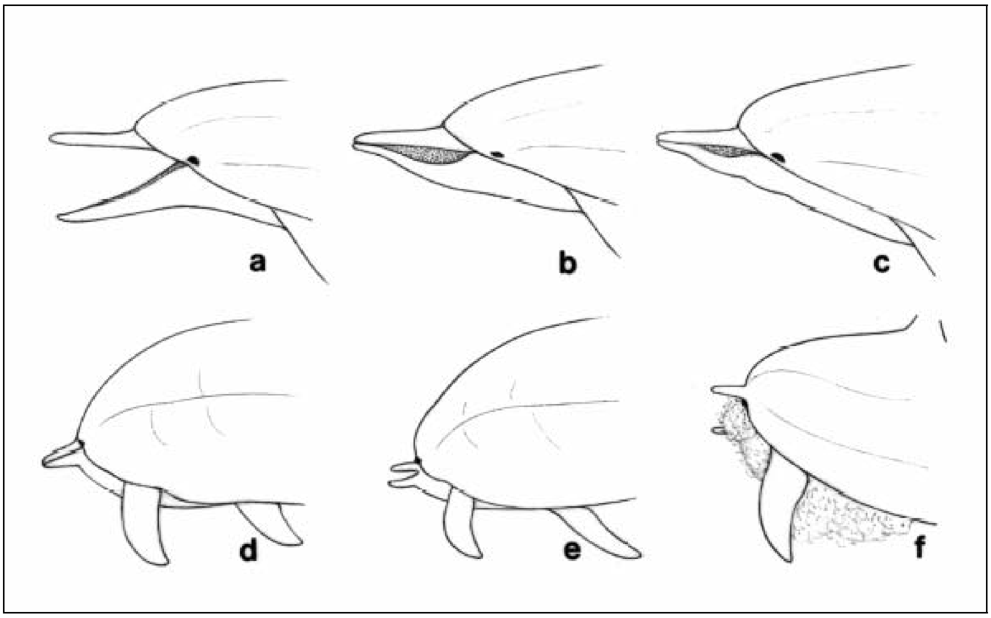

Figure 1. The six phases of vomiting behavior of the spinner dolphin: (a) opening beak, (b) closing beak, (c) swallowing water, (d) pausing, (e) opening beak about to void, and (f) voiding offal and water; note pigmented tissue on upper edge of lower mandible stretching throughout closing beak and swallowing water phases. Based on selected frames of a videotaped sequence made at close quarters (ZUEC tape #16).

Table 1. Duration of the six phases of vomiting behavior of the spinner dolphin, based on a videotaped sequence made at close quarters

Behavioral phase	**Duration (s)**
Opening beak (water intake)	0.667
Closing beak	1.033
Swallowing water	0.767
Pausing	4.500
Opening beak (to void)	0.201
Voiding offal and water	1.033

The vomits and feces of the spinner dolphin were sought as food by plankton-eating reef fish species, particularly the black durgon (*Melichthys niger*, Balistidae). Dolphins that opened their beaks were promptly and insistently sought after and followed by the durgons, even if the spinners soon withdrew out of the reach of the fish due to the swimming speed difference between the two species.

Discussion

Spinner dolphins vomited only after a meal rich in squid, a common food of these cetaceans at the study site (Silva-Jr. et al., 1996). Both Ommastrephidae and Cranchiidae are pelagic squid families (e.g., Voss et al., 1992; Wormuth, 1998), an expected prey type for this ceanic-foraging dolphin (Würsig et al., 1994). Because all vomits contained squid beaks, we surmise that the beaks caused discomfort and/or irritation (most probably of mechanical origin) to the dolphins' digestive tracts and that the water intake and vomiting are behaviors by which it gets rid of the nuisance. Vomiting in humans is a result of peripheral stimuli from visceral organs due to exogenous and endogenous substances that accumulate during irritation or inflammation of the stomach (Andrews & Hawthorn, 1988). In dolphins and other mammals, the mechanisms inducing vomiting may be similar. What we call pausing may be a period during which the water probably caused physiological and/or mechanical changes within the stomach and facilitated voiding by increasing the volume of the stomach contents. The wallowed water possibly created visceral afferent impulses which activated the so-called vomit center in the brain and induced the respiratory muscles to contract and expel the tomach contents (Argenzio, 1993).

No vomiting behavior was recorded for the Hawaiian populations of spinner dolphins, possibly due to their feeding primarily on fishes (Würsig et al., 1994). Thus, sporadic ingestion of irritating objects (squid beaks) would result in their vomiting only occasionally.

The spinner dolphins' vomits and feces are fed upon by several reef fish species (Sazima et al., 2003). Therefore, besides getting rid of a nuisance to its digestive tract, the vomiting spinners provide a predictable and rich particulate food source for plankton-eating reef fishes at Fernando de Noronha Archipelago. The black durgons apparently learned that a dolphin is about to void based on the first observable phase of the vomiting sequence (beak opening), since dolphins that opened their beaks were promptly sought after and followed by the durgons, even if the cetaceans voided later and out of the reach of the fish, or did not void at all.

Acknowledgments

We thank the student staff of the Centro Golfinho Rotador (Daniela, Jessy, Márcia, Thalassa, and Vanessa), as well as the field helpers (Antônio, Dinho, Fagner, and Marquinhos), for logistical support and help in the field; L. Wahba (Canal Azul) for video-recording a vomiting dolphin at close quarters, on which tape the drawings were based; E. Z. Borghi for the drawings; C. Bellini (Tamar) for help in the field and additional videorecording; C. Sazima for help in the field and some of the photographs used in the analyses; the Atlantis diving center for free use of diving facilities; the Ibama for issuing permits to study spinner dolphins and reef fishes in the Fernando de Noronha National Marine Park; and the CNPq, FAEP-Unicamp, FAPESP, Fundo Nacional do Meio Ambiente (FNMA/MMA), and Petrobras for essential financial support.

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CAPÍTULO 3

The cetacean offal connection: feces and vomits of spinner dolphins as a food source for reef fishes

The cetacean offal connection: feces and vomits of spinner dolphins as a food source for reef fishes

Ivan Sazima, Cristina Sazima and José Martins Silva-Jr.

Keywords: Cetacean offal, spinner dolphin, reef fishes, black durgon, whalesucker, coprophagy, planktivory, feeding switch, tropical West Atlantic.

Bulletin of Marine Science, 72(1): 151-160, 2003

Abstract

At Fernando de Noronha Archipelago, southwest Atlantic, reef fishes associated with spinner dolphins (*Stenella longirostris*) were recorded when the cetaceans congregated in a shallow inlet. In the reef waters the dolphins engaged in several behaviors such as resting, aerial displays and other social interactions, as well as eliminative behaviors such as defecating and vomiting. Twelve fish species in seven families were recorded feeding on dolphin offal. The black durgon (*Melichthys niger*) was the most ubiquitous waste-eater, and its group size was positively and significantly correlated with dolphin group size. The durgons recognized the postures a dolphin adopt prior to defecating or vomiting, and began to converge to an individual shortly before it actually voided. Offal was quickly fed upon, and the fishes

concentrated in the area occupied by the dolphins until the latter left the shallows. Since all the recorded offal-feeding species feed on plankton or drifting algae, feeding on cetacean droppings may be regarded as a switch from foraging on drifting organisms to foraging on drifting offal, a predictable food source in the inlet. Further instances of this cetacean-fish association are predicted to occur at sites where these mammals congregate over reefs with clear water and plankton-eating fishes.

Introduction

Feeding associations between fishes and mammals are uncommon, and include mammalian examples as diverse as hippopotamuses and monkeys (Hediger, 1953; Sabino and Sazima, 1999). Associations between fishes and cetaceans are more common than those with other mammal types due to the habitat these aquatic associates share. Associations of fishes with dolphins include formation of mixed schools for protection from predators and for feeding advantages (Würsig et al., 1994; Scott and Cattanach, 1998), as well as use of these mammals for ride (Fertl and Landry, 1999) and exploitation of their feces as food (Lodi and Fiori, 1987; Lodi, 1998).

Feeding on feces, or coprophagy, is a habitual foraging behavior for several fish species in the Pacific, fish feces being regarded as a diverse and rich food source (Bailey and Robertson, 1982; Robertson, 1982). The use of feces of the spinner dolphin (*Stenella longirostris*) as food is recorded for three reef fish species in southwest Atlantic (Lodi and Fiori, 1987; Lodi, 1998). Herein we advance the brief reports of the aforementioned authors, centering our study on the foraging behavior of the fishes. As the dolphin waste may be regarded as a particulate and predictable food resource, we hypothesized that the fish species feeding on offal are plankton-eaters, and that their numbers correlate with dolphin numbers. Besides general observations on the associations between reef fishes and spinner dolphins, we focused our study on three main questions: (1) Which reef fish species use dolphin offal as food and what are their general feeding habits? (2) Is the fish group size correlated with the dolphin group size? (3) Do the fishes approach this food source only when offal is already voided or do they recognize that a dolphin is about to void?

Methods

The study was conducted at the archipelago of Fernando de Noronha (03°50’S, 32°25’W), about 345 km off the northeastern coast of Brazil (see Maida and Ferreira, 1997; Carleton and Olson 1999, for map and description). The observation sessions were conducted at the Baía dos Golfinhos or Enseada do Carreiro de Pedra, a 15-25 m deep inlet used by spinner dolphins for resting and social interactions (Lodi and Fiori, 1987; Silva-Jr., 1996). The inlet bottom is a mixture of open sandy areas dotted with patchy reef formations similar to those found in another spinner dolphin resting place, Kealakekua Bay in Hawaii (Norris and Dohl, 1980; Wells and Norris, 1994).

Feeding associations between fishes and dolphins were observed directly, photographed, and videotaped during snorkeling over 18 days from May to October 2001. Snorkeling and passive diving are little disturbing methods particularly suited for study of marine mammals and open-water fishes (Silva-Jr., 1996; pers. obs.). Dolphins and fishes were given 1-3 min to habituate to divers before starting observation sessions of 35-70 min. Records concentrated in the morning, the best period for recording the association of fishes with defecating dolphins, as these mammals feed at night (Silva-Jr., 1996; Lodi, 1998). During observational sessions, ‘focal animal’ and ‘all occurrences’ samplings were used in 1006 min of direct observation in which all occurrences of specified actions (e.g., defecation, vomiting, offal ingestion) over a period were recorded (Altmann, 1974; Lehner 1979). We focused on waste-feeding events, i.e., the ingestion of offal by a given fish species on a defecate or vomit void by an individual dolphin. Each offal-feeding event was scored only once irrespective of the number of fish individuals feeding on a particular defecate or vomit. A defecate or vomit would score for two or three fish species simultaneously if this specific void was consumed by a mixed group. On the other hand, a fish species recorded feeding on offal in only one observation session would score more than once depending on the number of dolphin defecates or vomits the fish fed on this specific session. Size of fishes was estimated visually and later checked against specimens of similar size range caught at the study site or nearby.

The group size of black durgons associated with spinner dolphin groups was assessed through an adjusted version of the stationary sampling method of Bohnsack & Bannerot (1986), repeated regularly along transects of 200-400 m. Since the dolphin groups traveled back and forth through the inlet, the transects were traced across the inlet to intercept their path at least once or twice, thus allowing for records in the presence versus absence of the dolphins, as well as records with variable dolphin numbers. Two observers swam side by side at a regular pace for two min, then stopped and one of them counted and recorded all black durgon individuals sighted during a single 360° rotation within an imaginary cylinder of 10-12 m radius, while the other did the same with the dolphins. The observers swam/stopped/recorded repeatedly for a period of 30-50 min, thus making at least 5 samples per transect, in a total of 62 samples throughout the study. The relationship between the black durgon group size and the spinner dolphin group size was examined with use of Pearson's correlation (Zar, 1996). Records were limited to days when at least 250 dolphins were present within the inlet, a number judged minimal for this type of data recording (JMS-Jr., pers. obs.). Daily dolphin numbers were assessed through direct counts of surfacing individuals as they entered the inlet along the morning, sighted from a belvedere at the Baía dos Golfinhos (Silva-Jr., 1996).

Five specimens of the black durgon, *Melichthys niger*, the most ubiquitous fish recorded in association with dolphins, were examined for gut contents (due to the protected status of the study site we refrained from taking a larger sample). Feeding habits of the fish species recorded in association with dolphins were observed directly in the field or drawn from literature (Randall, 1967; Hobson, 1974). Four specimens of *M. niger* from the study site are deposited as vouchers in the Museu de História Natural, Universidade Estadual de Campinas (ZUEC 5349-1, 5350-3). Voucher photographs and video-records (tape # 8) of defecating spinner dolphins, and black durgons feeding on offal are on file in the ZUEC record collection. Usage of the name *Sotalia guianensis* for the marine tucuxi follows Monteiro-Filho et al. (2002).

Results

Spinner dolphin (*Stenella longirostris*) groups congregated at the study site over the morning and early afternoon, the first individuals entering the inlet at about 0600-0700 h and the last ones leaving at about 1300-1600 h. Daily dolphin numbers in the inlet ranged 18-2046 throughout the study period (mean= 575.99; SD± 449.83; N=138), most groups including adults of both sexes and juveniles. In the inlet the dolphins engaged in several behaviors such as resting, aerial displays and other social interactions, including parental care and copulation, as well as eliminative behaviors such as vomiting and defecating a rich particulate and/or amorphous matter (Fig. 1), whitish to pinkish, often in an oily matrix. Vomits contained squid beaks along with partly digested material. Shortly before defecating, the spinner dolphin habitually arched its body and contorted itself backwards (however, smaller amounts of feces may be voided with no such posture). A similar contortion, but directed forwards and preceded by 1-4 openings of the mouth, was made shortly before vomiting. Ratio of defecates to vomits varied from 3:1 to 20:1 throughout the study.

Twelve reef fish species in seven families were recorded feeding on the spinner dolphin offal (Table 1), the most ubiquitous of them being the black durgon (*Melichthys niger*). The black durgons apparently recognized the postures dolphins adopt prior to defecating and vomiting, as they promptly converged at individuals about to void. Thus, at the time of actual voiding variably sized groups of black durgons were close to the dolphin, some of them already feeding on its offal (Fig. 1). The durgons were particularly prone to follow dolphins about to vomit, probably due to richer nutrient contents of vomits compared to that of feces. As the offal sank, the mid-water hovering durgons individually picked off the drifting particulate and/or amorphous matter, foraging in a similar way they feed on planktonic organisms (i.e., with visually oriented strikes at individual prey or particle, see Hobson, 1974, 1991). Up to 80-100 durgon individuals congregated to feed on a particularly plentiful defecation (Fig. 2). The sinking offal was foraged on for 3-37 sec (mean= 10.5; SD±7.2; N=42), this variation related mostly to the amount and type of offal and the number of feeding fish.

Several durgon individuals flanked and followed the dolphins for up to 2-3 m, especially when the latter were cruising at low speed or resting. This following probably was related to the prospect of feces voiding, including those instances when offal was available in smaller amount and voided with no characteristic postures. Competition for offal is likely one cause for such following, since as soon as the first black durgon began to feed on the voided particles, all individuals within sight readily converged to the spot (Fig. 1).

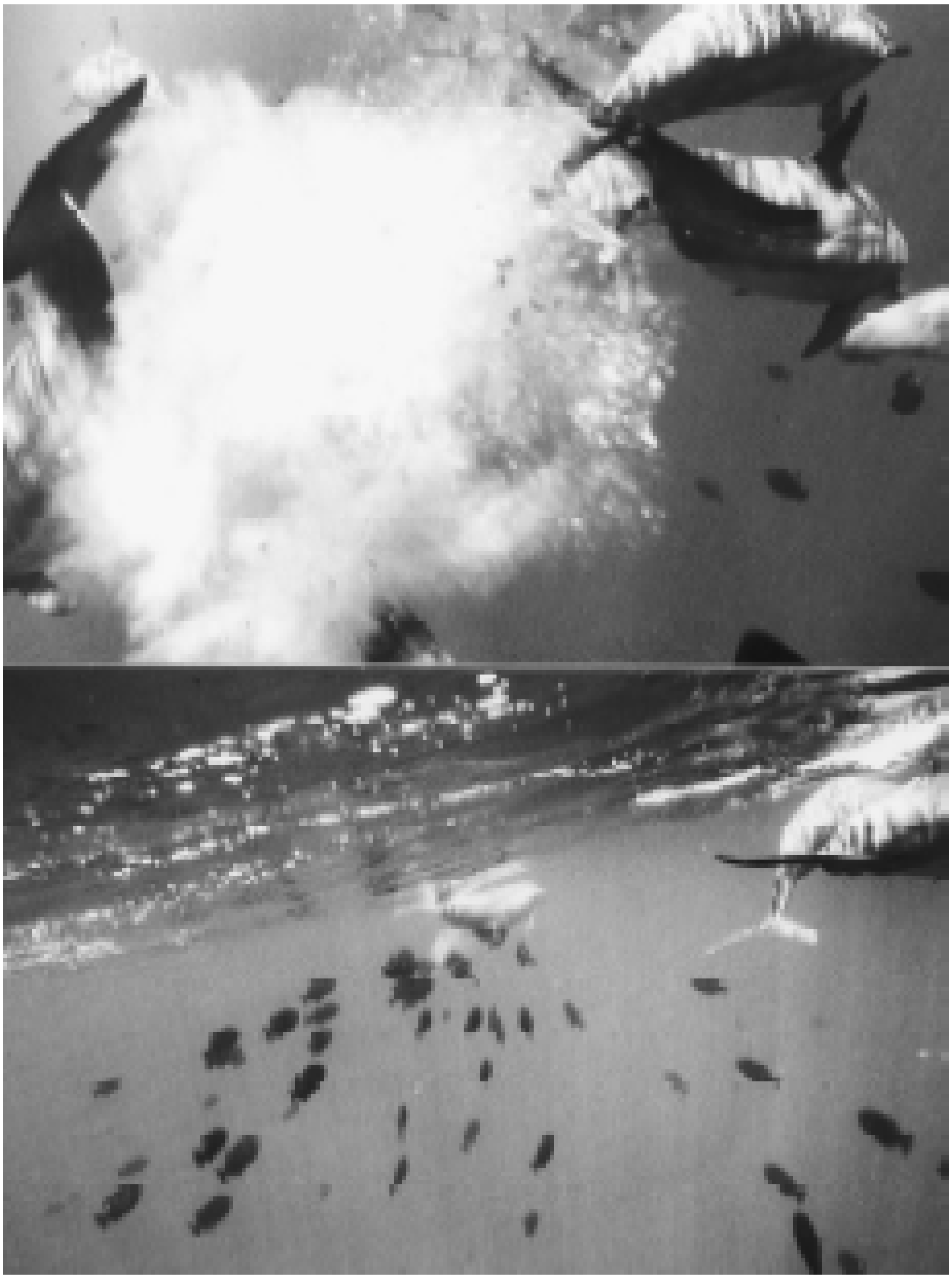

Figure 1. Black durgons (*Melichthys niger*) capitalize on spinner dolphin (*Stenella longirostris*) offal at Fernando de Noronha Archipelago, off northeast Brazil: a cloud of feces voided by one dolphin shows the type and amount of the food source thus available (above), and the fish readily converging to a defecating dolphin (below).

There was a tendency to find the durgon groups along with the dolphin groups within the inlet, even if the fish were unable to follow a dolphin's swimming pace (Fig. 2). The durgon groups began to converge and move as to intercept the cetaceans before these latter were actually within sight (apparently the fish were able to perceive the cetaceans by their moving or signaling, or learned the paths of the dolphins during the roaming of the latter within the inlet). The durgon groups size was positively and significantly correlated with dolphin groups size (r= 0.73; P< 0.0001; N= 62). As the dolphin groups moved to leave the inlet at early afternoon, the black durgon groups began to move closer to the shore. When spinner dolphins were absent from the inlet the black durgons concentrated along the shore and fed both on plankton and benthic organisms (this was particularly evident when the dolphins were absent for two or more consecutive days). Gut contents of black durgons (N=5) yielded unidentified amorphous and particulate material, as well as zooplankton (mostly crustaceans and tunicates) and algae fragments.

Figure 2. Two large groups of black durgons feeding upon defecates of spinner dolphins at Fernando de Noronha Archipelago.

All the other fish species here recorded foraging on dolphin offal represented about 22 % of total records (Table 1). The fish species recorded feeding on offal were present in the inlet throughout the study period except for the scad *Decapterus macarellus,* which is seasonal at Fernando de Noronha and occurs there from August to October (J.M. Silva-Jr., pers.obs.).

Table 1. Reef fish species recorded feeding on spinner dolphin offal at Fernando de Noronha Archipelago, off northeast Brazil (1006 min of direct observation over 18 days). N= number of feeding events (see methods); group size and total length (cm)= estimates for the recorded individuals (remora numbers refer to fish attached to a single dolphin); trophic categories based on field observations and literature records (Randall, 1967; Hobson, 1974); arrangement of families follows Nelson (1994).

Species	***N***	**Group size**	***Total length***	***Trophic category***
Exocoetidae				
Hemirhamphus brasiliensis	3	10	25	omnivore, planktivore
Carangidae				
Carangoides bartholomaei	6	1-2	25-40	carnivore, planktivore
Carangoides crysos	13	1-2	30-35	carnivore, planktivore
Caranx latus	3	1	40	carnivore, planktivore
Decapterus macarellus	2	30	20	planktivore
Echeneidae				
Remora australis	2	1-3	10-40	carnivore, planktivore (?)
Kyphosidae				
Kyphosus sectatrix	26	5-100	50-60	herbivore
Pomacentridae				
Abudefduf saxatilis	22	30-80	12-15	planktivore, omnivore
Chromis multilineata	3	15-40	10-12	planktivore
Acanthuridae				
Acanthurus coeruleus	2	2-3	25	herbivore
Balistidae				
Canthidermis sufflamen	7	2-3	50-60	planktivore
Melichthys niger	312	4-350	30-40	planktivore, omnivore

Among the habitual planktivores, the sergeant major (*Abudefduf saxatilis*) and the brown chromis (*Chromis multilineata*) often foraged in mixed groups with the black durgons, and fed on the particulate offal in a way similar to that described for the latter species (visually oriented picking). However, the brown chromis fed on the offal rarely as its groups did not venture far from the shallow, 2-6 m depth reef sites not often used by the dolphins (the few instances we recorded this damselfish feeding on offal were all near reef pinnacles). The mackerel scad (*D. macarellus*) and the ocean triggerfish (*Canthidermis sufflamen*) did not mix with the durgons, the latter traveling mostly alone.

The less habitual planktivores such as the blue runner (*Carangoides crysos*) and the yellow jack (*Carangoides bartholomaei*) roamed over the inlet and from time to time joined the reef fish groups to forage on offal. These two jacks and the horse-eyed jack (*Caranx latus*) made passes through the offal cloud, and either visually selected and engulfed particles or, less often, fed on offal through ram-filtering (see Anderson and Wassersug 1990, for a review of suspension-feeding in vertebrates).

Among the herbivores occasionally feeding on plankton, the Bermuda chub (*Kyphosus sectatrix*) picked off the feces in much the same way it caught drifting algae pieces, as also did the blue tangs (*Acanthurus coeruleus*) recorded among a mixed group of black durgons and sergeant majors. When larger groups (20-60 individuals) of chubs approached the dolphins to feed on offal, black durgons generally retreated. In the feeding record of the surface-dwelling ballyhoo (*Hemirhamphus brasiliensis*), the fish fed on offal available in the 5-10 cm layer below the surface, and thus seemed limited to feces voided by surfacing dolphins only. We recorded no a single instance of a fish feeding on the feces of co-specifics or any other fish species.

The whalesucker (*Remora australis*) made very short forays to forage on offal, detaching itself from its dolphin host to pick off a larger particle and quickly returning to its host. Feeding on offal by the whalesucker was recorded only while the dolphin group moved slowly and when a dolphin defecated or vomited immediately in front of the whalesucker's host.

Discussion

Fish feces were demonstrated as a rich food source for herbivorous, detritivorous, and carnivorous reef fishes in the Pacific (Bailey and Robertson, 1982; Robertson, 1982; Hobson, 1991). Feces from carnivorous fishes probably are nutrient-richer than those from herbivorous species and are sought by coprophagous fishes accordingly (Robertson, 1982). As spinner dolphins feed on squids, fishes, and shrimps (Würsig et al., 1994; Silva-Jr., 1996), their feces and vomits may be regarded as a nutritive and energy rich food source, possibly less dilute and richer than those of carnivorous fishes due to the particularities of water absorption by cetaceans (Eckert and Randall, 1988). Feeding on fish feces is a habitual behavior among several Indo-Pacific reef fish species (Robertson, 1982; Hobson, 1991; Randall, in press), but we recorded no a single instance of fish feces-eating at our study site. In another oceanic island in SW Atlantic, Trindade Island off southeastern Brazil, feces produced by two herbivorous species, the scarid *Sparisoma amplum* (mentioned as *S. viride*) and the kyphosid *Kyphosus* sp., are eaten by the black durgon (Lodi, 1998). We think that the absence (or rarity) of fish feces consumption by the reef fishes we noted at Fernando de Noronha may be related to the plentiful and presumably less dilute and more nutritive dolphin feces released in the inlet.

All the reef fishes recorded feeding on spinner dolphin offal at Fernando de Noronha feed on plankton or drifting algae to some extent. The zooplankton and algae fragments recovered from the gut contents of the black durgons are consistent with previous findings at other sites, and species of *Chromis* and *Abudefduf* are well known reef planktivores, as is the case of the open-water dwelling *C. sufflamen* and *D. macarellus* (Randall, 1967; Hobson, 1974, 1991). Several carangid species, including *C. crysos*, were recently recorded foraging on plankton either by ram-feeding of picking off individual plankters (Sazima, 1998, CS and IS pers. obs.). Species of *Hemirhamphus* and *Kyphosus* feed habitually on drifting algae fragments (Randall, 1967; Carvalho-Filho, 1999), whereas species of *Acanthurus* feeds in this way occasionally (Sazima and Sazima, 2001; IS pers. obs.). Thus, feeding on cetacean droppings by the aforementioned fishes may be regarded as a simple switch from foraging on drifting plankton or algae fragments to foraging on a novel and predictable plankton-like drifting food. However, even if regarded as an opportunistic feeding switch, offal-foraging apparently became habitual for black durgons in the Baía dos Golfinhos, as the spinner dolphin occupation of the inlet is about 90% of the days throughout the year (Silva-Jr., 1996). The significantly positive correlation here recorded between black durgon numbers and dolphin numbers is indicative of the importance of cetacean offal as a food source for these reef fish.

The “predictive” behavior recorded herein for black durgons, converging to dolphin individuals before these actually voided, is similar to that recorded for some coprophagous Pacific reef fishes (Robertson, 1982). The tendency of some fish species to behave in a characteristic manner shortly before and during defecation enable the coprophagous fishes to predict the appearance of this food source and facilitate feeding on the sinking feces (Robertson, 1982). At Fernando de Noronha the foraging movements performed by the first black durgon to reach the feces readily attracted nearby individuals, and thus to perceive and learn the pre-eliminative behavior of spinner dolphins is advantageous to lessen intraspecific competition for this resource.

Due to their occasional habit of picking at drifting algae, the parrotfish *Sparisoma axillare* (IS pers. obs.) and other scarids may be potential dolphin waste-eaters, the more so as several parrotfishes are already recorded as coprophages in the Pacific (Robertson, 1982). The plankton-eating Noronha wrasse *Thalassoma noronhanum* (Francini-Filho et al. 2000) may be another potential coprophage when the cetaceans pass close to the reef, as these fish rarely venture far from the substrate. This labrid species was recorded feeding on fish feces at several sites in Fernando de Noronha (H.M. Overmeer, pers. comm.; IS pers. obs.), but no labrids are recorded feeding on fish feces in the Pacific (Robertson, 1982).

Feeding on dolphin offal by the whalesucker *R. australis* was recorded rarely, although its occurrence is probably much commoner, perhaps even a habitual foraging mode. Its attachment to a dolphin would allow easy access to this food source, the more so as spinner dolphins commonly dashed their feces over individuals at their rear within the group.

This defecating behavior differs from that reported for the bottlenose dolphin, *Tursiops truncatus*, which seldom dashes its feces over other individuals (Shinohara et al., 1999). Scarcity of offal feeding records by the whalesucker may be explained by its feeding earlier than the other recorded fishes (due to its living on the very offal source) and its observation being hindered by the attachment itself (within an offal cloud its very short foraging forays would be scarcely perceptible). At least one species of remora is known to filter plankton by ram-feeding (Clarke & Nelson, 1997), and another possible way for the whalesucker to feed on offal is simply to open its mouth to filter, with no need to detach from its host. Our suggestion that feeding on dolphin offal may be habitual for *R. australis* is strengthened by the finding of an unidentified "…white, granular, mushy substance…" as the only stomach contents of seven specimens examined by Radford and Klawe (1965). This description fits the overall aspect of spinner dolphin feces we recorded. The whalesuckers studied by Radford and Klawe (1965) were attached to the common dolphin (*Delphinus delphis*).

Robertson (1982) aptly pointed out that coral reefs offer a combination of conditions that facilitate coprophagic interactions among vertebrates. We predict that further instances of cetacean offal-feeding fishes may be recorded at sites where these marine mammals habitually congregate for resting and other activities, provided that the water is clear and plankton-eating reef fishes are found nearby. One such site may be Kealakekua Bay in Hawaii, where large groups of spinner dolphins congregate over most of the year (Norris and Dohl, 1980; Wells and Norris, 1994). We suggest that additional sites where cetacean offal may be feed upon by reef fishes in SW Atlantic include St. Paul's Rocks, off NE Brazil, where bottlenose dolphins (*Tursiops truncatus*) are regularly found close to the island (Caon and Ott, 2000) and the Enseada dos Currais, an inlet at Anhatomirim in S Brazil favored by marine tucuxis (*Sotalia guianensis*) for feeding, resting, and social activities (Flores, 1999). The black durgon is very common at St. Paul's Rocks even in open water (Lubbock and

Edwards, 1981), whereas the sergeant major (*Abudefduf saxatilis*) is a common planktivore at Anhatomirim and other reef sites in S Brazil (IS pers. obs.). Another possible site where reef fishes may feed on cetacean offal is Abrolhos Archipelago, off E Brazil, where humpback whales (*Megaptera novaeangliae*) congregate over shallow reef sites during the calving season (Engel, 1996). Even if the adult feed and/or defecate little or not at all at these calving grounds, the suckling calves probably defecate a nutrient-rich material. These and other similar situations merit a closer investigation to verify whether the cetacean-fish association presented here is restricted to Fernando de Noronha Archipelago (a condition which we repute as highly unlikely) or is a more widespread, although generally unrecorded phenomenon.

Acknowledgments

We thank the student staff of the Centro Golfinho Rotador (Daniela, Jessy, Lizete, Márcia, Thalassa, and Vanessa), as well as the field helpers (Antônio, Dinho, Fagner, and Marquinhos) for logistic support and help in the fieldwork; C. Bellini (TAMAR) for help in the field and video-recording; the Águas Claras diving center for free use of diving facilities; J. Zuanon for reading an earlier version of the manuscript; J. E. Randall for supplying unpublished records of coprophagy by surgeonfishes; A. M. Infante, L. B. Klaczko, and M.C. Munhoz for statistical advice; the IBAMA for permits to study reef fishes and spinner dolphins in the Parque Nacional Fernando de Noronha; the CNPq, FAEP-Unicamp, FAPESP, Fundo Nacional do Meio Ambiente (FNMA/MMA), and Petrobras for essential financial support.

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CAPÍTULO 4

Whalesuckers and a spinner dolphin bonded for weeks: does host fidelity pay off?

Whalesuckers and a spinner dolphin bonded for weeks: does host fidelity pay off?

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Biota Neotropica v3 (n2) http://www.biotaneotropica.org.br/v3n2/pt/abstract?short-communication+BN01303022003

Abstract

The whalesucker *Remora australis* (Echeneidae) is an oceanic diskfish found attached to cetaceans only and its habits are therefore poorly known. At the Fernando de Noronha Archipelago, off North-eastern Brazil, spinner dolphins *Stenella longirostris* (Delphinidae) regularly congregate in large groups in a shallow bay, which allows for underwater observations of their behaviour and their fish associates. In the course of a broader study of this elusive diskfish, we had the opportunity to made multiple records of two whalesucker couples (three of the fish naturally marked) attached to the same individual dolphin in two different years, over periods of 47 and 87 days respectively. In all the sightings the whalesucker individuals of a couple were recorded side-by-side and positioned on their host's belly. We surmise that at least one of the couples was a reproductive pair, as the belly of the larger fish was noticeably swollen in the last sighting, and the bulge on its belly was bilateral and extended almost uniformly to the vent, a strong indication of fully mature gonads. Moreover, its size matched those of the mature females of this diskfish species. To our knowledge, this is the first time that attachment fidelity of the whalesucker to any cetacean host is documented in the wild. We hypothesize that attachment fidelity to the same individual host increases the whalesucker's chance to mate, and suggest further that the highly social nature of the spinner dolphins facilitates encounters between potential mating partners. Our study indicates that host fidelity possibly is not an uncommon feature of the whalesucker behaviour, albeit difficult to recognise. In one of the above recorded whalesuckers the natural marking was a crescentic scar characteristic of the wounds inflicted by the cookiecutter *Isistius brasiliensis* (Dalatiidae), a first record of the attack of this shark to any diskfish species.

Key words: Fish-cetacean association, host attachment fidelity, mate finding, Echeneidae, Delphinidae,Southwestern Atlantic

Resumo

A rêmora-das-baleias *Remora australis* (Echeneidae) é um peixe-pegador oceânico que vive agarrada somente a cetáceos, sendo seus hábitos mal conhecidos devido a esta característica. No Arquipélago de Fernando de Noronha, ao largo do Nordeste do Brasil, os golfinhos-rotadores *Stenella longirostris* (Delphinidae) congregam-se regularmente em grandes grupos numa baía rasa, o que permite o estudo subaquático de seu comportamento e dos peixes associados. Ao longo de um estudo amplo deste peixe-pegador pouco conhecido, tivemos a oportunidade de fazer registros múltiplos de dois pares de rêmoras (três delas com marcas naturais), agarradas ao mesmo golfinho em dois anos distintos, por períodos de 47 e 87 dias, respectivamente. Em todas as observações, os indivíduos de cada par de rêmoras foram registrados um ao lado do outro e posicionados no ventre do hospedeiro. Supomos que pelo menos um dos pares fosse um casal reprodutivo, pois o ventre do indivíduo maior apresentava saliência bilateral bem perceptível, que se estendia até o orifício cloacal, uma característica de fêmeas com gônadas maduras. Além disso, este indivíduo apresentava comprimento correspondente ao de fêmeas maduras desta espécie. Até onde sabemos, esta é a primeira vez que a fidelidade de associação desta espécie de rêmora a qualquer cetáceo é documentada na natureza. Propomos aqui que a fidelidade de associação ao mesmo hospedeiro aumente a possibilidade da rêmora se reproduzir. Adicionalmente, sugerimos que a natureza altamente social dos golfinhos-rotadores facilite o encontro entre parceiros para reprodução. Os nossos registros indicam que a fidelidade ao hospedeiro possivelmente não seja um componente incomum do comportamento da rêmora-das-baleias, embora difícil de reconhecer. Numa das rêmoras registradas, a marca natural era uma cicatriz em forma de meia-lua, característica da mordida causada pelo tubarão-charuto *Isistius brasiliensis* (Dalatiidae), primeiro registro de ataque deste tubarão a uma espécie de rêmora.

Palavras-chave: *Associação entre peixes e cetáceos, fidelidade ao hospedeiro, encontro entre parceiros, Echeneidae, Delphinidae, Atlântico Sudoeste*

Introduction

Remoras or diskfishes (Echeneidae) attach to several types of marine vertebrates, from sharks to cetaceans (Cressey and Lachner, 1970; Fertl and Landry, 1999). Remoras may benefit from this association in several ways, such as ride, feeding, and protection from predators (Strasburg, 1959; Cressey and Lachner, 1970; Alling, 1985; Katona & Whitehead, 1988). Whereas some diskfish species attach to a broad array of hosts, other species are prone to attach to particular host types. For instance, a hostspecialised remora is the whalesucker (*Remora australis*) which, as its common name indicates, lives attached to cetaceans only, and thus its habits are poorly known (Follett & Dempster, 1960; Rice & Caldwell, 1961; Radford & Klawe, 1965).

At the Fernando de Noronha Archipelago, Southwestern Atlantic, the spinner dolphins *Stenella longirostris longirostris* (Delphinidae) regularly congregate in a shallow bay (Lodi and Fiori, 1987; Silva-Jr., 1996), offering ideal conditions for underwater observations of their behaviour (Silva-Jr., 1996; Sazima et al., 2003). As the whalesucker is one of the habitual fish associates of the spinners in the bay (Sazima et al., 2003), we started a medium-term (two years) study of this elusive diskfish to obtain a general view of its habits, and to gain some insight on what possible advantages this diskfish may obtain from its association with the cetacean. Besides seeking a general view of the whalesucker-dolphin association over our study, we tried to answer two more specific questions, based on an initial impression that some individual dolphins carried their “own” whalesuckers for extended periods: 1) For how long an individual whalesucker may attach itself to the same dolphin? 2) Is there any advantage for the whalesucker in doing so? This paper relates to these questions, and reports on two well-documented instances of whalesuckers-dolphin individual bond.

Material and Methods

The study was conducted at the Fernando de Noronha Archipelago (03°50’S, 32°25’W), about 345 km off North-eastern Brazil (see Maida & Ferreira, 1997; Carleton & Olson, 1999, for map and description). Observations were made in the Baía dos Golfinhos or Enseada do Carreiro de Pedra, a 15-25 m deep bay used by the spinner dolphins for resting and social interactions (Lodi & Fiori, 1987; Silva-Jr., 1996). The bay is an intangible protected area of the Fernando de Noronha National Marine Park. The association between whalesuckers and dolphins was observed directly and photographed during snorkelling and passive diving over 108 days (1-5 days distributed monthly from September 2000 to March 2003). Observations were concentrated in the morning, the best period for behavioural observations of spinner dolphins (Silva-Jr., 1996; Sazima et al., 2003). During observational sessions of 35-70 min, ‘focal animal’ and ‘all occurrences’ samplings were used in 71 h of direct observation in which all occurrences of specified actions of the whalesuckers (e.g., moving over the host body) over a given period were recorded (Altmann, 1974; Lehner 1979).

To answer our main question (i.e., that an individual whalesucker associate with a particular dolphin individual for an extended period), we needed reliable individual identifications of both the dolphins and the whalesuckers. Photo-identification of small cetaceans is a widespread procedure to identify individuals by natural marks such as fin shapes, nicks, scars, and pigment patterns (Würsig & Jefferson, 1990) and has been successfully used to identify individual spinner dolphins in the Pacific (Norris et al., 1994) and the Atlantic (Silva-Jr., 1996). On the other hand, such marks are much more difficult to find on a whalesucker, a slate grey fish that spends most of its time underneath its host. However, three whalesucker individuals bore unmistakable natural marks (see below) that allowed us to identify them.

Total length (TL) of whalesuckers was conservatively estimated against the greater width of the host's pectoral fluke, which in one of our largest spinner dolphins (1.87 m TL) measured 10 cm. We surmised that any fish smaller than its host's pectoral fluke width was smaller than 10 cm TL, and similar relationships (e.g., dolphin's dorsal fin height) were used to estimate the size of larger fish. Voucher photographs (paper copies) of whalesuckers and spinner dolphins with natural marks are in the file of photo-identified individuals housed at the Centro Golfinho Rotador in Fernando de Noronha, and selected scanned photographs are on file at the Museu de História Natural, Universidade Estadual de Campinas (ZUEC).

Results and Discussion

In two well-documented instances we had the opportunity to verify our assumption that some individual whalesuckers associate to the same individual dolphin for periods up to about three months. The longest association period lasted 87 days, and was recorded on three occasions (15 September; 7 and 11 December 2000). The dolphin measured about 1.8 m TL (probably a male) and bore a series of nicks on the posterior edge of the dorsal fin. The naturally marked whalesucker was recognised by its crooked vertebral column and measured about 26 cm TL, a clear underestimate due to its distorted body This whalesucker was accompanied by an individual of about 32 cm TL, which bore no natural marks and thus was unrecognisable as the same individual on the three sightings.

The second instance relates to a shorter bond (74 days) but involves a couple of recognisable whalesuckers (Fig. 1), recorded on four occasions. The first and second sightings were on 11 and 14 December 2002, the third one was on 14 February 2003, and the final record was on 5 March 2003. The dolphin was the same individual of the first description. In the first sighting the larger whalesucker (about 55 cm TL) bore a fresh, characteristic crescentic wound caused by a cookiecutter shark on its right flank, which progressively healed to a still visible crescentic scar and a small protuberance (see Jones, 1971 for wound illustrations). The other whalesucker (about 45 cm TL) had a dark pigmented, elongate marking on its right side close to the belly. As the dolphin in the both above described instances was the same individual, this implies that in some moment between 11 December 2000 and 11 December 2002 it either acquired a new remora couple or at least one of its whalesuckers was replaced.

Fig. 1. A spinner dolphin (*Stenella longirostris*) at Fernando de Noronha Archipelago, SW Atlantic, with a couple of whalesuckers (*Remora australis*) attached to its body. All the members of the trio had natural marks, allowing their unmistakable recognition on four occasions over a period of 74 days.

Cookiecutters are known to attack several cetacean species, including spinner dolphins (see Gasparini & Sazima, 1996 for a review in the SW Atlantic), and this seems to be the first record of a cookiecutter shark biting a whalesucker or any other diskfish species (Jones, 1971; Tomás & Gomes, 1989). In the large file of photo-identified spinner dolphins housed at the Centro Golfinho Rotador, we found another whalesucker individual wounded by a cookiecutter shark.

Both whalesuckers of the latter instance described herein were adults (see Radford & Klawe, 1965), and in all sightings the fish were side-by-side and positioned on their host's belly. We surmise that this particular couple was a reproductive pair, as the belly of the larger fish was noticeably swollen in the last sighting, and its size matched those of the few mature females recorded to date (Radford & Klawe, 1965). The swelling on the belly of the supposed female was bilateral and extended almost uniformly to the vent (Fig. 2), a strong indication of fully mature gonads (Helfman et al., 1997).

Fig. 2. The same whalesucker couple attached to the hind-body of the same spinner dolphin seen on Fig 1. On this last record (5 March 2003), the bilateral bulge seen on the belly of the larger suckerfish strongly indicates a ripe female.

To our knowledge, this is the first time that attachment fidelity of the whalesucker to any cetacean host is documented in the wild. Moreover, there is a reasonable possibility that the second recorded fish couple was a prospective mating pair (see above). Host fidelity would increase pair bonding and mating chance due to the closeness of two adult individuals of opposite sex, which in itself may induce gonad maturation (Helfman et al., 1997). Thus, we hypothesise that attachment fidelity to the same individual host increase the whalesucker's mating chance, and suggest further that the highly social nature of the spinner dolphins

(Norris et al., 1994) facilitate encounters between potential mating partners. The fact that the same dolphin individual changed at least one of its whalesuckers (perhaps even acquired a new couple) over a period of two years, lends some support to this latter suggestion. Notwithstanding the fact that our assumptions are based on only one individually recognisable spinner dolphin, we suspect that the bond type recorded here would not be uncommon but is likely to go undetected due to our inability to recognise whalesucker individuals.

Acknowledgements

We thank the student staff of the Centro Golfinho Rotador, as well as the field helpers for logistic support and help in the fieldwork; C. Sazima for comments on the manuscript; the Ibama for issuing permits to study spinner dolphins and reef fishes in the Fernando de Noronha National Marine Park; the CAPES, CNPq, FAEP-Unicamp, FAPESP, Fundo Nacional do Meio Ambiente (FNMA/MMA), and Petrobras for essential financial support throughout the study.

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Title: Whalesuckers and a spinner dolphin bonded for
weeks: does host fidelity pay off?
Authors: José Martins Silva-Jr and Ivan Sazima
Biota Neotropica, Vol. 3 (number 2: 2003
http://www.biotaneotropica.org.br/v3n2/pt/
abstract?short-communication+BN01303022003
Date Received 07/16/2003
Revised 09/30/2003
Accepted 10/24/2003
ISSN 1676-0611

CONSIDERAÇÕES FINAIS

De modo geral, o comportamento do golfinho-rotador que ocorre ao redor de Fernando de Noronha é similar ao do golfinho-rotador que ocorre no Havaí (NORRIS et al., 1994; LAMMERS, 2004), especialmente no que se refere às categorias descanso, cópula e jogo. Os demais comportamentos aqui relatados foram pouco documentados nos golfinhos-rotadores havaianos, mas provavelmente também sejam semelhantes e constituem um padrão para a espécie e, em alguns comportamentos, para golfinhos que vivem em grupos.

Diferentemente do que afirmaram Lodi e Fiori (1987), que não detectaram a existência de períodos de descanso dos golfinhos-rotadores em Fernando de Noronha, foi aqui registrado que o comportamento mais freqüente entre os golfinhos-rotadores na Baía dos Golfinhos é o de descanso. O comportamento de descanso, relatado no Capítulo I desta tese, é semelhante ao registrado para *Stenella longirostris* no Havaí (NORRIS & DOHL, 1980; WÜRSIG, WELLS & NORRIS, 1994), para *Lagenorhynchus obscurus* na Patagônia (WÜRSIG & WÜRSIG, 1980) e para *L. obliquidens* em cativeiro (GOLEY, 1999). Essa similaridade pode indicar um padrão de comportamento de descanso para golfinhos que vivem em grupo.

O comportamento de nadar lado-a-lado e de ter contatos físicos, observados em fêmeas e filhotes de golfinhos-rotadores em Fernando de Noronha, parece ser comum para golfinhos, como registrado para *Stenella longirostris* e *Tursiops truncatus* em cativeiro (TAVOLGA & ESSAPIAN, 1957; JOHNSON & NORRIS, 1994; GUBBINS et al., 1999).

As descrições e documentações de amamentação de golfinhos-rotadores, aqui apresentadas, parecem ser as primeiras para golfinhos em ambiente natural, de acordo com a revisão de Whitehead e Mann (2000). O comportamento de amamentação, aqui descrito, não difere significativamente do registrado para outras espécies de golfinhos em cativeiro (JOHNSON & NORRIS, 1994; COCKROFT & ROSS, 1990).

O comportamento de cópula do golfinho-rotador de Fernando de Noronha é similar ao registrado para o golfinho-rotador havaiano (WELLS & NORRIS, 1994), sendo que os grupos de cópula aqui relatados são maiores que os do Havaí. Essa diferença provavelmente está relacionada ao número máximo de indivíduos que se concentram em cada área (cerca de 70 indivíduos no Havaí e 2.000 em Fernando de Noronha).

A formação dos subgrupos comportamentais de cópula de golfinhos-rotadores é bem fluída, com a entrada e saída contínua de fêmeas e machos do subgrupo, provavelmente devido à competição sexual, como descrito por ARAUJO (1996) para o sagüi *Callithrix jacchus* (Callitrichidae).

ÖSTMAN (1991) relaciona a interação agressiva entre machos adultos de golfinhos durante o comportamento reprodutivo e os toques do rostro do macho na genitália da fêmea como indícios de dominância no relacionamento.

A grande incidência do comportamento da fêmea em impedir tentativas de cópula de macho provavelmente está relacionada à escolha do macho pela fêmea. Mesmo se a maioria das fêmeas de espécies que formam grandes grupos tem acesso a elevado número potencial de cópula, existem evidencias da escolha ativa dos parceiros pelas fêmeas, que pode ser um importante determinante de sucesso reprodutivo para ambos os sexos (WHITEHEAD & MANN, 2002). A grande maleabilidade dos golfinhos em ambientes tridimensionais permite à fêmea se esquivar do macho de várias maneiras (MESNICK & RALLS, 2002) e assim fazer escolhas entre os machos do grupo. Mesmo o maior sucesso reprodutivo de certos machos em particular, como relatado abaixo, parece relacionado à escolha da fêmea.

O caso registrado de um macho ter tido mais sucesso na cópula que os outros golfinhos do grupo permite supor que certas fêmeas favorecem machos, em particular os que apresentem um comportamento aparentemente mais estimulante, e com isso aumentaria o sucesso reprodutivo desses machos “criativos”. Outro caso registrado, de um macho com o rostro defeituoso ter sido impedido de copular pelos golfinhos do grupo, levanta uma questão interessante a ser analisada: a que machos dentro de um grupo reconhecem um macho fisicamente diferente e desenvolvem um comportamento coordenado para dificultar as tentativas de cópula do indivíduo "defeituoso", impedindo assim seu sucesso reprodutivo.

A prática de atividades sexuais entre machos pode ser uma ação agressiva de dominância de um indivíduo sobre o outro, como sugerido por Psarakos et al. (2003) e observado para o golfinho-pintado (HERZING & JOHNSON, 1997).

Como a estrutura social do golfinho-rotador é fluida e transitória, com grupos do tipo de "fissão-fusão" (LAMMERS, 2004), em que as funções se alternam entre indivíduos, coligações ou grupos (NORRIS & JOHNSON, 1994), a prática de atividades sexuais golfinhos do mesmo sexo parece funcionar também como estabilizadores ou coordenadores de vínculo e podem ser mais comum do que nossas observações indicam. Outra explicação muito especulativa (embora não possa ser totalmente desprezada) é a de que os indivíduos envolvidos experimentam algumas sensações táteis prazerosas com esse comportamento de cópula não-reprodutiva. Esta última explicação contradiz Silva-Jr. (1996), quando afirma não ocorrer comportamento homossexual entre os golfinhos-rotadores de Fernando de Noronha.

A estratégia sexual dos golfinhos-rotadores em Fernando de Noronha caracteriza uma estratégia reprodutiva da forma promíscua e polígama, onde os parceiros da cópula reprodutiva não são definidos e onde atividades sexuais também são realizadas sem fins reprodutivos, com o objetivo de alcançar prazer sexual ou afetivo. Essa estratégia resulta em uma estrutura social muito fluída, onde inexiste a figura paterna, os laços familiares derivam da relação mãe-filho e os machos adultos investem na proteção dos membros vulneráveis, como fêmeas com filhotes, semelhante ao que ocorre com o *Callithrix jacchus,* no qual, embora exista a paternidade e a maternidade definida, o cuidado com a prole é comunitário (YAMAMOTO et al., 1995).

Os jogos com algas, aqui registrados entre os golfinhos-rotadores de Fernando de Noronha, possivelmente tenham uma função interativa, sendo a alga o instrumento dessa interação entre os golfinhos, diferentemente da afirmação de que ao jogar com objetos os golfinhos transferem para o objeto o senso de socialização (WÜRSIG, 2002). A interpretação de Würsig (2002) parece aplicar-se mais ao comportamento dos golfinhos-rotadores ao perseguirem o peixe cangulo-preto, também relatado aqui.

O encontro agonístico entre *Stenella longirostris* e *S. atenuatta* observado na Baía dos Golfinhos é compatível com a idéia de Psarakos, Herzing e Marten (2003), de que existe um alto potencial de agressividade entre essas duas espécies de golfinhos, especialmente quando uma está em menor número que a outra. Também é possível especular que os golfinhos-pintados observados eram machos e que estavam sendo expulsos da Baía dos Golfinhos, área de reprodução (SILVA-JR., SILVA & PEREIRA, 1996), como forma de evitar a competição reprodutiva, visto que há registro da existência em Fernando de Noronha de um suposto híbrido de golfinho-rotador com golfinho-pintado (Silva-Jr., comunicação pessoal) .

Levantamos a hipótese de que os golfinhos-rotadores evitam ocupar simultaneamente uma área com baleias-jubartes por que à alta freqüência dos sons emitidos por elas (freqüência dominante entre 120 e 4000 Hz) seria um agente perturbador para os golfinhos-rotadores, que apresentam freqüência dominante entre 6,8 e 16,6 Hz (RICHARDSON et al., 1995).

As observações subaquáticas em Fernando de Noronha indicam que os golfinhos enfrentam tubarões em circunstâncias particulares, como para proteção de filhotes. A eficiência na defesa contra tubarões pode ser observada na grande taxa de sobrevivência dos golfinhos, indicada pelas cicatrizes de mordidas de tubarões em animais vivos (CORKERON, MORRIS & BRYDEN, 1987; WELLS & SCOTT, 2002).

A utilização das fezes e dos regurgitos dos golfinhos-rotadores como uma fonte de alimento por peixes recifais pode ser interpretada como uma importante função ecológica dos golfinhos para Fernando de Noronha, por meio da reciclagem e da dispersão de nutrientes. O hábito dos peixes se alimentarem dos excrementos de cetáceos pode ser interpretado como uma mudança oportunista do comportamento de forrageio, já que todas as espécies registradas se alimentando de excrementos de golfinhos alimentam-se preferencialmente de plâncton ou algas à deriva na coluna d'água (RANDALL, 1967; HOBSON, 1974, 1991).

O comportamento de regurgito registrado nos golfinhos-rotadores de Fernando de Noronha nunca tinha sido reportado para golfinhos em ambientes naturais. Como os regurgitos são compostos de restos de lulas e parasitos, relacionamos o regurgito a uma provável irritação provocada pelos bicos de lulas. Como em algumas ocasiões, junto com os regurgitos foram eliminados vermes (*Anisakis* sp., Anisakidae), pode-se supor que o processo de regurgito também tenha a função de eliminar vermes estomacais.

A aparente sazonalidade do comportamento de vomitar dos golfinhos-rotadores em Fernando de Noronha, predominantemente no segundo semestre, deve-se a que nesse período a oferta de lulas é maior nas proximidades de Fernando de Noronha (SILVA-JR., SILVA & PEREIRA, 1996).

A fidelidade ao hospedeiro observada entre rêmoras e golfinhos-rotadores é aqui interpretada como um modo de aumentar a chance de acasalamento desses peixes. A proximidade de duas rêmoras adultas do sexo oposto pode induzir à maturação das gônadas (HELFMAN, COLLETTE & FACEY, 1997), e a natureza social do golfinho-rotador (NORRIS et al., 1994) provavelmente facilita o encontro entre parceiros sexuais potenciais. A mordida acidental do tubarão-charuto na rêmora pode ser interpretada como uma vantagem indireta do golfinho nessa associação.

Podem ser atribuídas quatro principais funções ecológicas para os golfinhos-rotadores em Fernando de Noronha: predadores de pequenos peixes, lulas e camarões em alto mar; presa de tubarões; fornecedor de alimento para peixes recifais planctófagos nas proximidades do Arquipélago; facilitador da reprodução das rêmoras.

No que se refere ao turismo de observação de golfinhos, sabe-se que barcos a motor causam efeitos indiretos na vida selvagem, efeitos esses difíceis de ser isolados e estudados (KNIGHT & GUTZWILLER, 1995). Norris e Reeves (1978) afirmam que as perturbações antropogênicas que provocam maiores gastos energéticos durante comportamentos críticos, como reprodução e descanso, podem ter efeitos em longo prazo, reduzindo o bom estado biológico da população de cetáceos. Assim, o crescimento desordenado do turismo em Fernando de Noronha, especialmente do turismo náutico, está alterando o comportamento e a ocupação do Arquipélago pelos golfinhos-rotadores como já previsto por Perrin (1987) e registrado por Silva-Jr., Silva e Pereira (1996), ao contrário do relatado por Lodi, Almeida e Pimentel (1994).

O Plano de Manejo do Parque Nacional Marinho de Fernando de Noronha (IBAMA, 1990) e o Plano de Ação dos Mamíferos Aquáticos do Brasil (IBAMA, 2001) recomendam a continuidade e a especialização dos estudos sobre os golfinhos-rotadores de Fernando de Noronha, para fornecer subsídios para a preservação dessa população de cetáceos e do seu ecossistema. Assim, pretende-se dar continuidade às pesquisas em andamento, bem como investir em estudos mais detalhados, incluindo estimativas populacionais, foto-identificação, interação com o turismo náutico, bioacústica, comportamento alimentar, caracterização molecular e monitoramento por satélite dos deslocamentos dos golfinhos.

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