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Distribuição, Influência de Características de Locais para Reprodução na Ocupação e Estimativas de Abundância de trinta-réis-anãos (*Sternula superciliaris*), gaivotas (*Phaetusa simplex*) e corta-águas (*Rynchops niger*) no Arquipélago de Anavilhanas, Amazonas, Brasil

Rebecca María Zarza Aguilera

Manaus, Amazonas.

Setembro 2010

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Sinopse:

Descrevemos a distribuição, estimamos a abundância e a proporção de área ocupada de colônias de trinta-réis-anãos (*Sternula superciliaris*), gaivotas (*Phaetusa simplex*) e corta-águas (*Rynchops niger*) no Arquipélago de Anavilhanas. Consideramos diferencias de detecção entre observadores e estimamos a relação entre características de locais para reprodução

Palavras-chave: aves coloniais; Laridae; nidificação.

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RESUMO

Informações ecológicas sobre a ocorrência e abundância das espécies são cruciais para avaliar a influência de fatores ambientais sobre populações, para reconhecer mudanças no tamanho das populações e para reconhecer locais importantes para a manutenção de populações viáveis. Reconhecer relações entre as populações e características ambientais pode ser útil para gerar predições sobre efeitos de eventos futuros. Estimamos a distribuição, a influência das características de praias para reprodução na ocupação e a abundância, considerando probabilidades de detecção de trinta-réis-anãos (*Sternula superciliaris*), gaivotas (*Phaetusa simplex*) e corta-águas (*Rynchops niger*) no Arquipélago de Anavilhanas, Amazonas, Brasil, durante as estações reprodutivas 2008 e 2009. Em 2008 e 2009 registramos a presença ou ausência de indivíduos nidificando em visitas repetidas a cada praia disponível no arquipélago para estimativas de ocupação. Em 2009 utilizamos o método de dois observadores em pontos de contagem para estimar a abundância das aves no arquipélago considerando possíveis diferenças de detecção entre observadores. Localizamos 26 praias disponíveis em 2008 e 30 em 2009. Uma praia abrigou ≥ 28% do total de trinta-réis-anão contados e dois locais concentraram ≥ 65% das gaivotas contadas durante as temporadas de reprodução de 2008 e 2009. A probabilidade de detecção, p (SE) em 2008 e 2009, do trinta-réis-anão foi 0,8272 (0,0534) e 0,8737 (0,0341), da gaivota foi 0,8668 (0,0512) e 0,7323 (0,0577), do corta-água foi 0,8321 (0,0551) e 0,9429 (0,0392). A ocupação no arquipélago, psi (SE) em 2008 e 2009, do trinta-réis-anão foi 0,5841 (0,0982) e 0,6334 (0,0880), da gaivota foi 0,5025 (0,0986) e 0,4006 (0,0896), do corta-água foi 0,5432 (0,0987) e 0,2333 (0,0772). Trinta-réis-anões, gaivotas e corta-águas preferiram nidificar em praias maiores, ilhas com pouca ou sem vegetação, praias com maior exposição a água circundante, locais mais distantes da terra firme e/ou de ilhas e locais mais próximos às maiores colônias. O número total de indivíduos contados em 2008 foi 133 trinta-réis-anões, 72 gaivotas e 103 corta-águas e as estimativas de abundância em 2009 (N ± SE) foram 192,36(± 1,24) trinta-réis-anões, 79,56 (± 0,77) gaivotas e 31,22(± 0,48) corta-águas. A probabilidade de detecção geral, ou seja, de uma ave ser contada quando dois observadores presentes foi alta para as três espécies (p ≥ 0,992), mas foi diferente entre espécies e foi menor para cada observador. Nossos resultados sugerem que o uso de locais para reprodução de trinta-réis e corta-águas nestes dois anos foi influenciado por uma combinação entre características do local e atração intra-específicas entre as aves. Sugerimos, com base em nossos resultados, o uso do método de dois observadores para pontos de contagem para estimativas mais acuradas de abundância, avaliações de mudanças no tamanho de populações e medidas de conservação para aves associadas a ambientes aquáticos.
Palavras-chave: arquipélago fluvial; aves coloniais; características da praia; dois observadores; Laridae; probabilidade de detecção; trinta-réis-grande; talha-mar

ABSTRACT

Ecological information on species occurrence and abundance are crucial to assess the influence of environmental factors on the populations, to recognize changes in population sizes and to identify key sites to maintain viable populations. We estimated the distribution, influence of site features on colony site occupancy and abundance estimates accounting for detection probabilities of Yellow-billed Terns(*Sternula superciliaris*), Large-billed Terns (*Phaetusa simplex*) and Black Skimmers (*Rynchops niger*) breeding in the Anavilhanas Archipelago, Amazonas, Brazil. We did repeated surveys on beaches available in 2008 and 2009 breeding seasons and conducted point counts with a double observer approach in 2009. We mapped 26 potential sites in 2008 and 30 in 2009, one site hosted ≥ 28% of total Yellow-billed Terns counted and two sites hosted ≥ 65% of Large-billed Terns counted. Detection probability, p (±SE) in 2008 and 2009, for Yellow-billed Tern was 0.8272 (±0.0534) and 0.8737 (±0.0341), for Large-billed Tern was 0.8668 (±0.0512) and 0.7323 (±0.0577), for Black Skimmer was 0.8321 (±0.0551) and 0.9429 (±0.0392). Site occupancy, psi (SE) in 2008 and 2009, for Yellow-billed Tern was 0.5841 (±0.0982) and 0.6334 (±0.0880), for Large-billed Tern was 0.5025 (±0.0986) and 0.4006 (±0.0896), for Black Skimmer was 0.5432 (±0.0987) and 0.2333 (±0.0772). Terns and Black Skimmers preferred to nest in larger beaches, islands with small percent of or no vegetation cover, beaches more exposed to open water, sites further away from river margin, more isolated from island, and closer to main colonies. A total of 133 Yellow-billed Terns, 72 Large-billed Terns and 103 Black Skimmers were counted in 2008 and in 2009 abundance estimates (N ± SE) were for Yellow-billed Tern = 192.36 (± 1.24), for Large-billed Tern = 79.56 (± 0.77) and for Black Skimmer = 31.22 (± 0.48). Overall detection probability-p (probability of a bird being detected when two observers counting) was high for the three species (p ≥ 0.992), but it was different between species and between observers and was lower for each observer separate. Our results suggest that breeding site use by terns and Black Skimmer may be influenced by a combination among habitat features and intraspecific attraction of these birds. Based in our estimates of detection probabilities we suggest the use of the double observer approach for point counts for more accurate abundance estimates, population changes assessment and conservation planning for waterbirds.

Key-words: colonial waterbirds; detection probabilities; double observer; freshwater archipelago; Laridae; nesting site features; terns.

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INTRODUÇÃO

Os ambientes aquáticos representam 6%, ou 300,000 km^2 da Amazônia Brasileira e mais de 100,000 km^2 de lagos e pântanos (Scott and Carbonell 1986). As aves aquícolas são componentes bem distribuídos nos sistemas fluviais amazônicos (rios, lagos). As variações sazonais no nível das águas na bacia amazônica governam processos geomorfológicos, hidrológicos e ecológicos (Alsdorf *et al*. 2000) e podem ter influência em aspectos vitais de organismos associados a ambientes aquáticos, como no uso de locais para descanso durante a migração (e.g. Bolster and Robinson 1990) e para nidificação. Aspectos sobre a biogeografia e especiação de aves de planícies de inundação foram estudados amplamente na região amazônica, mas há pouco conhecimento sobre a autoecologia, etologia e biologia reprodutiva dessas aves (Petermann 1997).

Aparentemente o pulso do nível d'água é o fator principal que influência a reprodução de aves de planícies de inundação (Preston 1962) enquanto disponibiliza habitats especiais associados a corpos de água. Porém, em áreas úmidas tropicais as interações espaciais e temporais entre as aves de planícies de inundação e o habitat são ainda pouco conhecidas, principalmente na grande região da bacia amazônica (Petermann 1997).

Informações ecológicas sobre a ocorrência e abundância das espécies são cruciais para avaliar influência de fatores ambientais sobre populações. Reconhecer essas relações pode ser útil para gerar predições sobre efeitos de eventos futuros (Begon *et al.*2006), tais como mudanças no tamanho das populações no tempo e no espaço (MacKenzie and Kendall 2002; Kissling *et al.* 2007).

Mudanças no número de indivíduos são incluídas em estimativas de crescimento de populações e tendências populacionais, e.g. estimativas de declínio para espécies ameaçadas e tendências de incremento de populações de espécies invasoras são usualmente informações base para estratégias de conservação de espécies (MacKenzie and Kendall 2002). Assim, a consideração dos fatores físicos e bióticos que influênciam mudanças na distribuição e abundância em populações de uma espécie é importante para uma maior viabilidade das estimativas de tamanho e tendências populacionais

(Kissling *et al.* 2007).

Visto que muitas espécies de aves aquícolas são coloniais, o reconhecimento de quais os fatores que influênciam a ocorrência e abundância das aves poderia melhorar o conhecimento sobre os mecanismos reguladores do comportamento de agrupamento em colônias e de seleção de habitat para a reprodução.

Alguns fatores que influênciam a distribuição e abundância de uma espécie são a disponibilidade de recursos, as interações com outras espécies e entre indivíduos da própria espécie e condições ambientais (Begon *et al.* 2006). A nidificação em colônias pode ser vantajosa, e.g. pela redução do risco de predação, porém, pode incrementar a competição por recursos como alimento e locais para nidificar (Moller 1987). Logo, a presença e abundância de outros indivíduos da mesma ou de outra espécie poderiam influênciar o uso de locais para reprodução (Custer *et al.* 1980).

A seleção de habitat para reprodução pode ser influênciada por fatores ambientais em diferentes níveis espaciais (Boe 1993). Para aves da planície de inundação da bacia amazônica, a disponibilidade de habitat para reprodução poderia ter influência no uso de habitat em um nível regional, e características do local como a disponibilidade de recursos poderia atuar localmente. Por isto, compreender as relações entre as características de locais de reprodução e a distribuição e abundância de aves de planícies de inundação é importante para conhecer melhor a biologia dessas aves, seus deslocamentos, dinâmicas populacionais, e ocupação do habitat nesses ambientes amazônicos.

O Arquipélago de Anavilhanas é um arquipélago fluvial com ca. 300 ilhas que oferece gradientes em características do habitat e por isto é plausível para testar hipóteses e fazer experimentos para avaliar as respostas das aves às características do habitat.

Uma abordagem compreensível para conhecer as respostas das aves às variações do habitat precisa de dados sobre variáveis ambientais em uma ampla escala espacial que usualmente supera os métodos de medidas em campo (Kerr and Ostrovsky 2003). Por sua vez, os Sistemas de Informação Geográfica (SIG) oferecem ferramentas poderosas e efetivas com relação ao custo-benefício, para medir e analisar

variáveis ambientais abrangendo grandes áreas e para quantificar habitats para reprodução de aves aquícolas em paisagens fragmentadas, como os arquipélagos (Heinänen *et al.* 2008).

A influência de fatores ambientais no sucesso reprodutivo e uso de habitat de trinta-réis e do corta-águas (*Rynchops niger*) foi foco de poucos estudos em outras regiões do mundo (e.g. Burger 1981b; Burger 1982; Molina 1996). A influência do tipo de habitat e de sua disponibilidade na abundância e ocorrência de outras espécies de trinta-réis e do corta-água foram pesquisadas principalmente em locais costeiros (e.g. Gochfeld 1983; Erwin and Smith 1985; Simmons 1998; Krogh and Schweitzer 1999; Branco 2003a; Heinänen *et al.* 2008; Scarton 2008; Yorio *et al.* 1998) e poucos estudos foram desenvolvidos em ambientes fluviais (e.g. Kirsch 1996; Molina 1996; Raeder 2003). De fato, as relações entre fatores ambientais e a distribuição e abundância de trinta-réis (*Sterna spp*) tem sido pouco abordadas e há poucos dados quantitativos sobre essas relações, prevalecendo, ate hoje, as considerações feitas por Burger (1982).

Estudos prévios sobre colônias do trinta-réis anão (*Sternula superciliaris*), da gaivota (*Phaetusa simplex*) e do corta-água tem abordado a influência do tamanho de colônias do curiango-da-praia (*Chordeiles rupestris*) no sucesso reprodutivo das primeiras quando nidificando em colônias mistas (Groom 1992). Também foi estimada a abundância de indivíduos a partir da produção de ovos de Gaivotas e Corta-águas de uma única colônia (Raeder 2003); e foi estudado o sucesso reprodutivo e a distribuição dos ninhos do Trinta-réis-anão, da Gaivota e do Corta-água também em uma colônia (Krannitz 1989)

O Corta-água nidifica nas costas do sudeste e sudoeste no Hemisfério Norte (Krannitz 1989, Molina 1996). Na América do Sul nidifica junto ao Trinta-réis-anão (*Sternula superciliaris*) e a Gaivota (*Phaetusa simplex*) no interior do continente, em praias nos sistemas dos rios Amazonas e Paraná (Preston 1962, Groom 1992, Raeder and Bernhard 2003, Maugeri 2005). As interações espaciais e temporais destas aves com o habitat são mal conhecidas na Amazônia (Petermann 1997) e aparentemente o único fator que influência a época de reprodução destas espécies seria a variação

nos corpos d'água (Preston 1962), por disponibilizar habitats apropriados. No Pantanal e na Amazônia, praias de drenagem aparecem a cada ano por alguns meses quando o nível d'água diminui o suficiente (Raeder and Bernhard 2003), oferecendo uma oportunidade ideal para compreender como os locais de reprodução destas aves estão segregados espacialmente (Krannitz 1989).

OBJETIVOS

Objetivo Geral

Avaliar a distribuição, abundância e a influência de características de praias na ocupação do Trinta-réis-anão, da Gaivota e do Corta-água no Arquipélago de Anavilhanas.

Objetivos Específicos

- Descrever a distribuição do Trinta-réis-anão, da Gaivota e do Corta-água no Arquipélago de Anavilhanas:
- Estimar a influência de características de praias na ocupação de colônias do Trinta-réis-anão, da Gaivota e do Corta-água no Arquipélago de Anavilhanas:
- Estimar a abundância do Trinta-réis-anão, da Gaivota e do Corta-água no Arquipélago de Anavilhanas considerando probabilidades de detecção.

Artigo

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Distribution, Influence of Site Features on the Occupancy and Abundance Estimates of Yellow-billed Terns (*Sternula superciliaris*), Large-billed Terns (*Phaetusa simplex*) and Black Skimmers (*Rynchops niger*) breeding in Anavilhanas Archipelago, Amazonas, Brazil

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Abstract.- Ecological information on species occurrence and abundance are crucial to assess the influence of environmental factors on the populations, to recognize changes in population sizes and to identify key sites to maintain viable populations. We estimated distribution, influence of site features on site occupancy and abundance accounting for detection probabilities of Yellow-billed Terns (*Sternula superciliaris*), Large-billed Terns (*Phaetusa simplex*) and Black Skimmers (*Rynchops niger*) breeding in the Anavilhanas Archipelago, Amazonas, Brazil. We surveyed beaches available in 2008 and 2009 breeding seasons and conducted point counts with a double observer approach in 2009. We mapped 26 potential sites in 2008 and 30 in 2009, one site hosted ≥ 28% of total Yellow-billed Terns counted and two sites hosted ≥ 65% of Large-billed Terns counted. Detection probability, p (±SE) in 2008 and 2009, for Yellow-billed Tern was 0.8272 (±0.0534) and 0.8737 (±0.0341), for Large-billed Tern was 0.8668 (±0.0512) and 0.7323 (±0.0577), for Black Skimmer was 0.8321 (±0.0551) and 0.9429 (±0.0392). Site occupancy, psi (SE) in 2008 and 2009, for Yellow-billed Tern was 0.5841 (±0.0982) and 0.6334 (±0.0880), for Large-billed Tern was 0.5025 (±0.0986) and 0.4006 (±0.0896), for Black Skimmer was 0.5432 (±0.0987) and 0.2333 (±0.0772). Terns and Black Skimmers preferred to nest in larger beaches, islands with small percent of or no vegetation cover, beaches more exposed to open water, sites further away from river margin, more isolated from island, and closer to main colonies. A total of 133 Yellow-billed Terns, 72 Large-billed Terns and 103 Black Skimmers were counted in 2008 and in 2009 abundance estimates (N ± SE) were for Yellow-billed Tern = 192.36(±1.24), for Large-billed Tern = 79.56(±0.77) and for Black Skimmer = 31.22 (±0.48). Overall detection probability-p (probability of a bird being detected when two observers counting) was high for the three species (p ≥ 0.992), but it was different between species and between observers and was lower for each observer separate. Our results suggests that breeding site use by terns and Black Skimmer may be influenced by a combination among habitat features and social attraction of these birds. Based in our estimates of detection probabilities we suggest the use of the double observer approach for point counts for more accurate waterbirds abundance estimates, population changes

assessment and conservation planning.

Key-words: colonial waterbirds; detection probabilities; freshwater archipelago; nesting site features

Running Head: terns and Black Skimmer in Anavilhanas

Tropical wetlands provide habitats for a wide variety of plants, fishes, birds and mammals. Aquatic environments represent 6%, or 300,000 km^2 of Brazilian Amazonia, and over 100,000 km^2 of lakes and swamps (Scott and Carbonell 1986). Aquatic birds are ubiquitous components of Amazonian freshwater systems (rivers, lakes and wetlands). Seasonal variations in the level of water bodies govern geomorphological, hydrological and ecological processes at the Amazon Basin (Alsdorf *et al.* 2000) and might also influence vital aspects of organisms associated to aquatic environments, e.g. Bolster and Robinson (1990). Biogeography and speciation of floodplain birds has been extensively studied in the Amazon floodplain region but little is known about the autecology, ethology and breeding biology of these birds (Petermann 1997). Apparently water level pulse is the main factor that influence breeding of floodplain birds (Preston 1962) making available special habitats associated to water bodies. However, in tropical wetlands the spatial and temporal interactions of floodplain birds with its habitat are poorly known, principally for the huge region of Amazon Basin (Petermann 1997).

To recognize relationships among environmental features and species abundance and occurrence can be useful to make predictions about possible consequences of future events on populations (Begon *et al.* 2006), such as changes on population size on time and space (MacKenzie and Kendall 2002; Kissling *et al.* 2007). Ecologists are interested in changes in population size because these are considered in models of population growth rates under several conditions (MacKenzie and Kendall 2002) and estimates of population trends are taken into account in conservation biology, e.g. trends of decline of a population can be base line information for species management strategies (Duca *et al.* 2009). Considering physical and biotic factors that influence changes on distribution and abundance of a species population is important for robust estimates of population size and trends (Kissling *et al.* 2007).

Some factors influencing species distribution and abundance are resources availability, interactions between conspecific, with other species and with environmental conditions (Begon *et al.* 2006). Colonial breeding can be advantageous e.g. by reduction of predation risk, although it may increase

competition for food and nest sites (Moller 1987). Hence presence and abundance of other individuals of the same or other species may influence breeding site use (Custer *et al.* 1980).

Habitat selection for breeding can be influenced by environmental features at different spatial levels (Boe 1993). For floodplain birds in the Amazon Basin such as terns and Black Skimmers, breeding habitat availability might influence habitat use at a regional level, and sites features such as resources availability, might work at local level. Therefore, the understanding of relationships between breeding site features and the distribution and abundance of floodplain birds is crucial to learn more about species biology, their movements, population dynamics and habitat occupancy in seasonal environments. In particular, as many waterbirds species are colonial, the recognition of which factors influence the occurrence and abundance of these birds may increase our understanding on the mechanisms underlying their behavior to aggregate in colonies and its influence in habitat selection for breeding. Anavilhanas Archipelago, in the Central Amazon, is a freshwater archipelago of ca. 300 islands which shows gradients in habitat characteristics and therefore it is suitable and convenient for hypothesis testing and field experiments to address bird responses to habitat features. The archipelago is also part of a Brazilian National Park and the results of this work will be considered in the Parks' Management Plan

The influence of environmental features on reproductive success and breeding habitat use by terns and Black Skimmers (*Rynchops niger*) were subject of a few number of studies in other regions of the world (e.g. Burger 1981; Burger 1982; Molina 1996). The influence of habitat type and habitat availability on abundance and occurrence of other species of terns and Black Skimmer were investigated mainly on coastal habitats (e.g. Gochfeld 1983; Erwin and Smith 1985; Simmons 1998; Krogh and Schweitzer 1999; Branco 2003a; Heinänen *et al.* 2008; Scarton 2008; Yorio *et al.* 1998) and only a few studies were conducted in freshwater environments (e.g. Kirsch 1996; Molina 1996; Raeder 2003).

Black Skimmers nest in beaches of southeastern coastline in North America (Krannitz 1989; Molina

1996). In South America Black Skimmers nest usually with Yellow-billed Tern (*Sternula superciliaris*) and Large-billed Tern (*Phaetusa simplex*) on sandy beaches and sandbars of rivers and lakes of Amazon and Paraná rivers systems (Preston 1962; Groom 1992; Raeder and Bernhard 2003; Maugeri 2005). In the Amazon and Pantanal floodplains, beaches and sandbars become available for a few months when water level drops low enough (Raeder and Bernhard 2003), offering and ideal opportunity to understand how terns and Black Skimmers breeding sites are spatially segregated (Krannitz 1989).

At the Peruvian Amazon, Groom (1992) showed a negative influence of colony size of Sand-colored Nighthawk (*Chordeiles rupestris*) in the breeding success of Yellow-billed Tern, Large-billed Tern and Black Skimmer (hereafter "terns and Black Skimmer"), when breeding in mixed species colonies. At the Brazilian Amazon Raeder and Bernhard (2003) developed a method to estimate Large-billed Terns and Black Skimmers abundance based on eggs production in a single colony, and Krannitz (1989) found a spatial segregation of nests in one colony of terns and Black Skimmers.

The spatial distribution of mixed colonies of terns and Black Skimmer has not been explored before nor elsewhere. Neither it has been addressed what habitat characteristics influence the use of nesting sites by these species. Results presented here are the first documenting Yellow-billed Tern, Large-billed Tern and Black Skimmer breeding colonies distribution, site occupancy and abundance estimates of nesting adults in Central Amazonia. These are also the first estimates of occupancy and abundance of Yellow-billed Terns and Large-billed Terns, taking into account detection probabilities.

The aims of the study were: 1) to describe the distribution of Yellow-billed Terns, Large-billed Terns and Black Skimmers breeding coloniesat the Anavilhanas Archipelago and compare its distribution in 2008 and 2009 breeding seasons; 2) to estimate the influence of site physical characteristics and percent of vegetation cover on the probability of occupancy of terns and skimmers across the archipelago in 2008 and 2009 breeding seasons; and 3) to estimate the abundance of breeding adults

for terns and skimmers-accounting for possible differences in detection probabilities between observers and among the three species.

METHODS

Study Area

Surveys were conducted at islands of the Anavilhanas Archipelago, Amazonas, Brazil (02º03'S and 03º02'S, 60º22'W and 61º12'W). The archipelago is part of the Anavilhanas National Park managed by Instituto Chico Mendes (ICMBio – MMA, Brazil), located in the Eastern portion of the Amazonas state and 40 km northwest from Manaus. Anavilhanas has an area of 350.000 ha including the entire archipelago in the Negro river and an extensive area covered with terra firme forest on the left margins of the river (Figure 1). The archipelago is mainly covered by 100.000 hectares of Igapo forest, a seasonally flooded forest inundated by black water and relatively poor in nutrients (Prance 1980).

The Negro river width can reach up to 20 km, but the river channel where the sand beaches were located, ranges from one to three km. River depth can have a seasonal variation of ten meters between dry and rainy seasons (UNESCO 2008). During the dry season (September to December), water level drops and sandbanks and sand beaches in islands of the archipelago, the breeding habitat of terns and skimmers, are exposed. More information describing the environments of Anavilhanas Archipelago is available in Cintra *et al.* (2007).

Mapping potential nesting sites

Beaches availability in Anavilhanas Archipelago depends on the river level during the dry season and it varies among years. Field surveys extended from 23 October to 1 December 2008 and from 29 October to 21 December 2009, covering most of the dry season in the study area, when terns and Black Skimmer nest. In order to find the potential nesting sites available each year, the Negro river was navigated from northern to southern boundaries of the Anavilhanas Archipelago. The geographic coordinates of each sand beach in islands and all sandbars available were recorded using

a GPS device.

Site Covariates for Occupancy Models.

We chose seven site covariates to build occupancy models, based on information on the biology of terns and Black Skimmer and literature review about breeding habitat use including other tern species. The seven covariates we used in model building describe physical features of sites - beach area, beach proximity, island proximity, distance to river margin, beach exposure to open water, and distance to main colonies; and one additional covariate represents a biotic characteristic-island vegetation cover.. All detection/non-detection data were collected by the same observer and in similar weather conditions and adults and nests of terns and Black Skimmers are easy to identify. Therefore, beach size was the only covariate considered in detection estimates.Description of covariates is resumed in Table 1.

Covariates Data Gathering. We measured beaches areas, islands areas and percentage of vegetation cover of islands, with the GIS software (Global Mapper V6.09) using a color composition of a Landsat TM-5 rectified image.

To measure beach exposure we drew a circle shape file over a Landsat TM-5 rectified image. The circle covered the larger beach surveyed and water surrounding it. We placed the circle centered on each beach and calculated the proportion of the circle not occupied by land. We used GIS software ArcView 3.2 for circle drawing and for the proportion of land measurements.

We used the medium proximity index-MPI (de Oliveira and Vetorazzi 2002) as a measure of beaches proximity. MPI considers an average distance and areas of sites in a predefined ratio with respect to site of interest. Because of the spatial configuration of the Anavilhanas Archipelago, instead of a predefined radio for beaches proximity covariate, we used the distance to the nearest five beaches to each beach in beaches MPI, and the nearest five islands to each beach for island MPI. For distance to river margin covariate we measured the distance from each beach to the nearest point in both river margins. The Nearest features v.3.8b extension (Jenness 2007) for GIS

software (ArcView 3.2) was used for distances measurements.

Occupancy Estimates

In 2008 we surveyed 26 beaches for occupancy estimates and in 2009 we surveyed the same 26 beaches plus another four beaches for a total of 30 beaches.

We visited the beaches two to five times and recorded detection or non detection of breeding adults of Yellow-billed Terns, Large-billed Terns and Black Skimmers. We searched for nests of terns and Black Skimmers at each beach surveyed to confirm the use of the site for breeding. When the surveys started, nests already had eggs and no chicks were found. Most chicks hatched about the same period of time, beginning eight days after the surveys begun. Hence we consider each beach an independent location since nesting birds could not use two locations at the same time for breeding.

We created detection histories for each survey location from the results of the repeated surveys (2008: N = 26; 2009: N = 30). Maximum-likelihood methods, implemented in the program PRESENCE (MacKenzie *et al.* 2002), were used to estimate occupancy and detection probabilities based on detection histories of all the surveys.

Abundance Estimates

In 2008 breeding season, one observer (R. Zarza) counted individuals of terns and Black Skimmers at each colony.

In 2009 breeding season we used a double observer approach (Nichols *et al.* 2000) to estimate detection probabilities and unbiased abundances of nesting terns and Black Skimmers. Two observers visited each colony together and counted in silence the number of birds seen. The number of birds each observer counted was recorded in a table.

Species and observer identity were the two covariates included in models for estimates of detection probabilities used for abundance estimates.

Terns and Black Skimmers showed aggressive behavior against observers, during visits to colonies

birds congregated above the observers as they approximated to the beaches. Because of that each beach was considered a point count. Thus detection probabilities and abundance were estimated for the Anavilhanas Archipelago as a whole.

Modeling approach and parameter estimators are detailed in Nichols *et al.* (2000) and are described briefly here: x_{ij} was the number of birds counted by observer i (i = 1, 2) on each beach when observer j (j = 1, 2) was the primary observer, p_i was the detection probability for observer i, and p was the probability of a bird being detected by at least one observer [$p = 1-(1-p_1)\ (1-p_2)$]. Birds detection probabilities then was estimated as $p_1 = (x_{11}x_{22} - x_{12}x_{21})(x_{11}x_{22}+x_{22}x_{21})^{-1}$, $p_2 = (x_{11}x_{22} - x_{12}x_{21})(x_{11}x_{22}+x_{22}x_{12})^{-1}$, and $N = (\sum x_{ij})p^{-1}$. We used the program DOBSERV (Hines 2000) to obtain estimates of detection probabilities by observers and species and abundance estimates for each species.

Model Selection

Akaike information criterion – AIC or its variants, were used for models selection from detection/non-detection data and from count data. AIC is an information theoretic measure used to select a parsimonious model considering adequate explanation of data variation and the number of parameters (Burnham and Anderson 2002).

Because AIC values are on relative scale, it is recommended to compute and use the difference between AIC values (ΔAIC) over all candidate models in the set (Burnham and Anderson 2002). The model with the lower AIC value, i.e. ΔAIC=0, was considered to better support our data. However detection and occupancy models with $\Delta AIC \leq 2$ were also considered for inferences as these are not significantly different from the model with lower AIC value (Burnham and Anderson 2002).

For occupancy estimates we tested models fit to data running 100 parametric bootstraps in Program PRESENCE by the procedure described in Mackenzie and Bailey (2004) with overdispersion of data indicated by the variance inflation factor $\hat{c}$.>1. As suggested by MacKenzie and Bailey (2004)

QAIC criterion was used in model selection for overdispersed data and standard errors were inflated by a factor of √ĉ. AIC criterion was used for model selection from non overdispersed detection/non-detection data. AIC and QAIC were computed by program PRESENCE.

We used a second order AIC (AICc) with a small sample size bias adjustment for model selection among detection probabilities estimates from count data, as recommended by Burnham and Anderson (2002) when N is small in relation to number of parameters. AICc was computed by program DOBSERV.

RESULTS

Distribution

In 2008 all of the 26 beaches available at the archipelago were surveyed. In 2009, four additional beaches were included in the surveys. Only one additional beach was available at the archipelago in 2009 and could not be surveyed. That beach was inaccessible given the extremely low water level of Negro river in the area, during 2009 dry season.

Nesting Yellow-billed Terns were detected at 15 beaches, Large-billed Terns at 13 beaches, Black Skimmers at 14 beaches and ten beaches were not occupied in 2008 breeding season.

In 2009, nesting Yellow-billed Terns were detected at 19 beaches, including two new sites not available in 2008. Large-billed Terns were detected at twelve beaches and one was a new site, unavailable in 2008. Black Skimmers were detected at seven beaches, all of which were also occupied in 2008. The number of beaches reused for nesting in 2009 by Yellow-billed Terns was 13 (86.7% of sites used in 2008) and by Large-billed Terns was ten (76.9% of sites used in 2008). Seven beaches were not used by terns or skimmers in either 2008 or 2009.

Occupancy

Evidence of overdispersion of the data for Yellow-billed Tern (2008: ĉ. = 1.72, P = 0.12; 2009: ĉ = 3.13, P = 0.03) and for Large-billed Tern in 2009(ĉ = 2.18, P = 0.05) was provided by Goodness-of-fit simulation. As suggested by MacKenzie and Bailey (2004) QAIC criterion was used for the

model selection for the overdispersed data set and standard errors were inflated by a factor of $\sqrt{\hat{c}}$. Data for Large-billed Tern in 2008($\hat{c}$ = 0.87, P = 0.29) and for Black Skimmer (2008: $\hat{c}$ = 0.73, P = 0.49; 2009: $\hat{c}$ = 0.16, P = 0.87) did not present evidence of poor fit and AIC criterion was used in model selection procedures.

From the models for each year with constant detection and occupancy probabilities, the overall detection probability, p (Standard Error) in 2008 and 2009, for Yellow-billed Tern was 0.8272 (0.0534) and 0.8737 (0.0341), for Large-billed Tern was 0.8668 (0.0512) and 0.7323 (0.0577), for Black Skimmer was 0.8321 (0.0551) and 0.9429 (0.0392). The overall site occupancy, psi (Standard Error) in 2008 and 2009, for Yellow-billed Tern was 0.5841 (0.0982) and 0.6334 (0.0880), for Large-billed Tern was 0.5025 (0.0986) and 0.4006 (0.0896) and for Black Skimmer was 0.5432 (0.0987) and 0.2333 (0.0772).

Site covariates for occupancy models.

The best supported occupancy and detection probability models for detection/non-detection data for 2008 breeding season, are presented in Table 2. The more parsimonious model for Yellow-billed Tern data was the model including distance to main colonies as covariate for occupancy probabilities. For Large-billed Tern and Black Skimmer the best supported model was an additive model including beach size, distance to river margin, and islands proximity as covariates for occupancy probabilities. For Yellow-billed Tern the additive model with beach size and distance to main colonies as covariates was also supported. For Black Skimmer the additive model with beach size, distance to river margin and beach proximity as covariates for occupancy and the model with beach size and distance to river margin were also supported.

The parameter estimates for models with Δ QAIC ≤ 2 for Yellow-billed Tern and Δ AIC ≤ 2 for Large-billed Tern and Black Skimmer for 2008 breeding season are resumed in Appendix I. The verification of the direction and magnitude of the effects of site covariates on occupancy probabilities in 2008 indicates what follows. Occupancy probabilities for Yellow-billed decreased

with greater distances to main colonies. Terns and Black Skimmers occupancy were positively influenced by increasing beach size. Sites located at longer distance to river margin and to other islands had more probabilities of being occupied by Large-billed Tern and Black Skimmer. Finally, Black Skimmer occupancy was negatively affected by beach proximity.

The best supported occupancy and detection probabilities models for detection/non-detection data of 2009 breeding season are presented in Table 2. For Yellow-billed Tern and Large-billed Tern the more parsimonious model was the null model, with no covariates neither for site occupancy nor detection probabilities. For Black Skimmer the more parsimonious model for occupancy and detection probabilities was an additive model that included the percent of islands vegetation cover and beach exposure degree as covariates.

Seven models, each including only one covariate, were also well supported for both terns' occupancy probabilities (Table 2).. For Black Skimmers occupancy and detection probabilities another five additive models were well supported and each model included the two covariates island vegetation cover and beach exposure summed to beach proximity, beach area, distance to river margin, distance to main colonies and island proximity (Table 2).

The parameter estimates for models with $\Delta QAIC \leq 2$ for Yellow-billed Tern and Large-billed Tern and $\Delta AIC \leq 2$ for Black Skimmer for 2009 breeding season are summarized in Appendix II and III.

Interpretation of the direction and magnitude of the influence of site covariates on occupancy and detection probabilities are next. Terns and Black Skimmer site occupancy probabilities were positively influenced by beach area (Figure 2 a), distance to river margin (Figure 2 b) and beach exposure (Figure 2 c) and were negatively related to percent of islands vegetation cover (Figure 2d). Yellow-billed Tern site occupancy probabilities had positive relationship with beach proximity (Figure 2 e) and islands proximity (Figure 2 f) and were negatively related to distance to main colonies (Figure 2 g). Occupancy probability for Large-billed Tern was positively influenced by the distance to main colonies (Figure 2 h) and was negatively related with beach area (Figure 2 a) and

islands proximity (Figure 2 f). Occupancy probabilities for Black Skimmer was positively affected by beach exposure (Figure 2 c) and distance to main colonies (Figure 2 i), and was negatively related to beach proximity (Figure 2 e), islands proximity (Figure 2 f) and percent of islands vegetation cover (Figure 2d).

Abundance

A total of 133 Yellow-billed Terns, 72 Large-billed Terns and 103 Black Skimmers were counted in 2008 breeding season. Total counts for 2009 breeding season were 195 Yellow-billed Terns, 79 Large-billed Terns and 31 Black Skimmers. Comparing the two breeding seasons, numbers of birds counted at each nesting site varied with shifts among sites for Yellow-billed Terns (Figure 3 a), were mostly maintained for Large-billed Terns (Figure 3 b) and dramatically dropped for Black Skimmers (Figure 3 c).

One site, B10 hosted the main colony of Yellow-billed Terns in the archipelago, with ≥ 28% of total birds of this species counted, both years. The other sites had heterogeneous colony sizes ranging from two to 20 Yellow-billed Terns (Figure 3 a). Two sites, B30 and B38, hosted the main colonies of Black Skimmer in 2008 and the main colonies of Large-billed Tern in 2008 and 2009 (Figure 3 b). Large-billed Terns counted at sites B38 and B30 summed ≥ 65% of total individuals and the counts ranged from two to four individuals at the other sites. Breeding Black Skimmers counted at sites B30 and B38 summed 75% of total birds counted in 2008 and two to five individuals were counted at every other site. Colony sizes of this species were more homogeneous in 2009 ranging from two to eight adults counted per site (Figure 3 c).

Double observer approach. The best supported model for the count data in 2009 was the model p (s,i) which included species and observer identity as covariates for detection probabilities estimates. The model p (.,i), including observer identity alone as covariate, was also supported with ΔAICc 1.74 and with non-significant difference from the best supported model (Table 3). The probabilities that a bird was detected when two observers were counting were high for Yellow-billed Tern =

0.9948, for Large-billed Tern = 0.9944, and for Black Skimmer = 0.9920. However the probabilities of bird detection by one observer alone were lower and varied among species. The secondary observer had a higher detection probability (p ± SE) for Yellow-billed Terns = 0.96 ± 0.04 and Black Skimmers = 0.96 ± 0.04 compared to the primary observer with p for Yellow-billed Terns = 0.85 ± 0.03 and for Black Skimmers = 0.80 ± 0.07. For Large-billed Tern p was higher for the primary observer = 0.94 ± 0.03 than for the secondary observer = 0.91 ± 0.03 .

Standard errors could not to be calculated for abundance estimates for model p (s,i) given the high values of p which are used for variance matrix estimates and then for standard error estimates. Hence as suggested in Hines (2000), we present abundance estimates with the SE for the other model supported by our count data, model p (., i), which included only observer identity as covariate for detection probabilities estimates. For the model p (.,i) abundance estimates (N ± SE) were for Yellow-billed Tern = 192.36 ± 1.24, for Large-billed Tern = 79.56 ± 0.77 and for Black Skimmer = 31.22 ± 0.48.

DISCUSSION

Distribution, occupancy and site features

We have assessed the distribution of suitable and used sites for reproduction of terns and Black Skimmer at the scale of Anavilhanas Archipelago. Results presented here are the first documenting terns and Black Skimmer breeding colonies distribution and estimates of site occupancy and abundance of nesting adults in Central Amazonia. These are also the first estimates of occupancy and abundance of Yellow-billed and Large-billed Terns taking into account detection probabilities. The high proportion of nesting sites re-used by Large-billed Terns, the colonization of only two new sites while more were available, and the similarity in numbers of pairs using the same sites both years suggest colony site tenacity for this species. Yellow-billed Terns seemed to have lower colony site tenacity and more plasticity to use new sites, compared to Large-billed Terns. Even thou Yellow-billed Terns presented a high proportion of nesting sites re-use, it used six new sites when

more sites were available and the numbers of pairs using each site varied between years. Black Skimmers' decrease in the proportion of sites occupied, despite there were all re-used sites, and their drop in numbers of breeding adults in 2009, suggests a much lower site tenacity and probably a higher sensibility to disturbance. No previous records of the distribution of breeding colonies and colony site use by terns and Black Skimmer at the study area were available to compare with our results. In Solimões River, nesting site tenacity over three years was reported for one Large-billed Tern colony by Raeder (2003) , but Gochfeld and Burger (1996) indicated the unpredictability of colony locations as results of changes in nesting sites use among years. For Black Skimmers Gochfeld (1978) suggests that colonies in rivers beaches and sandbars should show less site fidelity as sites are ephemeral in a breeding season and among years.

Our estimates of the proportion of area occupied by terns and Black Skimmers are similar to the results reported by Groom (1992) of 45% of beaches used by these species at the Manú River, in the Peruvian Amazon

According to our results, terns and Black Skimmer preferred to use for nesting, larger beaches and islands with small percent or no vegetation cover in Anavilhanas Archipelago. Usually more diverse environments are found in larger islands, because these have more extent of vegetation cover, thence those sites are more suitable to accomplish habitats needs of most birds (Hildén 1965). However, those characteristics of larger islands may be negative for birds that nests on beaches because vegetation may offer hiding and perching sites for potential predators, like falcons and hawks. These species were found by Groom (1992) to be responsible for more than 50% of terns and Black Skimmers nest predation. Also, Burger (1981b) suggests that in islands the availability of food resources other than tern chicks may influence the presence of predators and more vegetated areas are prone for it. The negative influence of more vegetated area in larger islands was apparently overcome in Anavilhanas Archipelago, as larger sites used by terns and Black Skimmers where mostly bare sandbanks with no vegetation. However, the vegetation succession in older islands can in subsequent

years produce desertion of the sites by nesting terns as it has been showed in the northern hemisphere (Soots and Parnell 1975) and influence site fidelity.

Terns and Black Skimmer also preferred more isolated sites which were more distant to river margin and/or other islands. This preference may be influenced by the negative effect of isolation in colonization of sites by more sedentary species (e.g. terrestrial mammals and reptiles). According to Burger (1981b) presence of terrestrial predators in islands is positively related to mainland proximity.

Predation of nests in Black Skimmer colonies influence negatively the repeated use of breeding sites (Burger 1981) and causes breeding sites abandonment by terns (Branco 2003b). The probabilities of site occupancy by terns and Black Skimmers might have been influenced indirectly by the influence of the extent of islands' vegetation cover and the proximity to mainland and other islands on the presence of potential predators.

Terns and Black Skimmer are mainly piscivores (Willard 1985). The higher occupancy probabilities for beaches more exposed to open water may be related to an increase in chances of terns and Black Skimmer to forage closer to nests sites. Foraging closer to nesting sites may increase reproductive success as it decreases time bird spends away from the nest and increases feeding frequencies and quantities to fledglings. We are exploring this question in another paper, with nest success data collected during the same field work.

In colonial birds, pairs prospect for abundance of other individuals, being attracted to established colonies and usually only the first pair chooses a site for breeding not influenced by other individuals presence or abundance (Heinänen 2008). Thus, for breeding site selection in colonial species, inter or intraspecific attraction are essential (Heinänen 2008). If there are enough resources, low or no disturbances and high breeding success in a site, more individuals tend to colonize the site and the probabilities of birds attaching to existing colonies are higher than to establish new colonies (Matthiopoulos *et al.* 2005). Social attraction apparently had an important role in colony site choice

for Large billed Terns and Black Skimmers, as these birds concentrated in two main colonies and only one or two pairs nested in other sites, and of sites closer to main colonies showed higher probabilities of occupancy. Conspecific attraction seemed to be more important for Yellow-billed Terns, as most of their colonies were larger and they established monospecific colonies. The lower influence of distances to any beach in site occupancy by Yellow-billed Terns in 2009 may be a result of their wider distribution that year.

Nesting terns and Black Skimmers did not use all the beaches present at the archipelago neither in 2008 nor 2009 breeding season. This differentiated habitat use suggests preference for some sites and model selection suggests that the nesting site use may be influenced by a combination among habitat features and social attraction of these birds.

Abundance Estimates

Excluding the main colonies, numbers birds of the three species in most colonies in Anavilhanas were similar to those of 1-12 pairs per colony reported by Groom (1992) in the Manú River, Perú. Numbers of Large-billed Tern and Black Skimmer in Anavilhanas were lower compared to colony sizes ($N \approx 242$ pairs and $N \approx 74$ pairs) registered by Krannitz (1989) in one colony at the Trombetas river,, and much smaller compared to estimates by Raeder (2003) of 9822 pairs of Large-billed Tern and 1743 pairs of Black Skimmers in one sandbank in Solimões river. The great difference in abundance between our results and those reported for the Solimões river colony by Raeder (2003) could be explained by the higher productivity in white water rivers like Solimões river, and thus less limited food resources (Raeder 2003), compared to black water rivers as Negro river. Less production in black-water floodplains than in white-water floodplains is confirmed for phytoplankton. However in Solimões mainstream the periphyton productivity is lower than in black water environments (Puttz and Junk 1997) and fishes abundance are very low, apparently as cause of overfishing (Batista and Petrere 2006). Raeder (2003) attributes the this great concentration of Large-billed Terns and Black Skimmer in the Solimões river colony to the lack of other nesting sites

available near that sandbank, mainly due to cattle ranching and egg harvest in neighbor potential sites. As Anavilhanas Archipelago is a National Park, there are no cattle ranching or human settlements in the islands and terns and Black Skimmer should not be prone to restrain their distribution to one site and being more widespread and not concentrated in only one huge colony. We consider that abundance estimates of Yellow-billed Tern, Large-billed Tern and Black Skimmer should take into account detection probabilities. Even when overall detection probabilities, or probabilities of a bird being counted by at least one of the two observers, were high using the double observer approach, detection probabilities by only one observer where lower. Hence estimates from counts by only one observer would yield to biased estimates of population size and changes would be more difficult to detect.

Estimates of regional population size of most waterbirds species have a low or very low accuracy and rarely, there are formal assessment of accuracy or counts estimates available (Morrison *et al.* 2000). The Neotropical Waterbirds Census is the main source of data for estimates of waterbirds population sizes in the Neotropics (Espinosa 2008) and usually methods to account for detection probabilities estimates are not considered in these counts and neither are the detection probabilities considered in the abundance estimates (see López-Lanús and Blanco 2005). Information about population sizes has intrinsic biological importance (Morrison *et al.* 2000). Waterbirds population sizes in particular have become considerably important in conservation planning, e.g. estimates of waterbirds are used to assess the importance of congregation sites for protection under the Ramsar Convention on Wetlands of International Importance and as Important Bird Areas – IBAs (Morrison *et al.* 2000, Delany, Scott and Helmink 2006). Based on our results of differences in detection probabilities between observers and between species and their effects in abundance estimates, we encourage the use of the double observer approach for waterbirds counts in the region. This in order to improve the accuracy in abundance estimates and hence to improve the recognition of changes in population sizes and of important sites for conservation.

Management and conservation.

Eggs of terns, gulls and Black Skimmers are collected by local people in marine islands (Branco 2003 a,b) and also in the Amazon basin (e.g. Preston 1962, Raeder and Bernhard 2003). Constant presence of people and egg collection in breeding sites can cause to abandon of sites by terns (Yorio *et. al.* 1994, Branco 2003b). Anavilhanas Archipelagos' islands experience tourists' visitation, given the beauty of its landscape and its proximity to Manaus city. In fact, we recorded some events of egg harvest by locals in its beaches. Since Anavilhanas Archipelago is part of a National Park, we highlight the importance of confirmation of colony sites fidelity and the consideration of the main colony sites identified for the park management plan.

We suggests the maintenance of long term colonies monitoring to assess colony site fidelity yet not well explored elsewhere for Yellow-billed Tern and Large-billed Tern. And we also suggest that mark recapture methods should be implemented to test for site fidelity by individual birds

Anavilhanas Archipelago should be considered for conducting studies on terns and Black Skimmers site fidelity, as well as other breeding related studies, as many colonies of these birds are found within relatively short distances, which will allow comparisons and further hypotheses testing.

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TABLES

Table 1. The seven covariates considered in model building, codes used for each in model names in Tables and Appendices and description of each covariate.

Covariate Name	Symbol	Description
Island vegetation cover	VG	Proportion of vegetation cover of the island area
Beach area	S	Beach Area in kilometers squared
Beach proximity index	BP	Measure of site isolation with respect to other beaches
Island proximity index	IP	Measure of beach isolation with respect to islands
Distance to river margin	RM	Distance (km) from the beach to nearest point at both river margins
Exposure	EXP	Exposure of the beach to open water
Distance to main colonies	COL	Distance (km) to colonies with higher numbers of adults for each species

Table 2. Models for site occupancy and detection probability for Yellow-billed Tern – YBTE, Large-billed Tern – LBTE and Black Skimmer – BLSK for 2008 and 2009 breeding season in Anavilhanas Archipelago. Lower values of delta QAIC indicates more parsimonious models. In model names: S: Beach area, RM: Distance to river margin, EXP: Exposure, VG: Island vegetation cover, BP: Beach proximity index, IS: Island proximity index and COL: Distance to main colonies.

Species/Year	Model	ΔQAIC	QAIC weight	Model Likelihood	Number of Parameters
YBTE/2008	psi(COL),p(.)	0	0,2789	1	3
	psi(S+COL),p(.)	0,52	0,215	0,7711	4
YBTE/2009	psi(.),p(.)	0	0,16	1	2
	psi(IS),p(.)	1,3	0,0835	0,522	3
	psi(S),p(.)	1,53	0,0744	0,4653	3
	psi(RM),p(.)	1,55	0,0737	0,4607	3
	psi(VG),p(.)	1,68	0,0691	0,4317	3
	psi(EXP),p(.)	1,78	0,0657	0,4107	3
	psi(.),p(S)	1,84	0,0638	0,3985	3
	psi(COL),p(.)	1,91	0,0616	0,3848	3
	psi(BP),p(.)	1,96	0,06	0,3753	3
LBTE/2009	psi(.),p(.)	0	0,1044	1	2
	psi(.),p(S)	0,73	0,0725	0,6942	3
	psi(S),p(.)	0,82	0,0693	0,6637	3
	psi(BP),p(.)	0,83	0,0689	0,6603	3
	psi(EXP),p(.)	1,37	0,0526	0,5041	3
	psi(COL),p(.)	1,64	0,0478	0,4584	4
	psi(RM),p(.)	1,69	0,0476	0,4561	4
	psi(VG),p(.)	1,79	0,046	0,4404	3
	psi(IS),p(.)	1,87	0,0448	0,4296	3
		ΔAIC	AIC weight		
LBTE/2008	psi(S+RM+IS),p(.)	0	0,4613	1	5
BLSK/2008	psi(S+RM+IS),p(.)	0	0,3021	1	5
	psi(S+RM+BP),p(.)	1,14	0,1709	0,5655	5
	psi(S+RM),p(.)	1,69	0,1298	0,4296	4
BLSK/2009	psi(VG+EXP),p(.)	0	0,1353	1	4
	psi(VG+EXP+BP),p(.)	1,3	0,1353	1	5
	psi(VG+EXP+S),p(.)	1,39	0,0808	0,5975	3
	psi(VG+EXP+RM),p(.)	1,75	0,0706	0,522	5
	psi(VG+EXP+COL),p(.)	1,94	0,1821	0,4991	5
	psi(VG+EXP+IS),p(.)	1,97	0,0605	0,4471	3

Table 3. Models of detection probabilities-p using a double observer approach for the count data of nesting Yellow-billed Terns, Large-billed Terns and Black Skimmers in 2009 breeding season at Anavilhanas Archipelago. The models Likelihood values, number of parameters (K), AICc and ΔAICc values, and goodness-of-fit tests (G-O-F). G-O-F test is the G-test statistic computed by program DOBSERV. In models "s" is species, "i" is observer identity. Lower values of AICc indicates more parsimonious models.

Model	Likelihood	K	AICc	ΔAICc	G-O-F
P(s,i)	-10,48	6	33,25	0,00	1,000
P(.,i)	-15,48	2	34,99	1,74	0,125
P(.,.)	-21,23	1	44,48	11,23	0,003
P(s,.)	-20,60	3	47,28	14,03	0,001

APPENDIX I. Untransformed parameter estimates (betas) for detection probability and occupancy models with ΔAIC <2 for Yellow-billed Tern-YBTE, Large-billed Tern-LBTE and Black Skimmer for 2008 breeding season in Anavilhanas Archipelago. Abbreviations: S: Beach area, RM: Distance to river margin, BP: Beach proximity index, IS: Island proximity index, COL: Distance to main colonies and int: intersection.

Species/Year	Model	ΔAIC		Parameter	Estimate	SE	Upper 95% CI	Lower 95%CI
YBTE/2008	psi(COL),p(.)	0	Detection	int	1,933679	0,49024523	2,52791065	0,60614935
			Occupancy	int	0,350615	0,62851966	1,58251353	-,88128353
				COL	-1,426829	0,82838112	0,196798	-3,050456
	psi(S+COL),p(.)	0,52	Detection	int	1,576536	0,48754925	2,53213253	0,62093947
			Occupancy	int	0,719954	0,81064896	2,30882596	-,86891796
				COL	-1,539249	0,87035483	0,16664647	-,24514447
				S	2,068454	2,23108327	6,44137721	-,30446921
LBTE/2008	psi(S+RM+IS),p(.)	0	Detection	int	1,887359	0,47128364	2,81107493	0,96364307
			Occupancy	int	2,27776	1,57320923	5,36125009	-,80573009
				S	7,34805	4,03119825	15,2491986	-,55309857
				RM	3,438808	2,02999865	7,41760535	-,53998935
				IS	-1,939474	1,15596915	0,32622553	-,20517353
BLSK/2008	psi(S+RM+IS),p(.)	0	Detection	int	1,616809	0,390559	2,38230464	0,85131336
			Occupancy	int	1,92467	1,216554	4,30591284	-,46297884
				S*	6,284661	3,1596	12,477477	0,091845
				RM	1,949827	1,1888	4,279875	-0,380221
				IS	-1,274254	0,799161	0,29210156	-,84060956
	psi(S+RM+BP),p(.)	1,14	Detection	Int	1,569833	0,400725	2,355254	0,784412
			Occupancy	Int	1,889491	1,246287	4,33221352	-,55323152
				S*	6,264819	3,101168	12,3431083	0,18652972
				RM	1,393989	0,898066	3,15419836	-,36622036
				BP	-0,876983	0,619121	0,33649416	-,09046016
	psi(S+RM),p(.)	1,69	Detection	int	1,554456	0,40325	2,344826	0,764086
			Occupancy	int	1,506338	1,032436	3,52991256	-,51723656
				S	5,188428	2,701275	10,482927	-0,106071
				RM	1,113505	0,67947	2,4452662	-0,2182562

APPENDIX II. Untransformed parameter estimates (betas) for detection probability and occupancy models with ΔQAIC <2 for Yellow-billed Tern-YBTE,and Large-billed Tern-LBTE for 2009 breeding season in Anavilhanas Archipelago. Abbreviations: S: Beach area, RM: Distance to river margin, EXP: Exposure, VG: Island vegetation cover, BP: Beach proximity index, IS: Island proximity index, COL: Distance to main colonies and int: intersection.

Species/Year	Model	ΔQAIC	Parameter		Estimate	SE	Upper 95% CI	Lower 95%CI
YBTE/2009	psi(.),p(.)	0	Detection	int	1,933679	0,54688929	3,005582008	0,861775992
			Occupancy	int	0,546632	0,67063353	1,861073719	-,767809719
	psi(IS),p(.)	1,3	Detection	int	1,933688	0,54688044	3,005573662	0,861802338
			Occupancy	int	0,618776	0,72271755	2,035302398	-,797750398
				IS	0,665384	0,94996254	2,527310578	-,196542578
	psi(S),p(.)	1,53	Detection	int	1,933632	0,54693354	3,005621738	0,861642262
			Occupancy	int	0,614519	0,72777444	2,040956902	-,811918902
				S	0,637476	1,24809072	3,083733811	-,808781811
	psi(RM),p(.)	1,55	Detection	int	1,933673	0,5468946	3,005586416	0,861759584
			Occupancy	int	0,58531	0,69760125	1,95260845	-0,78198845
				RM	0,500533	0,84354483	2,153880867	-,152814867
	psi(VG),p(.)	1,68	Detection	int	1,93368	0,54688752	3,005579539	0,861780461
			Occupancy	int	0,563617	0,68383419	1,903932012	-,776698012
				VG	-0,369174	0,6906186	0,984438456	-,722786456
	psi(EXP),p(.)	1,78	Detection	int	1,933673	0,5468946	3,005586416	0,861759584
			Occupancy	int	0,55862	0,6799455	1,89131318	-0,77407318
				EXP	0,311196	0,69238329	1,668267248	-,045875248
	psi(.),p(S)	1,84	Detection	int	1,918785	0,54828582	2,993425207	0,844144793
				S	0,268222	0,80400303	1,844067939	-,307623939
			Occupancy	int	0,546701	0,67066362	1,861201695	-,767799695
	psi(COL),p(.)	1,91	Detection	int	1,918785	0,54828582	2,993425207	0,844144793
			Occupancy	int	0,550805	0,67405848	1,871959621	-,770349621
				COL	-0,189751	0,67741086	1,137974286	-,517476286
	psi(BP),p(.)	1,96	Detection	int	1,918785	0,54828582	2,993425207	0,844144793
			Occupancy	int	0,549103	0,67242831	1,867062488	-,768856488
				BP	0,131965	0,7076991	1,519055236	-,255125236
LBTE/2009	psi(.),p(.)	0	Detection	int	1,006454	0,43537012	1,859779435	0,153128565
			Occupancy	int	-0,403172	0,55208144	0,678907622	-,485251622
	psi(.),p(S)	0,73	Detection	int	0,906249	0,44945972	1,787190051	0,025307949
				S	0,627938	0,77976464	2,156276694	-,900400694
			Occupancy	int	-0,397669	0,55348892	0,687169283	-,482507283
	psi(S),p(.)	0,82	Detection	int	1,005927	0,43572236	1,859942826	0,151911174
			Occupancy	int	-0,376148	0,58660836	0,773604386	-,525900386
				S	0,73871	0,87196716	2,447765634	-,970345634
	psi(BP),p(.)	0,83	Detection	int	1,006288	0,43547816	1,859825194	0,152750806
			Occupancy	int	-0,485203	0,60502844	0,700652742	-,671058742
				BP	-0,739115	0,81299508	0,854355357	-,332585357
	psi(EXP),p(.)	1,37	Detection	int	1,006513	0,43533164	1,859763014	0,153262986
			Occupancy	int	-0,424339	0,56762884	0,688213526	-,536891526
				EXP	0,457435	0,59495112	1,623539195	-,708669195
	psi(COL),p(.)	1,64	Detection	int	1,006513	0,43533164	1,859763014	0,153262986
			Occupancy	int	-0,41676	0,56158304	0,683942758	-,517462758
				COL	-0,348275	0,59248544	0,812996462	-,509546462
	psi(RM),p(.)	1,69	Detection	int	1,006513	0,43533164	1,859763014	0,153262986
			Occupancy	int	-0,409181	0,5587148	0,685900008	-,504262008
				RM	0,312415	0,57060216	1,430795234	-,805965234
	psi(VG),p(.)	1,79	Detection	int	1,006513	0,43533164	1,859763014	0,153262986
			Occupancy	int	-0,409974	0,55727772	0,682290331	-,502238331
				VG	-0,262941	0,57277776	0,85970341	-1,38558541
	psi(IS),p(.)	1,87	Detection	int	1,006513	0,43533164	1,859763014	0,153262986
			Occupancy	int	-0,408264	0,55556092	0,680635403	-,497163403
				IS	-0,210424	0,59693876	0,95957597	-1,38042397

APPENDIX III. Untransformed parameter estimates (betas) for detection probability and occupancy models with ΔAIC <2 for Black Skimmer-BLSK in 2009 breeding season in Anavilhanas Archipelago. Abbreviations: S: Beach area, RM: Distance to river margin, EXP: Beach Exposure, VG: Island vegetation cover, BP: Beach proximity index, IS: Island proximity index, COL: Distance to main colonies and int: intersection.

Species /Year	Model	Delta AIC	Parameter		Estimate	SE	Upper 95% CI	Lower 95%CI
BLSK/2009	psi(VG+EXP),p(.)		Detection	int	2,80335	0,2912936	3,374285456	2,232414544
			Occupancy	int	0,108734	0,5010896	1,090869616	-0,873401616
				VG*	-1,818349	0,486584	-0,86464436	-2,77205364
				EXP*	1,433011	0,3686956	2,155654376	0,710367624
	psi(VG+EXP+BP),p(.)	1,3	Detection	int	2,80335	0,2912936	3,374285456	2,232414544
			Occupancy	int	-2,506846	0,4578484	-,609463136	-3,404228864
				BP	-0,466402	0,2408244	0,005613824	-0,938417824
				VG*	-1,617297	0,4556088	-,724303752	-2,510290248
				EXP*	1,365227	0,3788388	2,107751048	0,622702952
	psi(VG+EXP+S),p(.)	1,39	Detection	int	2,80335	0,2912936	3,374285456	2,232414544
			Occupancy	int	-2,636431	0,4824192	-,690889368	-3,581972632
				S	0,355984	0,19444	0,7370864	-0,0251184
				VG*	-1,54578	0,4826588	-,599768752	-2,491791248
				EXP*	1,388272	0,3697572	2,112996112	0,663547888
	psi(VG+EXP+RM),p(.)	1,75	Detection	int	2,80335	0,2912936	3,374285456	2,232414544
			Occupancy	int	-2,511742	0,4874336	-,556372144	-3,467111856
				RM	0,495218	0,3823052	1,244536192	-0,254100192
				VG*	-1,742844	0,45537	-0,8503188	-2,6353692
				EXP*	1,235884	0,3858644	1,992178224	0,479589776
	psi(VG+EXP+COL),p(.)	1,94	Detection	int	2,80335	0,2912936	3,374285456	2,232414544
			Occupancy	int	-2,753844	0,5051632	-,763724128	-3,743963872
				VG*	-1,778706	0,4937236	-,811007744	-2,746404256
				EXP*	1,460713	0,3757648	2,197212008	0,724213992
				COL	0,131356	0,2231372	0,568704912	-0,305992912
	psi(VG+EXP+IS),p(.)	1,97	Detection	int	2,80335	0,2912936	3,374285456	2,232414544
			Occupancy	int	-2,721731	0,5030684	-,735716936	-3,707745064
				VG*	-1,781959	0,4954272	-,810921688	-2,752996312
				EXP*	1,421481	0,36759	2,1419574	0,7010046
				IS	-0,087029	0,211178	0,32687988	-0,50093788

Captions to all figures

Figure 1. Study Site: Anavilhanas Archipelago. Sites surveyed indicated by a letter and number.

Figure 2. Relationship between Yellow-billed Tern, Large-billed Tern Site Occupancy probabilities (Psi) and site covariables: a) Beach area, b) Distance to river margin, c) Beach Exposure, d) Island vegetation cover, e) Beach proximity index, f) Island proximity index, g, h and i) Distance to main colonies.

Figure 3. Number of adults of Yellow-billed Tern (YBTE), Large-billed Tern (LBTE) and Black Skimmer (BLSK) counted per site in 2008 (black bars) and 2009 (gray bars) breeding seasons at Anavilhanas Archipelago.

FIGURES

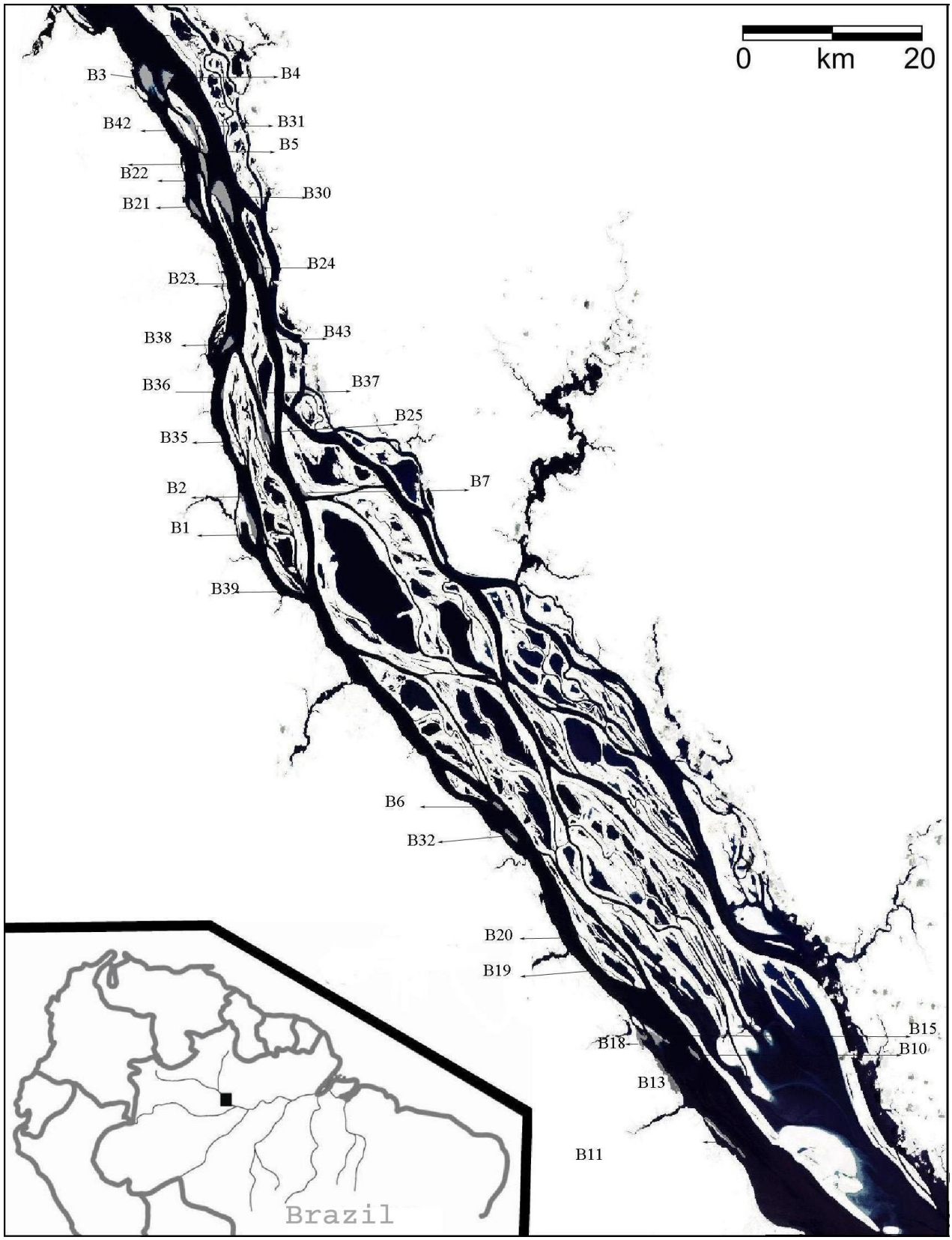
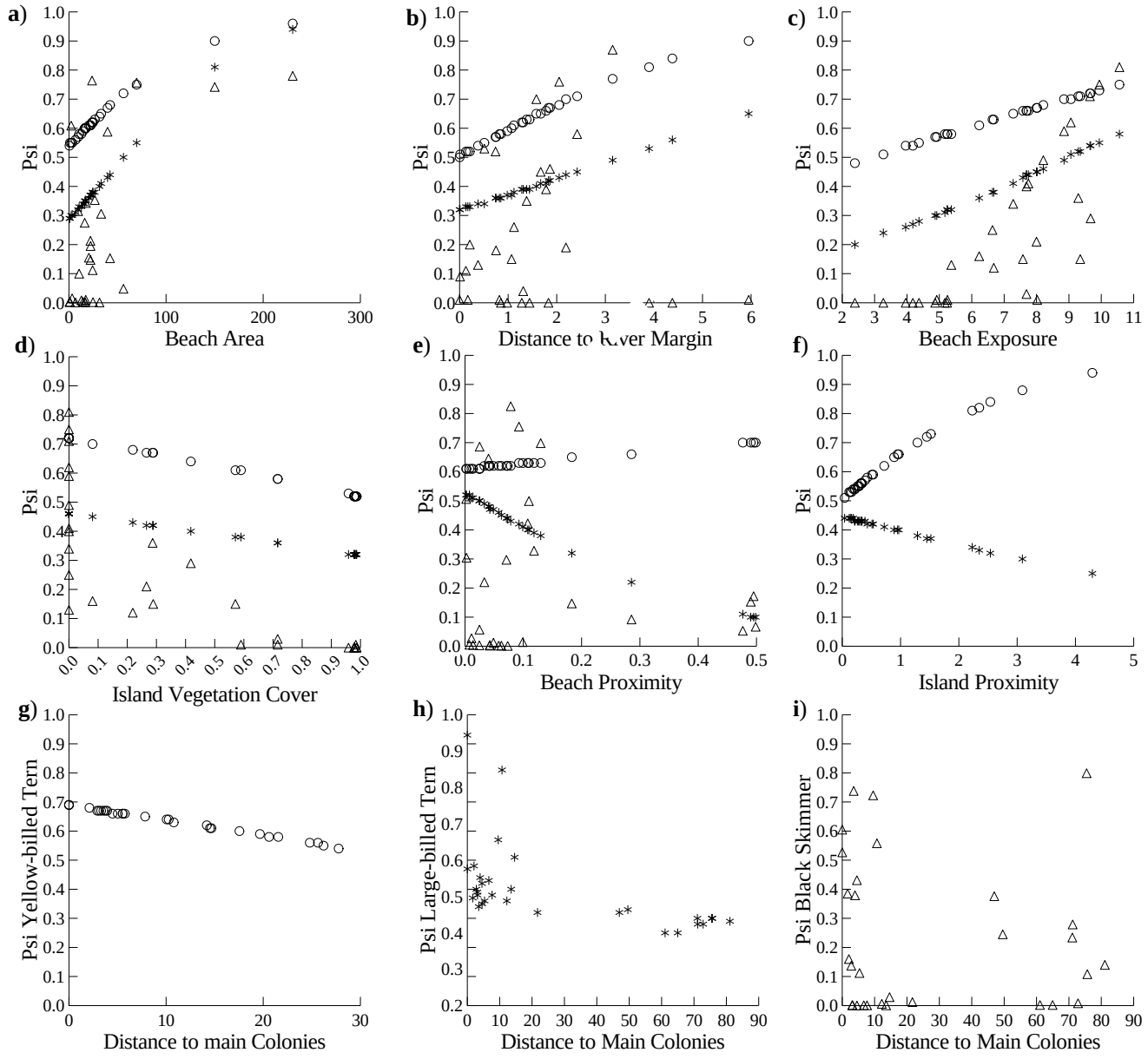


Figure 1



Legend: ○ Yellow-billed Tern, ∗ Large-billed Tern, △ Black Skimmer

Figure 2

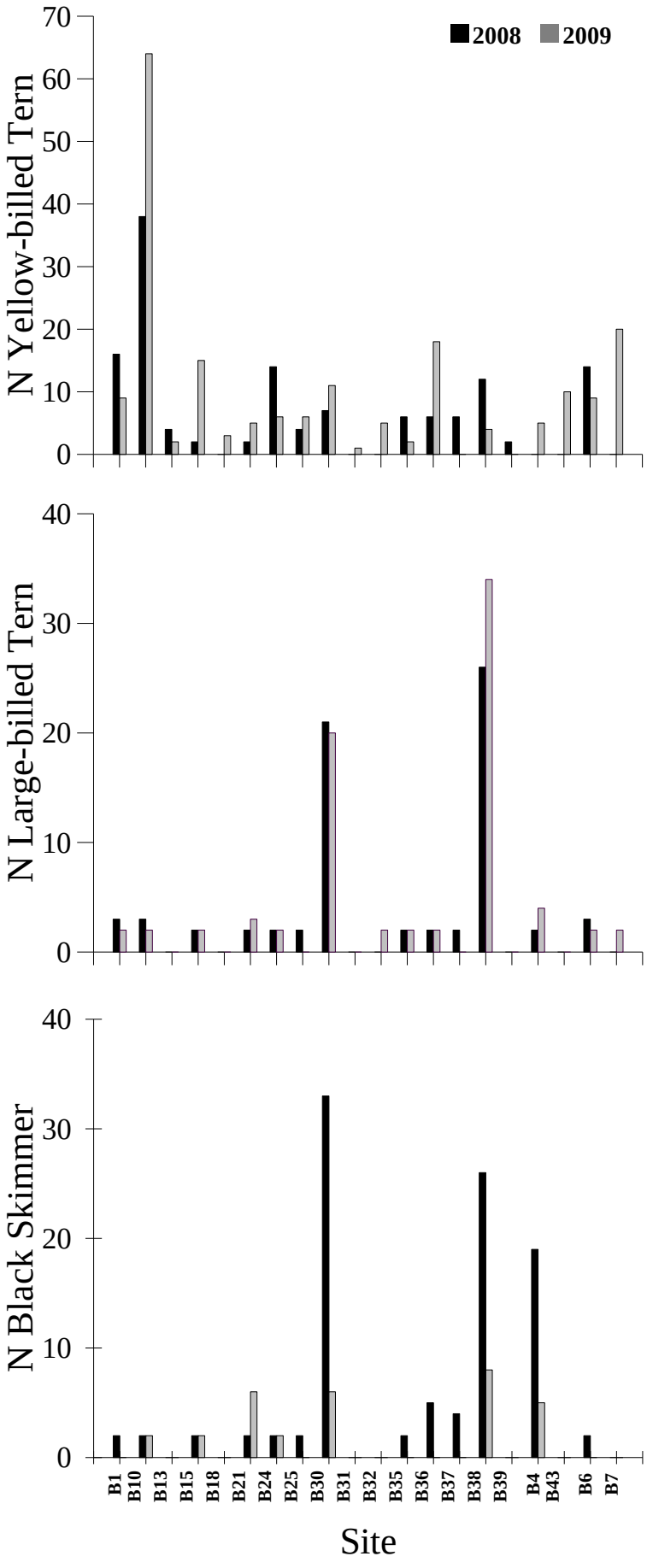

2008
2009
N Yellow-billed Tern
N Large-billed Tern
N Black Skimmer
0
10
20
30
40
50
60
70
B1
B10
B13
B15
B18
B21
B24
B25
B30
B31
B32
B35
B36
B37
B38
B39
B4
B43
B6
B7
Site

Figure 3

CONCLUSOES

Os resultados do presente estudo sugerem que o uso de locais para reprodução por trinta-réis e corta-águas teve influência das características do habitat e da atração social entre essas aves. Assim previsões sobre ocupação e distribuição dessas espécies não seriam acuradas quando incluindo unicamente as características de locais avaliadas nesse estudo. Com base nos resultados de diferença na probabilidade de detecção entre observadores, sugerimos o uso do método de dois observadores para pontos de contagem para estimativas mais acuradas de abundância, avaliações de mudanças no tamanho de populações e medidas de conservação para aves aquáticas.

Embasados em dados do presente estudo é sugerido que sejam mantidos monitoramentos das colônias ao longo prazo no arquipélago para avaliar a fidelidade aos locais de reprodução assim como para continuar incrementando o conhecimento sobre os trinta-réis-anão, as gaivotas e os corta-água.

Uma abordagem sobre outros fatores bióticos como a relação dessas espécies com predadores poderiam incrementar a compreensão dos padrões de uso de habitat dos trinta-réis-anão, das gaivotas e dos corta-água no arquipélago.

Como os ovos dos trinta-réis-anão, das gaivotas e dos corta-água são coletados no arquipélago e as praias utilizadas por turistas é sugerida a consideração das colônias identificadas como principais neste estudo, no plano de manejo do Parque Nacional Anavilhanas.

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APENDICE A. Cópias escaneadas da ficha de avaliação assinada de cada membro da banca do trabalho de conclusão escrito.

Instituto Nacional de Pesquisas da Amazônia - INPA
Programa de Pós-graduação em Ecologia

Avaliação de dissertação de mestrado

Título: **Distribuição, Influência de Características de Locais para Reprodução na Ocupação e Estimativas de Abundância de trinta-réis-anãos (*Sternula superciliaris*), gaivotas (*Phaetusa simplex*) e corta-águas (*Rynchops niger*) no Arquipélago de Anavilhanas, Amazonas, Brasil**

Aluno(a): **REBECCA MARÍA ZARZA AGUILERA**

Orientador(a): **Renato Cintra** Co-orientador(a): **Marina Anciães**

Avaliador: **Maria Alice dos Santos Alves**

Por favor, marque a alternativa que considerar mais apropriada para cada ítem abaixo, e marque seu parecer final no quadro abaixo

	Muito bom	Bom	Necessita revisão	Reprovado
Relevância do estudo	(x)	( )	( )	( )
Revisão bibliográfica	( )	(x)	( )	( )
Desenho amostral/experimental	(x)	( )	( )	( )
Metodologia	( )	(x)	( )	( )
Resultados	(x)	( )	( )	( )
Discussão e conclusões	(x)	( )	( )	( )
Formatação e estilo texto	(x)	( )	( )	( )
Potencial para publicação em periódico(s) indexado(s)	(x)	( )	( )	( )

PARECER FINAL

( ) **Aprovada**

(x) **Aprovada com correções** (indica que as modificações mesmo extensas podem ser incluídas a juízo do orientador)

( ) **Necessita revisão** (indica que há necessidade de uma reformulação do trabalho e que o revisor quer avaliar a nova versão do trabalho antes de emitir uma decisão final)

( ) **Reprovada** (indica que o trabalho não tem o nível de qualidade adequado para uma tese)

OBS. da avaliadora: o trabalho é relevante para a área do conhecimento e cumpre com as exigências para um mestrado. Meus comentários, correções e sugestões encontram-se diretamente no texto digital da dissertação, encaminhado juntamente com este arquivo por mensagem eletrônica.

Rio de Janeiro (Local), **26 de junho de 2010** (Data), Maria Alice S. Alves (Assinatura)

Comentários e sugestões podem ser enviados como uma continuação desta ficha, como arquivo separado ou como anotações no texto impresso ou digital da tese. Por favor, envie a ficha assinada, bem como a cópia anotada da tese e/ou arquivo de comentários por e-mail para pgecologia@gmail.com e claudiakeller23@gmail.com ou por correio ao endereço abaixo. O envio por e-mail é preferível ao envio por correio. Uma cópia digital de sua assinatura será válida.

Endereço para envio de correspondência:

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Brazil

Instituto Nacional de Pesquisas da Amazônia - INPA
Graduate Program in Ecology

Referee evaluation sheet for MSc thesis

Title: **Distribution, abundance estimates and influence of site features on occupancy of yellow-billed terns (*Sternula superciliaris*), large-billed terns (*Phaetusa simplex*) and black skimmers (*Rynchops niger*) breeding in the Anavilhanas Archipelago**

Candidate: **REBECCA MARÍA ZARZA AGUILERA**

Supervisor: **Renato Cintra** Co-supervisor: **Marina Anciães**

Examiner: **Andy J. Green, Estación Biológica de Doñana**

Please check one alternative for each of the following evaluation items, and check one alternative in the box below as your final evaluation decision.

	Excellent	Satisfactory	Needs improvement	Not acceptable
Relevance of the study	( )	(x)	( )	( )
Literature review	( )	(x)	( )	( )
Sampling design	(x)	( )	( )	( )
Methods/procedures	(x)	( )	( )	( )
Results	( )	( )	(x)	( )
Discussion/conclusions	( )	( )	(x)	( )
Writing style and composition	( )	( )	(x)	( )
Potential for publication in peer reviewed journal(s)	(x)	( )	( )	( )

FINAL EVALUATION

( ) Approved without changes

(x) Approved with changes (no need for re-evaluation by this reviewer)

( ) Potentially acceptable, conditional upon review of a corrected version (The candidate must submit a new version of the thesis, taking into account the corrections asked for by the reviewer. This new version will be sent to the reviewer for a new evaluation only as acceptable or not acceptable)

( ) Not acceptable (This product is incompatible with the minimum requirements for this academic level)

Sevilla, Spain **23 June 2010**

Place **Date** **Signature**

Additional comments and suggestions can be sent as an appendix to this sheet, as a separate file, and/or as comments added to the text of the thesis. Please, send the signed evaluation sheet, as well as the annotated thesis and/or separate comments by e-mail to pgecologia@gmail.com and claudiakeller23@gmail.com or by mail to the address below. E-mail is preferred. A scanned copy of

your signature is acceptable.

Mailing address:

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APENDICE B. Cópia escaneada da Ata da Aula de Qualificação

PG·ECO·INPA
PÓS-GRADUAÇÃO EM ECOLOGIA

INPA
INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA

Ministério da Ciência e Tecnologia
BRASIL UM PAÍS DE TODOS
GOVERNO FEDERAL

AULA DE QUALIFICAÇÃO

PARECER

Aluno(a): REBECCA MARIA ZARZA AGUILERA
Curso: ECOLOGIA
Nível: MESTRADO
Orientador(a): RENATO CINTRA
Co-Orientador(a): MARINA ANCIÃES

Título:

"Influência de características de habitas associados à reprodução na ocupação e abundância da gaivota (Phaetusa simplex), do trinta-réis-anão (Sternula superciliaris) e do corta-água (Rynchops niger) no Parque Nacional de Anavilhanas".

BANCA JULGADORA:

TITULARES:
Mario Cohn-Haft (INPA)
Albertina Lima (INPA)
Paulo Bobrowiec (INPA)

SUPLENTES:
Claudia Keller (INPA)
Jóse Luís C. Camargo (PDBFF)

EXAMINADORES	PARECER	ASSINATURA
Mario Cohn-Haft (INPA)	(X) Aprovado ( ) Reprovado	
Albertina Lima (INPA)	(X) Aprovado ( ) Reprovado	
Paulo Bobrowiec (INPA)	(X) Aprovado ( ) Reprovado	
Claudia Keller (INPA)	( ) Aprovado ( ) Reprovado	
José Luís C. Camargo (PDBFF)	( ) Aprovado ( ) Reprovado	

Manaus(AM), 23 de abril de 2009

BS: A banca sugere aprofundar mais nos conceitos relevantes para seu estudo e explicitar as hipóteses a serem testadas.

PROGRAMA DE PÓS-GRADUAÇÃO EM BIOLOGIA TROPICAL E RECURSOS NATURAIS – PIPG BTRN
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA PPG-ECO/INPA
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APENDICE C. Cópia escaneada da Ata da Defesa Pública da Dissertação

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ATA DA DEFESA PÚBLICA DA DISSERTAÇÃO DE MESTRADO DO PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA DO INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA.

Aos 10 dias do mês de setembro do ano de 2010, às 9:00 horas, no auditório do Programa de Pós-Graduação em Biologia de Água Doce e Pesca Interior BADPI/INPA, reuniu-se a Comissão Examinadora de Defesa Pública, composta pelos seguintes membros: Prof(a). Dr(a). **Marcelo Menin**, da Universidade Federal do Amazonas, , Prof(a). Dr(a). **Luiza Magalli Pinto Henriques**, do Instituto Nacional de Pesquisas da Amazônia, Prof(a). Dr(a). **Gonçalo Ferraz,** do Instituto Nacional de Pesquisas da Amazônia, tendo como suplentes o(a) Prof(a). Dr(a). Luciano Nicolas Naka, da Louisiana State University, e o(a) Prof(a). Dr(a). Camila Cherem Ribas, do Instituto Nacional de Pesquisas da Amazônia, sob a presidência do(a) primeiro(a), a fim de proceder a argüição pública da **DISSERTAÇÃO DE MESTRADO** de **REBECCA MARÍA ZARZA AGUILERA**, intitulada "Distribuição, influência de características de locais para reprodução na ocupação e estimativas de abundância de trinta-réis-anões (*Sternula superciliaris*), gaivotas (*Phaetusa simplex*) e corta-águas (*Rynchops niger*) no Arquipélago de Anavilhanas, Amazonas, Brasil", orientado(a) pelo(a) Prof(a). Dr(a). Renato Cintra, do Instituto Nacional de Pesquisas da Amazônia e co-orientado(a) pelo(a) Prof(a). Dr(a). Marina Anciães, do Instituto Nacional de Pesquisas da Amazônia.

Após a exposição, o(a) discente foi argüido(a) oralmente pelos membros da Comissão Examinadora, tendo recebido o conceito final:

[X] APROVADO(A) [ ] REPROVADO(A)

[X] POR UNANIMIDADE [ ] POR MAIORIA

Nada mais havendo, foi lavrada a presente ata, que, após lida e aprovada, foi assinada pelos membros da Comissão Examinadora.

Prof(a).Dr(a). Marcelo Menin

Prof(a).Dr(a). Luiza Magalli Pinto Henriques

Prof(a).Dr(a). Gonçalo Ferraz

Coordenação PPG-ECO/INPA