Universidade Federal do Pará
Núcleo de Ciências Agrárias e Desenvolvimento Rural
Empresa Brasileira de Pesquisa Agropecuária - Amazônia Oriental
Universidade Federal Rural da Amazônia
Programa de Pós-Graduação em Ciência Animal

Stefânia Araújo Miranda

Incubação de ovos e criação de filhotes de guará (*Eudocimus ruber*) no Parque Mangal das Garças: uma ferramenta para a conservação da espécie

Belém
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Tese apresentada para obtenção do grau de Doutor em Ciência Animal. Programa de Pós-Graduação em Ciência Animal. Núcleo de Ciências Agrárias e Desenvolvimento Rural. Universidade Federal do Pará. Empresa Brasileira de Pesquisa Agropecuária – Amazônia Oriental. Universidade Federal Rural da Amazônia.
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“A convivência entre o homem e a natureza é possível, mas depende de respeito para com as outras formas de vida e nossa disposição em permitir sua existência”

Olmos e Silva, 2003

RESUMO

A população de guará é considerada extinta em diversas regiões. A reprodução em cativeiro pode ser uma ferramenta importante para a conservação. Os objetivos foram desenvolver um protocolo alimentar e ambientação para a criação de filhotes de guará, intensificar a reprodução e aumentar o número de indivíduos em cativeiro, descrever as fases de desenvolvimento dos filhotes e desenvolver equações para estimar o crescimento. Os filhotes receberam três tipos de dietas: Dieta R (ração comercial), C (ração comercial e camarão) e P (ração comercial e peixe). A condição corporal e o peso dos filhotes foram obtidos diariamente e as medidas corporais a cada sete dias. A taxa de mortalidade na Dieta R foi 100% e nas Dietas C e P foram 0%. As médias dos pesos corporais e comprimentos dos ossos foram maiores com a Dieta P e as médias do comprimento da despigmentação do bico não foram diferentes com as Dietas C e P (P<0,05). A Dieta P apresentou maiores teores nutricionais. No Ano I a criação foi 100% artificial e no Ano II a criação em uma área do parque foi natural. Na criação artificial, o desenvolvimento dos membros e a condição corporal dos filhotes foram avaliados diariamente, e a pesagem a cada sete dias. A taxa de mortalidade foi menor e o número de nascimentos e a taxa de sobrevivência foram maiores durante a criação artificial. Todos os filhotes apresentaram ganho de peso (P<0,05), condição corporal boa e não foram observadas distrofias. As fases de desenvolvimento dos filhotes e o peso foram monitorados diariamente, e as mensurções da despigmentação do bico e ossos foram realizadas a cada sete dias. Os olhos abriram no dia 4,73 ± 0,12, no dia 6,31 ± 0,18 os filhotes se moveram dentro do ninho e no dia 15,3 ± 0,68 sairam do ninho. As médias do peso e das medidas dos ossos aumentaram (P<0,05). As médias da despigmentação do bico diminuiram (P<0,05). No 7º dia o bico começou a pigmentar e no dia 35º ficou completamente pigmentado. A correlação entre todos os parâmetros e os coeficientes de determinação das equações de regressão foram altos. A Dieta P foi considerada a melhor para a criação artificial. O protocolo proporcionou ambientação e alimentação adequadas, intensificou a reprodução e aumentou o número de guarás. Foi possível estabelecer as equações de estimativa de crescimento e descrever as fases de desenvolvimento dos filhotes. A pigmentação do bico foi considerada um parâmetro eficiente para estimar a idade.

Palavras-chave: Alimentação artificial. Ambientação artificial. Ave silvestre. Biometria corporal. Equação de crescimento. Peso corporal.

ABSTRACT

The population of scarlet ibis is considered to be extinct in several regions. Captive breeding techniques are complementary tools for species conservation. The objectives were to develop a feeding protocol and an ambient environment for the rearing of scarlet ibis chicks, to intensify reproduction in captivity and increase the number of ibises in the colony, describe the developmental stages of chicks and develop growth estimation equations. The chicks were fed with three diets: Diet C (commercial feed), S (commercial ration and shrimp) and F (commercial ration and fish). The body condition and weight were taken daily, and the body measurements every seven days. The mortality rate under Diet C was 100%, and 0% under Diets S and F. The mean body weight and bones lengths were higher with Diet F and the mean length of the unpigmented portion of the beak did not differ among the diets ($P<0.05$). Diet F had higher nutritional contents. Rearing was artificial during year I and natural during year II at one of the areas of the park. The limbs development and body condition were evaluated daily, and the weight every seven days during artificial rearing. The mortality rate was lower and the number of births and survival rate were higher during artificial rearing. All of the young exhibited weight gain ($P<0.05$), good body condition and no dystrophies were observed. The development stages of chicks and the weight were monitored daily, and the measurements of the beak and bones were taken every seven days. The eyes opened on day 4.73±0.12, the nestlings moved within the nest on day 6.31±0.18 and left the nest on day 15.3±0.68. The means weight and measurements of the bones increased ($P<0.05$). The means of beak despigmentation decreased ($P<0.05$). The beak pigmentation started on day 7º and on day 35º was completely pigmented. The correlation between all parameters and the determination coefficients of regression equations were high. Diet F was found to be best for the artificial rearing. The artificial rearing protocol provided an adequate environment and feeding, intensified the reproduction and increased the number of scarlet ibises. Growth estimation equations were developed to assess the chicks growth and was possible to describe the developmental stages. Beak pigmentation was found to be a useful parameter for estimating the age.

Keywords: Artificial environment. Artificial feeding. Body biometry. Body weight. Growth equation. Wild bird.

SUMÁRIO

1. INTRODUÇÃO

Eudocimus ruber é uma ave da ordem dos Pelecaniformes, da família Threskiornithidae (BIRDLIFE INTERNATIONAL, 2012). Conhecido popularmente no Brasil como guará, esse animal em outros lugares recebe nomes como scarlet ibis, guará-vermelho, guará-rubro, guará-piranga e corocoro rubro (RODRIGUES, 2006). O guará pode ser encontrado na Colômbia, Venezuela, Guiana, Guiana Francesa, Suriname, Brasil, Argentina, Trinidade e Tobago (BIRDLIFE INTERNATIONAL, 2012). A espécie ocorre principalmente na faixa costeira dos países, com exceção da Venezuela, onde é encontrada no interior do país (OLMOS; SILVA, 2003).

A população de guará é decrescente, apesar do estado de conservação ser considerado pouco preocupante (BIRDLIFE INTERNATIONAL, 2012). O guará é considerado extinto em diversas regiões onde antes era avistado (SICK, 1997; EBIRD, 2015), em perigo no Estado de São Paulo (SEMA, 2009) e criticamente ameaçado no Paraná (IAP, 2009) e Santa Catarina (CONSEMA, 2011). Os fatores que afetam o tamanho das populações de guarás, agora limitado em alguns lugares, são a perda de habitat, a destruição das áreas de nidificação e de alimentação, a caça excessiva, o comércio ilegal, colheita dos ovos e venda das penas para adorno (IPA, 2009). As técnicas de reprodução *ex situ* são ferramentas complementares para a conservação da espécie, pois os manejos de colônias em habitats fragmentados e das mantidas em cativeiro podem representar um grande grupo a ser preservado, reduzindo perdas para a espécie (FONTENELLE, 2007).

Os guarás são vistos em vários zoológicos do Brasil e em outros países. No entanto, ainda não existe um manejo reprodutivo eficiente dessa espécie em cativeiro e, nas poucas vezes que os animais reproduziram em zoológicos, os filhotes dependeram exclusivamente dos cuidados dos pais. Na natureza, podem ocorrer perdas dos filhotes causadas pela predação por outros animais, queda do ninho e abandono dos pais (OLMOS; SILVA, 2001). No Parque Mangal das Garças é frequente a queda de filhotes de aves dos ninhos feitos pelos pais, sendo o animal resgatado e criado artificialmente. Além disso, é constante o recebimento de filhotes, oriundos de apreensão pelos órgãos ambientais, em situação de risco e sem conhecimento da idade.

Olmos e Silva (2003) descreveram, *in situ*, algumas características fenotípicas e comportamentais dos adultos e filhotes de guarás, bem como a reprodução dos adultos. Além disso, constataram, através de exames de conteúdos estomacais, que os guarás em vida livre alimentam-se essencialmente de peixes, camarões, pequenos caranguejos e de insetos. Hass et al. (1999) citam ainda a ingestão de aranhas, gastrópodes e matéria vegetal.

Contudo, não existe na literatura um protocolo para criação artificial e muito pouco foi descrito sobre a biologia do desenvolvimento do filhote de guará. Procedimentos realizados para obtenção de parâmetros corporais em intervalos regulares, como biometrias e pesagens, não foram descritos, o que representa uma limitação para a estimativa da idade e avaliação do desenvolvimento dos filhotes em condições artificiais. Além disso, ainda não existe uma dieta específica para os filhotes dessa espécie, o que também dificulta a criação sob cuidados humanos.

Com o presente trabalho será possível comparar o desempenho dos filhotes de guarás alimentados com diferentes dietas, bem como desenvolver um protocolo para criação dos filhotes, com ambientação e alimentação artificiais, para intensificar a reprodução e aumentar o número de indivíduos no Parque Mangal das Garças. Somando a isso, será possível descrever o comportamento e as características físicas dos filhotes em condições artificiais, obter parâmetros para estimar a idade e avaliar o crescimento dos filhotes por meio da condição corporal, pesagens e biometrias do rádio, da tíbia, do tarso e da porção despigmentada do bico.

2. OBJETIVOS

2.1. GERAL

Avaliar o desempenho dos filhotes de guarás alimentados com diferentes dietas e desenvolver um protocolo para criação de filhotes de guará no Parque Mangal das Garças, intensificando a reprodução em cativeiro e aumentando o número de indivíduos do plantel, bem como obter parâmetros para estimar a idade e avaliar o crescimento dos filhotes.

2.2. ESPECÍFICOS

- Descrever a composição bromatológica de três diferentes dietas fornecidas para filhotes de guará;
- Comparar o desempenho dos filhotes recebendo diferentes alimentos, por meio de pesagens e biometrias do rádio, da tíbia, do tarso e da porção despigmentada do bico;
- Desenvolver, em condições artificiais, ambientação e alimentação para criação de filhotes de guarás, avaliando o protocolo por meio de observações clínicas diárias e pesagens dos filhotes;
- Descrever, em condições artificiais, o peso, os comprimentos do rádio, da tíbia, do tarso e da porção despigmentada do bico, bem como a coloração das penas, a idade de abertura dos olhos, a capacidade de locomoção e a saída do ninho;
- Relacionar a idade do filhote de guará com o peso e as medidas corporais, bem como estabelecer equações para estimar a idade e avaliar o crescimento.

3. REVISÃO DE LITERATURA

3.1. CLASSIFICAÇÃO DA ESPÉCIE

A espécie foi descrita primeiramente por Linneus (1758), inicialmente nomeada de *Scopolax rubra,* sendo mais tarde designada como *Eudocimus ruber* (RAMO; BUSTO, 1987). *Eudocimus ruber* é uma ave da ordem dos Pelecaniformes, família Threskiornithidae (BIRDLIFE INTERNATIONAL, 2012).

Conhecido popularmente no Brasil como guará, esse animal em outros lugares recebe nomes como scarlet íbis, guará-vermelho, guará-rubro, guará-piranga e corocoro rubro (RODRIGUES, 2006).

3.2. CARACTERÍSTICAS GERAIS DA ESPÉCIE

Os guarás são aves pernaltas com pescoço longo, destacando-se por sua bela plumagem vermelha (SICK, 1997). As únicas partes não vermelhas são as pontas das longas penas de voo e os olhos pretos, e o bico que vai do rosado até o enegrecido dependendo da faixa-etária e sexo (Figura 1). As duas pernas finas apresentam uma coloração rosada com uma camada de grandes escamas. Cada um dos quatro dedos com garras são parcialmente unidos por membranas interdigitais, mas ainda separados em algum grau para que sejam capazes de pousar em árvores (KUSHLAN, 1977).

Figura 1 - Guarás do Parque Mangal das Garças (Arquivo pessoal).

O comprimento do guará, mensurado da ponta da cauda até a ponta do bico varia de: 55 cm a 76,2 cm (HANCOCK; KUSHLAN; KAHL, 1992; KUSHLAN, 1977; MOOLCHAN, 2011; OLMOS; SILVA, 2003; PETERSON; PETERSON, 2002). O macho e a fêmea são semelhantes em aparência física, sendo os machos maiores que as fêmeas, pesando cerca de 750 g a 800 g, enquanto que as fêmeas pesam de 500 g a 640 g. Contudo, não existe na literatura dados de biometria e pesagem em filhotes. Os bicos dos machos são mais longos e menos curvos, medindo entre 15,5 cm e 17 cm, enquanto que o de uma fêmea oscila entre 12 cm e 13 cm (OLMOS; SILVA, 2003). O bico curvado para baixo é fino e longo como uma pinça. Seu longo pescoço auxilia o bico nos movimentos da cabeça durante busca e caça de presas em águas rasas. Além disso, usam o bico para espremer a glândula uropigial e aplicar o óleo em cada pena, espalhando com seu bico (ADAMS; CARROL, 2008).

Os guarás voam em bandos, com o seu pescoço mantido em linha reta juntamente com seu bico para frente, formando um grande “V”, o que reduz a resistência do vento e os tornam capazes de percorrer distâncias mais longas (KUSHLAN, 1977). Vivem cerca de 16 anos em vida livre, podendo chegar a 20 anos em cativeiro (HANCOCK; KUSHLAN; KAHL, 1992; RICKLEFS, 2000; NOVAES, 2009).

Seus hábitos alimentares e comportamentos de nidificação são muito influenciados pela qualidade do habitat, o que, consequentemente, acabou rotulando-os como bioindicadores das condições de habitat (POWELL; POWELL, 1986).

3.3. DISTRIBUIÇÃO GEOGRÁFICA

O guará pode ser encontrado na Colômbia, Venezuela, Guiana, Guiana Francesa, Suriname, Brasil, Argentina, Trinidade e Tobago (BIRDLIFE INTERNATIONAL, 2012; Figura 2). A espécie ocorre principalmente na faixa costeira dos países, com exceção da Venezuela, onde é encontrada no interior do país (OLMOS; SILVA, 2003).

Segundo Antas, Roth e Morrison (1990), até o século XIX, o Brasil abrigava grupos populacionais de guarás espalhados por uma grande extensão do litoral brasileiro, desde o Amapá ao Ceará e do Rio de Janeiro a São Paulo, Paraná e Santa Catarina. A população do sudeste ao sul sofreu um grande declínio, estando esse fato relacionado a alteração de seu habitat pelo homem (SANTOS et al., 2006). Atualmente, as populações de guarás no Brasil estão quase que exclusivamente restritas às regiões litorâneas dos estados do Amapá, Pará e Maranhão, tendo dois grupos em São Paulo, no município de Cubatão e Ilha Comprida

(SANTOS et al., 2006; SEMA, 2009; EBIRD, 2015), um grupo na Baía Paranaguá no Paraná e outro no Parque Natural Municipal da Caieira em Santa Catarina (EBIRD, 2015; Figura 2). Em 2013, foram observados 112 indivíduos da espécie na Baía Paranaguá e 50 indivíduos no Parque Natural Municipal da Caieira em 2015 (EBIRD, 2015).

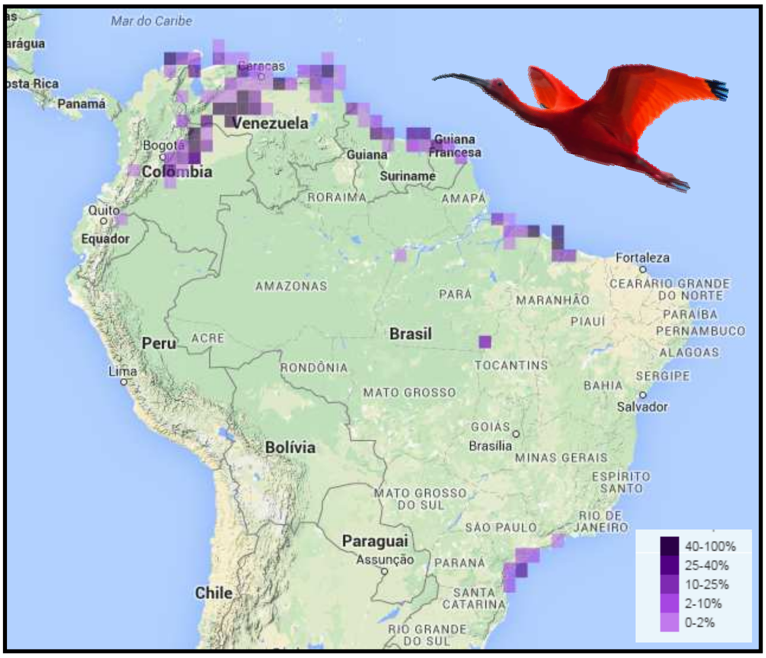

Figura 2 - Distribuição geográfica do guará e frequência de indivíduos nas regiões (adaptado EBIRD, 2015).

Habitam áreas pantanosas, manguezais, lagos e rios de curso lento, vivendo em bandos que procuram vegetação densa para dormir e nidificar, como os mangue (*Rhizophora* sp.), aturizais (*Drepanocarpus* sp.) e siriubais (*Avicennia* sp.) (HANCOCK; KUSHLAN; KAHL, 1992; RICKLEFS, 2000; NOVAES, 2009).

3.4. ESTADO DE CONSERVAÇÃO

O guará é protegido oficialmente pela legislação brasileira como uma espécie ameaçada de extinção (IBAMA, 1989). Além disso, as colônias de nidificação de todas as espécies de aves também são protegidas por lei (BRASIL, 1967).

A espécie é considerada extinta em diversas regiões onde antes era avistada, como por exemplo, do Piauí ao Rio de Janeiro (SICK, 1997; EBIRD, 2015), em perigo no Estado de

São Paulo (SEMA, 2009), criticamente ameaçado no Paraná (IAP, 2009) e em Santa Catarina (CONSEMA, 2011), sendo essas as últimas avaliações da espécie nas regiões citadas.

No entanto, de acordo com a Lista Vermelha de Espécies Ameaçadas da União Internacional para Conservação da Natureza (IUCN), a espécie é listada como pouco preocupante e com a população em declínio (BIRDLIFE INTERNATIONAL, 2012).

3.5. ALIMENTAÇÃO

Constatou-se através de exames de conteúdos estomacais, citados por Sick (1997), que os guarás são carnívoros alimentando-se essencialmente de peixes como o "muré" (*Gobius oceanicus Pallas*), de camarões, de pequenos caranguejos tais como o "chama-maré" (*Uca* sp.) e "aratu" (*Aratus pisonii*), e de insetos (*Dysticidae*). Hass, Matos e Machado (1999) citaram ainda a ingestão de aranhas, gastrópodes e matéria vegetal. Após avaliação de conteúdos estomacais de filhotes encontrados mortos, bem como de regurgitados produzidos por filhotes durante a temporada reprodutiva, Olmos, Silva e Prado (2001) constataram que todas as amostras apresentaram caranguejos, correspondendo a mais de 95,5% das presas consumidas. Entre os caranguejos mais predados estão *Eurythium limosun* (39,52%) e várias espécies de *Uca* sp. (27,6%). Nas amostras foram também identificados camarões (1,5%), gastrópodes (2,6%), peixe (0,1%), mutucas (0,3%) e vermes poliquetos (0,1%).

A ingestão do caranguejo tem uma ligação importante com a cor dos guarás. O vermelho das penas se deve a um pigmento chamado cataxantina, que é um derivado do caroteno (SICK, 1997; OLMOS; SILVA, 2003). O caroteno é o responsável pela cor da cenoura e da casca dos caranguejos e camarões, evidenciada quando são cozidos (OLMOS; SILVA, 2003). Hass (1996), por meio de análises bioquímicas, mostrou que os carotenos nas penas dos guarás são os mesmos daqueles encontrados em algumas presas, como o caranguejo chama-maré. Os guarás têm a capacidade de sequestrar os carotenoides acidogênicos do alimento e manufaturar cataxantina (β-caroteno neutro), através de facilitação bioquímica e/ou por ação da microflora intestinal (HASS; MATOS; MACHADO, 1999). Em cativeiro com a deficiência de carotenoides, os guarás tendem a ficar mais cor-de-rosa do que vermelhos, mas essa coloração pode ser recuperada adicionando-se cataxantinas ou cenoura no alimento que lhes é oferecido (SICK, 1997).

Atualmente já existem no mercado rações comerciais específicas para aves, como os flamingos, que necessitam de uma suplementação de carotenóides quando em cativeiro. A ração comercial proporciona maior facilidade no manejo alimentar em cativeiro, de forma mais higiênica e mantendo sua integridade física e química por mais tempo, quando comparada aos alimentos naturais (MEGAZOO, 2014). No entanto, a ração comercial extrusada[1] possui em sua composição alimentos de origem vegetal que não fazem parte da dieta dos Flamingos *in situ*, conforme descrito por Tobar et al.(2014).

Os guarás procuram comida apenas no início da manhã e logo antes do pôr do sol, ficando geralmente escondidos, descansando ou se limpando durante o calor do dia e a noite. Com o uso de seu bico longo e curvo eles sondam os lodaçais e águas rasas em busca de comida. Não precisam se esconder de sua comida, uma vez que seu bico longo é guiado pelo toque, e só são vistos por suas presas no momento em que elas são subitamente retiradas da água pela ponta do bico e atiradas para o esôfago (MOOLCHAN, 2011). O bico possui muitas enervações mecanorreceptoras, sendo muito sensível ao contato com a presa. Os guarás quase nunca forrageiam fora da água, o que sugere que a disponibilidade de presas no solo pode ser limitada em estação seca (FREDERICK; BILDSTEIN, 1992).

Forrageiam juntamente com outras espécies como cegonhas, colhereiros, garças e patos. Esse relacionamento mútuo entre espécies proporciona aos guarás uma melhor chance de se esconder dos predadores entre essas aves. Além disso, ter um grupo de aves pernaltas perto para perturbar e agitar águas rasas faz com que as presas se tornem mais fáceis de serem capturadas (HANCOCK; KUSHLAN; KAHL, 1992).

3.6. REPRODUÇÃO

3.6.1. Período de reprodução

O período reprodutivo dos guarás ainda é pouco elucidado na literatura, sendo ainda controverso entre os autores. No Brasil, foram encontrados grupos em período de reprodução ativa em maio, na Ilha Buzina, Maranhão (MORRISON; ANTAS; ROSS, 1987), junho e setembro na costa do Amapá (TEIXEIRA; BEST, 1981). No Pará, na ilha dos Pássaros, um ninhal foi encontrado reprodutivamente ativo no mês de agosto (ANTAS; ROTH;

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[1] Ração FL 32 (Megazoo Betim, MG) - Níveis de garantia: 110g/kg de umidade (máx.), 320g/kg de proteína bruta (mín.), 60g/kg de extrato etéreo (mín.), 45g/kg de matéria fibrosa (máx.), 110g/kg de matéria mineral (máx.), 22g/kg de cálcio (máx.), 18g/kg de cálcio (mín.), 3.000mg/kg de sódio (mín.), 9.000mg/kg de fósforo (mín.), 2.200mg/kg de ômega 3 (mín.), 400mg/kg de mananoligossacarídeos (mín.), 440mg/kg de beta-glucanas (mín.), 1.95mg/kg de extrato de cardo-mariano (mín.), 7.000 mg/kg de DL-metionina (mín.), 19g/kg de L-lisina (mín.), 3.000mg/kg de aditivos adsorventes de toxinas (mín.).

MORRISON, 1990; RODRIGUES; FERNANDES, 1994). Sick (1997) corrobora esses autores, afirmando que o período reprodutivo começa no inicio da seca, indo de julho a setembro (na região do Estado do Pará), embora haja relatos de reprodução durante período chuvoso nas Guianas. Olmos e Silva (2001) observaram que as aves, no município de Cubatão, São Paulo, começaram a se congregar em maior número no local da colônia a partir de meados de setembro e em novembro estavam construindo os ninhos e fazendo postura de ovos.

Hass, Matos e Machado (1999), na ilha do Cajual, Maranhão, observaram que os guarás iniciaram a temporada reprodutiva no inicio das chuvas, selecionando os sítios de reprodução em janeiro e estabelecendo colônia em fevereiro. Na região dos Lhanos da Venezuela, a estação reprodutiva dos guarás também coincide com as primeiras chuvas, sendo este fato relacionado com a maior abundancia de alimentos como peixes, crustáceos e insetos (BROUWER; VAN WIERINGEN, 1990).

No entanto, os últimos estudos de reprodução da espécie no Norte, Nordeste e Sudeste do Brasil foram em 1994, 1999 e 2001, respectivamente, e não existem levantamentos mais atuais sobre a reprodução da espécie, sendo uma limitação para avaliação do estado de conservação.

3.6.2. Características e comportamento

Quando estão em época de reprodução, o bico do macho torna-se negro brilhante, e suas pernas continuam vermelho-claras, enquanto que a fêmea apresenta o bico (que é mais fino) pardacento com a ponta enegrecida e suas pernas ficam vermelho-esbranquiçadas. Algumas fêmeas, durante a estação reprodutiva, podem apresentar edema na garganta, descrito por Sick (1997) como um “saquinho” de pele nua, cor-de-rosa, de cada lado da garganta.

Nos ninhais, grandes bandos de guarás vivem juntos, organizados em pares. No comportamento reprodutivo, o macho adota certas condutas para atrair a fêmea. Algumas táticas de exibição comuns são tentadas, como limpar com frequência a plumagem e sacudir, bater o bico, esfregar a cabeça, quebrar galhos e voos altos (HANCOCK; KUSHLAN; KAHL, 1992; OLMOS; SILVA, 2003). Cabe à fêmea a iniciativa de se aproximar de um macho selecionado, adotando uma postura submissa, um pouco agachada (OLMOS; SILVA, 2003). Os machos tornam-se agressivos com outros machos que entrarem no seu local de nidificação, usando seu bico, pernas e asas contra rivais, de modo a defender-se e a defender sua prole e companheira (HANCOCK; KUSHLAN; KAHL, 1992).

3.6.3. Ninho

O casal copula frequentemente enquanto o ninho é construído. A fêmea cuida da construção do ninho, enquanto o macho realiza um vaivém trazendo o material para a mesma (OLMOS; SILVA, 2003). Os ninhos são normalmente construídos em estreita proximidade um do outro, tendo por vezes, mais do que um ninho por árvore. Isso é feito provavelmente para diminuir o risco de predação, por ser mais fácil de enviar sinais de alerta para os outros. Grandes felinos e aves de rapina são seus principais predadores. (HANCOCK; KUSHLAN; KAHL, 1992; MOOCHAN, 2011). Os ninhos são plataformas irregulares, geralmente côncavas, sendo construídos sobre ramificações ou ao longo dos galhos, com ramos finos entrelaçados frouxamente. Os materiais utilizados na base dos ninhos são geralmente gravetos secos, podendo ser substituídos por ramos verdes com folhas, retirados das arvores de mangue ao redor (HASS; MATOS; MACHADO, 1999).

3.6.4. Ovos

A fêmea põe de 1 a 3 ovos, sendo que o primeiro ovo é posto 5 a 6 dias após o coito (HANCOCK; KUSHLAN; KAHL, 1992; SICK, 1997). Em ninhais na ilha do Cajual (Maranhão), Hass, Matos e Machado (1999) observaram que o número de ovos encontrados nos ninhos variou entre um (31,37%), dois (66,67%) e três ovos (1,96%). No entanto, em Cubatão, São Paulo, Olmos e Silva (2001) observaram que, no primeiro ciclo de nidificação, ninhos (99 ninhos) com um ovo corresponderam a 10%, com dois ovos a 35%, com três ovos a 53% e com quatro ovos a 1%. No segundo ciclo de nidificação (100 ninhos) a porcentagem de ninhos com um ovo foi 25%, dois ovos 50%, três ovos 22%, quatro ovos 2% e seis ovos 1%. Segundo Olmos e Silva (2001), essa diferença na postura de três ovos, durante o primeiro e segundo ciclos de nidificação, sugere que alguns casais poderiam estar realizando posturas de reposição após perderem suas ninhadas no primeiro ciclo, pois as aves que realizam múltiplas posturas consecutivas tendem a produzir um número decrescente de ovos. Já os ninhos com posturas maiores que três ovos representam caos, em que uma ou mais fêmeas põem ovos em ninhos alheios.

Os ovos de guará possuem coloração verde-claro (HANCOCK; KUSHLAN; KAHL, 1992; SICK, 2001), creme (HASS, 1996) ou azul-claro (OLMOS; SILVA, 2001) com manchas marrons. O comprimento, largura e peso dos ovos de guarás variam de 54,6 a 57,9 mm, 37,2 a 38 mm e 37,9 a 44 g, respectivamente (HASS, 1996; OLMOS; SILVA, 2001).

3.6.5. Período de incubação

Vários autores descrevem diferentes períodos de incubação: 25,8 ± 2,3 dias (HASS, 1996), aproximadamente 23 dias (BROUWER; VAN WIERINGEN, 1990), entre 21 e 24 dias (SICK, 1997; OLMOS; SILVA, 2001), por volta de três semanas (HEATH et al., 2003) e entre 19 a 23 dias (MOOCHAN, 2011).

3.7. FILHOTES

Os recém-nascidos são cobertos por uma plumagem negra, que muda gradualmente para cinza fosca e seu bico é mais retilíneo, de coloração clara com a ponta enegrecida (HANCOCK; KUSHLAN; KAHL, 1992). Com 29 a 31 dias de vida apresentam o bico escuro (OLMOS; SILVA, 2001). Emplumam totalmente a partir de 35 dias (MOOCHAN, 2011). Os imaturos são pardo-escuros, apresentam a região do baixo-dorso e coberteiras superiores da cauda brancas, e as penas de seu abdômen branco-amareladas (SICK, 1997). A mudança de coloração das penas tem início quando os animais começam a voar. A cor escarlate aparece pela primeira vez levemente em seu dorso e se espalha gradualmente ao longo do pescoço, laterais e asas (FREDERICK; BILDSTEIN, 1992, OLMOS; SILVA, 2003) (Figura 3). Entre 22 e 24 meses de idades ficam totalmente vermelhos (OLMOS; SILVA, 2003).

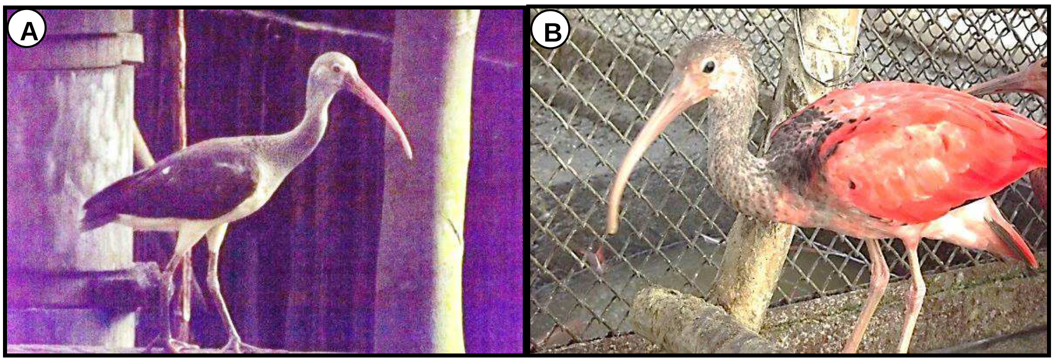

Figura 3 - Mudança na coloração das penas dos guarás. (A) Imaturo, com as penas de coloração pardo-escura. (B) Animal em processo de mudança gradual da coloração das penas (Arquivo pessoal).

Após o nascimento os filhotes são incapazes de fazer tarefas simples, como levantar suas próprias cabeças (HANCOCK; KUSHLAN; KAHL, 1992). Segundo Olmos e Silva (2001), a partir de observações realizadas no município de Cubatão, São Paulo, os filhotes de guarás entre um e três dias de vida são praticamente incapazes de se mover, erguem a cabeça, mas não o corpo. Com cinco a sete dias erguem o corpo, mas a capacidade de locomoção é limitada restringindo-se ao interior do ninho. Entre 11 e 13 dias de vida são capazes de mover-se pelos ramos ao redor do ninho e escalam para ninhos próximos, mas somente com 20 dias tornam-se independentes dos ninhos. A partir de 29 dias fazem voos curtos entre árvores próximas e entre 41 e 43 dias voam bem, perseguindo adultos para pedir comida. Entre 74 e 78 dias, os juvenis forrageiam sozinhos, alcançando a independência alimentar. Moochan (2011) também descreveu que com 75 dias de vida os guarás são independentes.

Tanto o macho quanto a fêmea de guará incubam os ovos, alimentam os filhotes e os protegem contra predadores (HANCOCK; KUSHLAN; KAHL, 1992; SICK, 1997; OLMOS; SILVA, 2001). Os pais demoram apenas o mínimo de tempo no ninho quando trazem comida para as crias, alimentando-as por regurgitação. A alimentação do recém-nascido exige que o adulto segure seu bico, fazendo com que o filhote levante a cabeça, para que o adulto possa regurgitar em seu bico (STANEK, 2009). Os recém-nascidos tendem a emitir um grito estridente para indicar quando estão com fome (HANCOCK; KUSHLAN; KAHL, 1992).

4. CAPÍTULO I

EVALUATION OF SCARLET IBIS (*Eudocimus ruber*) CHICKS BRED WITH DIFFERENT DIETS AT THE MANGAL DAS GARÇAS PARK

EVALUATION OF SCARLET IBIS (*Eudocimus ruber*) CHICKS BRED WITH DIFFERENT DIETS AT THE MANGAL DAS GARÇAS PARK

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ABSTRACT

The objective of this study was to evaluate three different diets fed to scarlet ibis chicks and the effects of these diets on chick performance. Five chicks were fed Diet C (commercial feed); 10 received Diet S (commercial feed and shrimp) and 10 chicks received Diet F (commercial feed and fish). The chicks were weighed, and the lengths of each chick's right radius, tibia, tarsus and the unpigmented portion of the right side of the beak were measured. The mortality rate under Diet C was 100%, and the mortality rate was 0% under Diets S and F. The mean body weight and radius, tibia and tarsus lengths were higher for chicks fed Diet F (P<0.05). The mean length of the unpigmented portion of the beak did not differ among the diets (P<0.05). Diet F had higher crude protein, ether extract and crude energy contents. Beak pigmentation was not influenced by diet. Diet F was therefore found to be best for the artificial rearing of scarlet ibis chicks.

Keywords: Body condition; Chick biometry; Chick feeding; Chick growth; Chick weight; Wild birds.

INTRODUCTION

The currently decreasing population sizes of scarlet ibis (*Eudocimus ruber*) (Birdlife International, 2012; Ebird, 2015) are affected by several factors such as excessive hunting, illegal trade, egg collection, commercialization of feathers for ornaments, habitat loss and the destruction of nesting and feeding areas (Sick, 1997; Ipa, 2009). Therefore, captive breeding techniques are complementary tools used for the conservation of species (Fontenelle, 2007).

Scarlet ibis are seen in various zoos in Brazil and around the world. However, during the few times that these animals reproduce in artificial environments, the chicks depend exclusively on parental care, as a specific diet for scarlet ibis adults and young has not yet been developed. This represents a limitation to scarlet ibis breeding under human care. At present, commercial feeds are available that are specific for certain birds, such as flamingos, which have feeding habits similar to those of the scarlet ibis (Tobar et al., 2014).

In the wild, scarlet ibis feed mainly on fish, shrimp, small crabs and insects (Sick, 1997). Hass et al. (1999) also report incidences of scarlet ibis consuming spiders, snails and plant material. After evaluating the stomach contents of chicks found dead, as well as stomach contents regurgitated by chicks during the reproductive season, Olmos et al. (2001) found that all samples analyzed contained crabs, corresponding to more than 95.4% of the prey identified. Shrimp (1.5%), snails (2.6%), fish (0.1%), horseflies (0.3%) and polychaete worms (0.1%) were also identified in the samples, indicating that the scarlet ibis is a carnivorous bird.

An evaluation of the body condition and development of scarlet ibis chicks fed different types of food will aid in the selection of a diet that promotes the best performance in individuals during early growth, contributing to the success of artificial breeding. In this sense, diets composed of commercial feed developed for flamingos, shrimp or fish may be used for the captive breeding of scarlet ibis chicks under human care.

The objective of this study was to evaluate three different diets fed to scarlet ibis chicks and their effects on chick performance through body condition, weight and biometry of the radius, tibia, tarsus and the unpigmented portion of the beak.

MATERIALS AND METHODS

Study site

This study was conducted at the Mangal das Garças Park, located in the city of Belém, Pará State, Brazil 1°27'48.9"S 48°30'17.8"W (Figure 1). There are 111 scarlet ibis adults inhabiting the park, distributed among three areas: Aningas Aviary (11 males and 8 females), Cavername Lake (34 males and 17 females) and the Extra Sector of the park (41 unsexed individuals). In all areas water is available *ad libitum* and extruded commercial feed[1] is provided from 7:00am to 4:00pm. The Mangal das Garças Park has an Authorization from the Management of Native Wildlife, no. 1501.8612/2014-PA, for rearing *Eudocimus ruber*. All animals receive technical assistance daily from a veterinarian and a biologist.

Figure 1- Mangal das Garças Park.

[1] Feed FL 32 (Megazoo Betim, Minas Gerais, Brazil) – **Guaranteed analysis:** 110 g/kg moisture (max.), 320 g/kg crude protein (min.), 60 g/kg ether extract (min.), 45 g/kg fiber (max.), 110 g/kg mineral content (max.), 22 g/kg calcium (max.), 18 g/kg calcium (min.), 3,000 mg/kg sodium (min.), 9,000 mg/kg phosphorus (min.), 2,200 mg/kg omega 3 (min.), 400 mg/kg mannooligosaccharides (min.), 440 mg/kg beta-glucans (min.), 1.95 mg/kg milk thistle extract (min.), 7,000 mg/kg DL-methionine (min.), 19 g/kg L-lysine (min.), 3,000 mg/kg toxin adsorbent additives (min.). **Ingredients:** ground whole corn, fish meal, poultry offal meal, soybean meal, dry beer yeast, crude soybean oil, limestone, vitamin mineral premix, sodium chloride (table salt), natural annatto dye, prebiotic (mannooligosaccharide), fungistatic additive (propionic acid), DL-methionine, adsorbent additive (esterified glucomannan yeast), antioxidant (BHA).

Egg management

Nests were inspected two times per day (morning and afternoon), and eggs were collected whenever they were encountered. Eggs were manually collected and transported to the nursery in a plastic egg container. Each collected egg was sanitized with gauze and moistened with saline solution. After evaluation, broken, cracked or punctured eggs were discarded. The date and site of collection were recorded with a graphite pencil on each egg.

Eggs were incubated in a digital incubator, with automatic egg turning programmed at two-hour intervals (IP 130 PS, Premium Ecológica Ltda, Belo Horizonte, Minas Gerais, Brazil). The temperature and humidity in the incubator were 37.4 ºC and 60%, respectively. Eggs in the incubator were inspected two times per day (morning and afternoon), and when the hole made by the hatchling hours before hatching was observed, the egg was transferred to a bird treatment unit (UTA, TD, Premium Ecológica Ltda, Belo Horizonte, Minas Gerais, Brazil) and kept under the same temperature and humidity conditions as the incubator until the end of hatching.

Chick selection and management

Twenty-five clinically healthy scarlet ibis chicks were selected. All animals were kept under the same artificial environmental conditions. Chicks were identified by bands made from adhesive bandage tape numbered from one to twenty-five.

After hatching, chicks were kept in artificial nests made of straw baskets and hay. The chicks remained in the bird treatment unit until their second day of life. During the third day, the nest with the chick inside was transferred to a fiberglass brooder (1.18 x 0.59 x 0.50 m) containing clay heaters with 25-watt lamps. The temperature and humidity of the nests were kept at approximately 32 ºC and 58%, respectively. After the chicks had left the nest, they were kept in brooders with hay and a heat source.

From the third day of life until the chicks left the nursery, they were exposed to direct sunlight for one hour before 9:00am and were given a mineral vitamin supplement[2] at a dose of two drops per chick once per day.

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[2] Avitrin Cálcio Plus (Coveli, Duque de Caxias, Rio de Janeiro, Brazil) – guaranteed analysis (kg): 125,000 IU vitamin A (min.), 800,000 IU vitamin D3 (min.), 2,000 mg magnesium (min.), 5,865 mg calcium (min.), 7,168 mg calcium (max.), 2,000 mcg vitamin B12 (min.).

After leaving the nursery, the chicks were transferred to an 18 m^2 enclosure equipped with two clay heaters with 60-watts bulbs, hay bedding, 15 cm diameter wooden perches and a skylight providing ventilation and natural light. The animals were kept in groups of up to 10 chicks (1.8 chicks/m^2).

Feeding management

The twenty-five chicks selected were divided into groups to receive three different diets with a paste-like consistency (puree):

Diet C – Five animals were fed a mixture of 50 g of crushed commercial feed for flamingos (Feed FL32[1]) and 150 ml of water. The mortality rate for chicks fed Diet C was 100%, and the supply of this diet was stopped.

Diet S – Ten animals were fed a mixture of 15 g of crushed commercial fed for flamingos (Feed FL32[1]) mixed with 100 ml of shrimp broth. The shrimp broth was prepared by blending 100 g of whole Amazon River prawn (*Macrobrachium amazonicum*) with 150 ml of water, and then the mixture was filtered through a sieve.

Diet F – Ten animals were fed a mixture of 15 g of crushed commercial feed for flamingos (Feed FL32[1]) mixed with 100 ml of fish broth. The fish broth was prepared by blending 100 g of mullet (*Mugil* spp.) fillet with 300 ml of water, and then the mixture was filtered through a sieve.

The selection of fish and shrimp as diet ingredients was based on Sick (1997) and Olmos et al. (2001). The feed was chosen because it was originally developed for flamingos, which have feeding habits similar to those of the scarlet ibis (Tobar et al., 2014). In addition, scarlet ibis adults from the park have adapted to this diet and responded positively to it, as evaluated by their reproduction and feather coloration. It was necessary to add a large volume of water to Diet F during broth preparation because fish have a lower water content than shrimp.

To evaluate the diets, the crude protein content was determined using the Kjedahl method (Detmann et al., 2012). The ether extract content was determined by an Ankom® XT 10 extractor (Ankom Technology, Macedon, New York, United States) and the crude energy level was determined using an IKA® Calorimeter System C200 (IKA, Guangzhou, Guangdong, China).

The fish and shrimp broths were prepared twice per day (morning and afternoon). The puree was prepared before each meal and heated in a microwave oven to 40 ºC. Chick feeding began 12 hours after hatching, as before this time, the animals consume the yolk reserve.

The puree was orally administered directly into the entrance of esophagus using a no. 10 gastric tube cut to 5 cm in length and attached to a disposable syringe. The animal's head was maintained at a 90° angle during feeding, and this position was maintained for at least 10 seconds after feeding to avoid reflux and choking.

The total number of meals per day, intervals, volume administered at each meal and total daily volume were chosen according to chick age, as described in Table 1. Chicks were stimulated to begin feeding alone after leaving the nest by offering the extruded commercial feed (Feed FL32[1]) in the bird feeder and water *ad libitum*. After each paste feeding, a technician encouraged the chick to eat the food in the feeder. Beginning on day 20, the feeding intervals of paste supply were increased every four days until only the extruded commercial feed (Feed FL32[1]) in a feeder was offered (Table 1). At this stage, the chicks were transferred to the nursery and housed with at least one independently feeding older chick to stimulate them to consume the feed.

Body condition, weight and biometry

To evaluate the effects of the different diets on the chicks, body condition, body weight and the lengths of the radius, tibia, and tarsus and of the unpigmented portion of the beak were monitored. Body condition was evaluated daily by inspecting and palpating the chest muscles and sternum, giving a score from one to three (Harrison and Ritchie, 1994), as follows: 1 – reduced pectoral musculature and sternum prominent, indicating poor body condition; 2 – rounded pectoral musculature with a slight depression on both sides of the sternum, indicating good body condition; 3 – pectoral muscles covering the entire sternum, indicating excess weight.

Table 1 – Feeding protocol developed to provide nutrition to 25 scarlet ibis chicks raised under artificial conditions on their 1st through 39th days of life.

Age (days)	Total feedings/day	Interval (hr)	Volume/feeding (ml)	Volume/day (ml)
1-2	13	1/1	0.5	6.5
3	13	1/1	1	13
4-7	13	1/1	2	26
8-11	13	1/1	3	39
12-15	13	1/1	4	52
16-19	13	1/1	5	65
*20-23	7	2/2	6	42
24-27	5	3/3	7	35
28-31	3	6/6	8	24
32-35	2	12/12	9	18
36-39	1	24/24	10	10

*Reductions in total feedings per day and in volume per day. Increase in feeding intervals and volume per feeding.

The chicks were weighed daily using a digital scale (Actlife Superinox-5, Balmak Indústria e Comércio Ltda, Cidade Industrial Santa Bárbara d'Oeste, São Paulo, Brazil), and measurements were taken every seven days by the same technician. During biometry, the lengths of the right radius, tibia and tarsus and of the unpigmented portion of the right side of the beak were measured using a 150 mm plastic caliper (Marberg Limited, Toronto, Ontario, Canada).

Weight and body measurements are parameters of body development. Measurements of the radius, tibia and tarsus were chosen because these are long bones easily measured in live animals, and because these bones undergo developmental pressure due to flight (Sick, 1997), making them good growth markers. Chicks were assessed beginning on the first day of life, shortly after hatching, and on all subsequent days, always in the morning. All data were recorded in an individual case report form.

Statistical analysis

The mortality and survival rates are presented as percentages. Data are presented as the mean ± standard error. Exponential regression analysis was used to test the relationship between age and bone length. Polynomial regression analysis was used to test the relationship between age and the length of the unpigmented portion of the beak. Student's t test was used to compare weights, bone lengths and the length of the unpigmented portion of the beak among diets. All analyses were performed in Statview 5.0 (SAS Institute Inc., Cary, North Carolina, United States), and results were considered significant when $P<0.05$.

RESULTS AND DISCUSSION

Although Olmos et al. (2001) found that crabs corresponded to more than 95.4% of the prey identified in the stomach contents and regurgitate samples of scarlet ibis chicks, shrimp and fish are cheaper and easier to store and prepare and are available for purchase throughout the entire year. Moreover, fish and shrimp are purchased on a weekly basis to feed other bird species at the park.

The contents of crude protein, ether extract and crude energy of each diet are shown in Table 2. Diet F, prepared with fish, contained the highest percentages of all of these components, and Diet C, prepared only with commercial feed, contained the lowest percentage. Diet S, prepared with shrimp, had nutritional values similar to those of Diet F.

Table 2 – Dry matter, crude protein, ether extract and crude energy contents in the three diets supplied to scarlet ibis chicks from the 1st to the 39th day of life.

	Dry Matter	Crude Protein		Ether Extract		Crude Energy	
	(%)	DM (%)	FM (%)	DM (%)	FM (%)	DM (Kcal/g)	FM (Kcal/g)
Diet C	92.50	33.45	7.70	3.31	0.76	4.119	0.47
Diet S	18.84	42.38	7.98	8.08	1.52	4.614	868.35
Diet F	18.16	44.33	8.05	10.49	1.91	4.713	855.40

Diet C: commercial feed. Diet S: commercial feed and shrimp. Diet F: commercial feed and fish.

DM: dry matter. FM: fresh matter

Chicks who received Diet C died in their first week of life, making it impossible to collect data for statistical analysis. At necropsy, no macroscopic changes were observed, suggesting that nutritional factors were responsible for the mortality. The unsatisfactory results (100% mortality) found in animals fed Diet C may be related to the quality of the nutrients present in feed developed for adult flamingos, which was not suitable for scarlet ibis chicks in the early stages of development. The chicks that received Diets S and F had 100% survival and body scores of two, indicating good nutritional status. It is possible that the higher crude protein content in these diets was important for chicks in the early stages of development. Therefore, the nutritional compositions of fish and shrimp are more suitable for the development of birds in the early stages of life.

In quails at the early stage of life, nutritional crude protein requirements are higher from the 1st to the 21st day of life (25%) and lower (22%) from the 22nd to the 42nd day of life (Silva and Costa, 2009). However, this finding cannot be extrapolated to the scarlet ibis because the nutritional requirements of quail and scarlet ibis are likely distinct, as these species have distinct feeding habits. Scarlet ibis most likely have higher crude protein requirements because they are carnivorous, feeding mainly on crustaceans in the wild (Olmos et al., 2001).

Figure 2 shows the relationship between age and weight in scarlet ibis chicks. The curve was best fit using an exponential model, as evaluated by the coefficient of determination (R^2; Figure 2), intercept values ($P < 0.0001$) and regression coefficient ($P < 0.0001$). Chicks that received Diets S and F gained weight from the 1st to the 36th day of life (Figure 2). By comparing the daily weights of scarlet ibis chicks fed Diets S and F, differences from the 7th to the 36th day were observed ($P < 0.05$), indicating that the weights of chicks fed Diet F were higher (Figure 2). Thus, chicks receiving Diet F gained weight faster than the chicks fed Diet S after the 7th day of life.

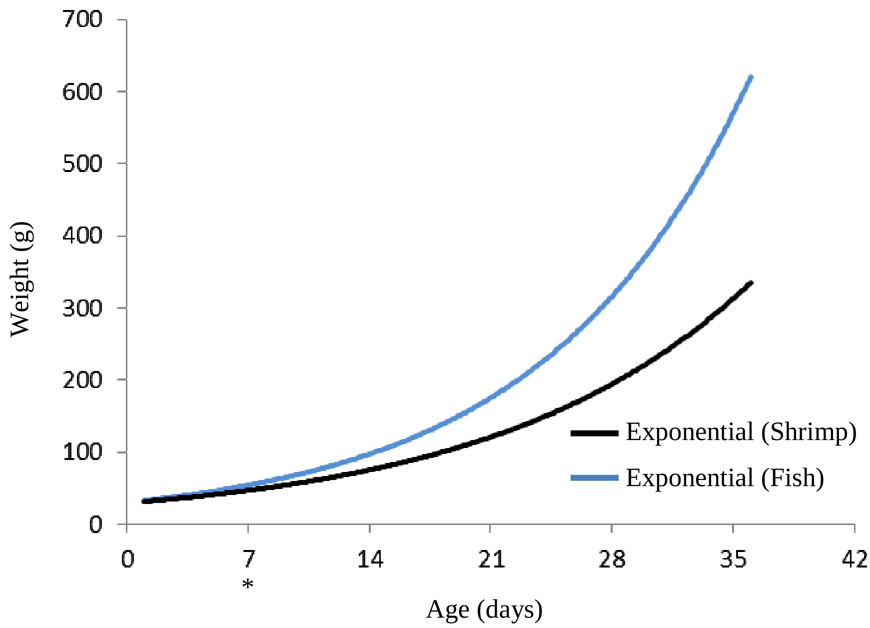


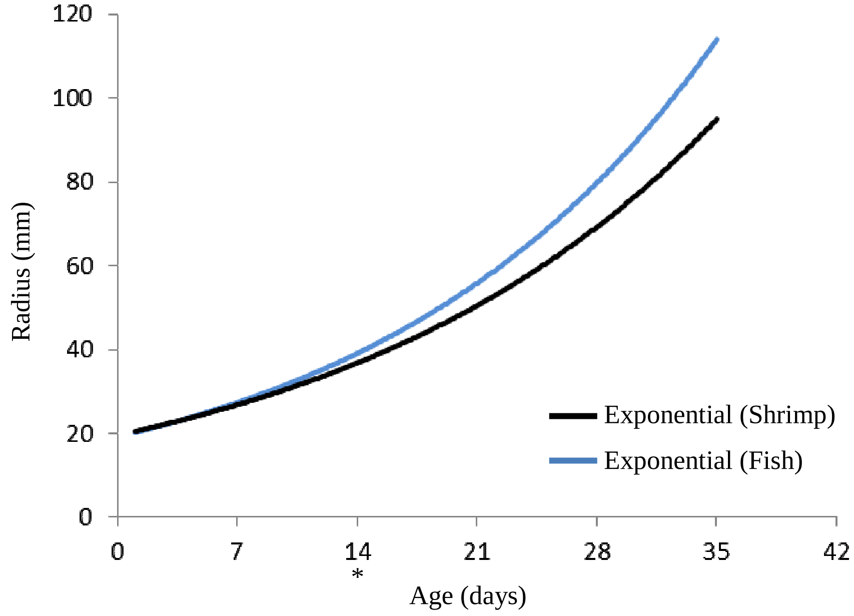
Figure 2 – Exponential regression analysis indicating the relationship between age and the daily weights of 20 scarlet ibis chicks fed Diet S (shrimp) and Diet F (fish) from the 1st to the 36th day of life.

Diet S: Weight = 28.8 x e^(0.068 x Age); R^2 = 0.95.

Diet F: Weight = 29.718 x e^(0.084 x Age); R^2 = 0.96.

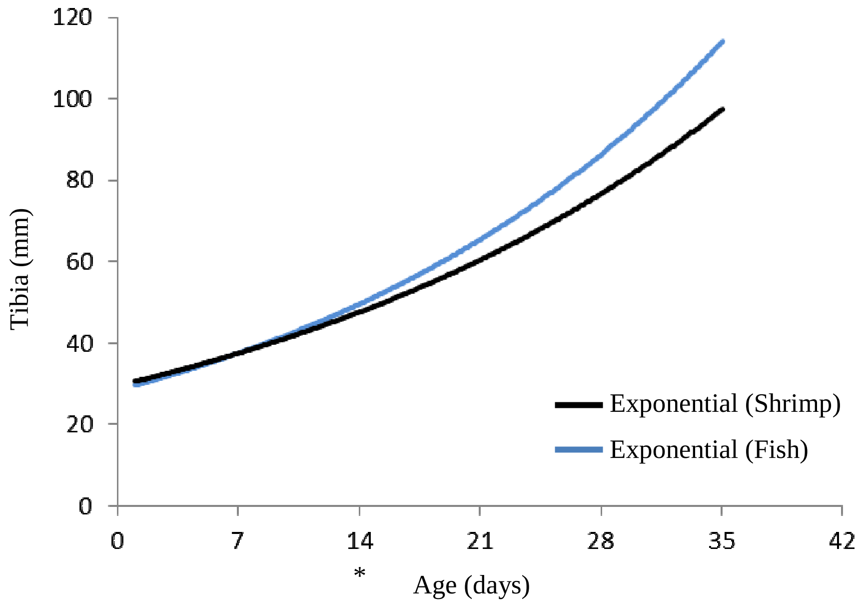
* Indicates the day when differences in the means among diets began to appear (P<0.05).

Figure 3 shows the relationship between age and the lengths of the radius, tibia and tarsus of the scarlet ibis chicks. The curve was best fit using an exponential model, as evaluated by the coefficient of determination (R^2; Figure 3), intercept values (P <0.0001) and regression coefficient (P <0.0001). The coefficients of determination also indicated that the lengths of the measured bones were highly correlated with age and that no growth restriction occurred. The lengths of the radius, tibia and tarsus of chicks fed Diets S and F increased from the 1st to the 35th day of life (Figure 3). When comparing the weekly measurements of the chicks fed Diets S and F, differences were found (P <0.05) from the 14th to the 35th day, indicating that the measured bones were longer in chicks fed Diet F (Figure 3). Therefore, the chicks fed Diet F grew faster than the chicks fed Diet S, starting at the 14th day of life.



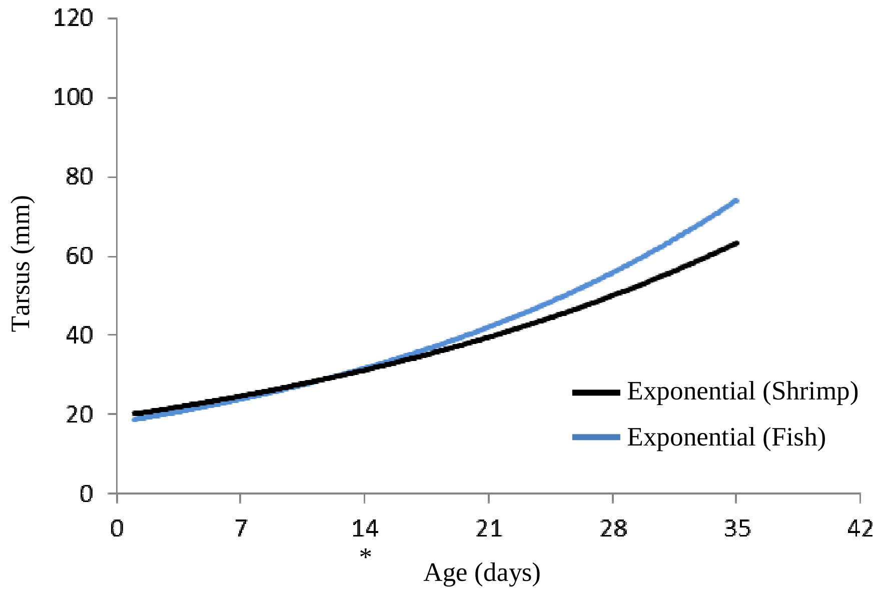
Diet S: Radius = 19.528 x e^(0.0452 x Age); R^2 = 0.98.

Diet F: Radius =19.12 x e^(0.051 x Age); R^2 = 0.97.



Diet S: Tibia = 29.535 x e^(0.034 x Age); R^2 = 0.95.

Diet F: Tibia =28.44 x e^(0.0397 x Age); R^2 = 0.97.



Diet S: Tarsus = 19.473 x e^(0.0337 x Age); R^2 = 0.94.

Diet F: Tarsus =17.976 x e^(0.0404 x Age); R^2 = 0.97.

Figure 3 – Exponential regression analysis indicating the relationship between age and the lengths of the radius, tibia and tarsus of 20 scarlet ibis chicks fed Diet S (Shrimp) and Diet F (fish) from the 1st to 35th day of life.

* Indicates the day when differences in the means among diets began to appear (*P*<0.05).

Figure 4 shows the relationship between age and the length of the unpigmented portion of the beaks of scarlet ibis chicks. The curve was best fit using a second-order polynomial model, as evaluated by the coefficient of determination (R^2; Figure 4), intercept values (*P* <0.0001) and regression coefficient (*P* <0.0001). The length of the unpigmented portion of the beaks of chicks fed Diets S and F decreased from the 1st to the 35th day of life, when the beak was completely pigmented (Figure 4). There was no significant difference in the weekly measurements of the unpigmented beak portion when comparing chicks fed Diets S and F (Figure 4). Therefore, beak pigmentation, a phenotypic characteristic of scarlet ibis chicks, is likely not influenced by the type of food supplied, in contrast to body weight and bone lengths.

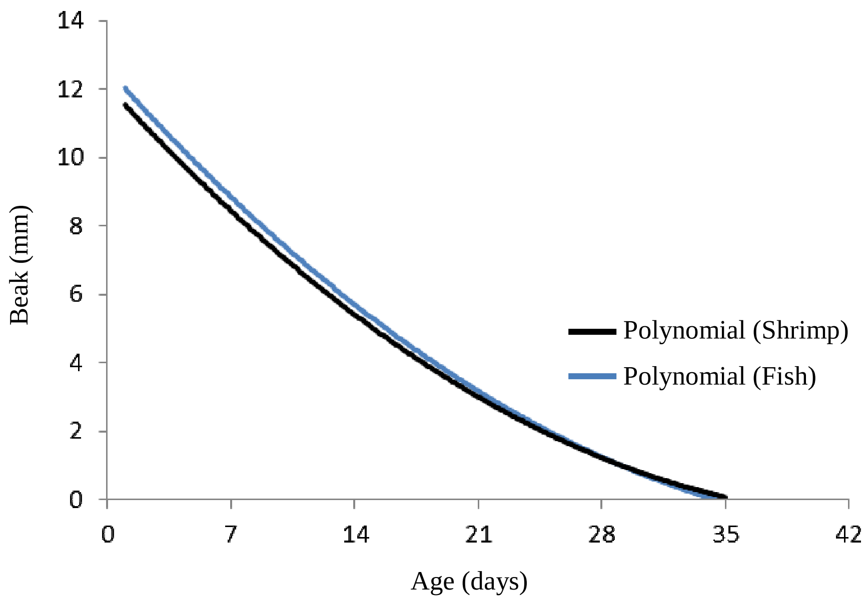


Figure 4 – Second-order polynomial regression analysis indicating the relationship between age and the length of the unpigmented portion of the beaks of 20 scarlet ibis chicks fed Diet S (shrimp) and Diet F (fish) from the 1st to the 35th day of life.

Diet S: Beak = 12.094 - 0.567 x Age + 0.006 x Age^2; R^2 = 0.96.

Diet F: Beak = 12.588 - 0.587 x Age + 0.006 x Age^2; R^2 = 0.97.

Despite the similar nutritional compositions of Diets S and F, chicks fed Diet F exhibited faster growth, reaching higher body weights and bone lengths at the end of rearing than chicks fed Diet S. The differences in the performance of the chicks may be related to the amino acid profiles and digestibility of the diets. The amino acid profiles may differ among the protein sources used (shrimp and fish). Moreover, chicks in early developmental stages may not have the enzymes necessary to aid in the digestion of crustaceans because in the wild they receive food regurgitated by an adult (Stanek, 2009). Further studies assessing the amino acid profiles and digestibility of these foods are needed.

Beginning on the 7th day of life, the diets provided likely affected the development of the chicks. Before this period, the chicks exhibited no differences in growth between diets, as their physical conditions were most likely still similar to when they were in the egg. The selection of a suitable diet is very important for artificial breeding because it reduces mortality rates, provides animals with more resistance to diseases, accelerates growth and decreases the time required to reach adulthood, rendering animals ready to breed earlier.

Considering the cost-benefit relationship of fish and shrimp, mullets are cheaper, corresponding to 75.7% of the price of local shrimp. In addition, with the same amount (g) of shrimp and fish, and consequently similar percentages of crude protein, twice as much Diet F was produced because of the addition of a larger amount of water needed in the preparation of the fish broth. Therefore, among the treatments tested, Diet F was considered more suitable for scarlet ibis chicks in the early stages of development and bred under human care.

This study may contribute to the artificial breeding of scarlet ibis in captivity, which can be a tool for the conservation of the species, as well as for the breeding of chicks seized or rescued from the wild and can also form a basis for breeding protocols for other species in the family Threskiornithidae.

CONCLUSION

Commercial feed should not be the exclusive source of food in the diet of scarlet ibis in the early stages of development and must be supplemented with animal ingredients such as shrimp and fish. Diets S and F, including shrimp and fish, respectively, had similar nutritional compositions, ensuring the growth of chicks. However, supplementation with fish is recommended because chicks that received Diet F exhibited faster growth and good body condition, as well as higher weights and longer radius, tibia and tarsus bones.

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5. CAPÍTULO II

DEVELOPING A PROTOCOL FOR REARING SCARLET IBIS (*Eudocimus ruber*) YOUNG AT MANGAL DAS GARÇAS PARK

DEVELOPING A PROTOCOL FOR REARING SCARLET IBIS (*Eudocimus ruber*) YOUNG AT MANGAL DAS GARÇAS PARK

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ABSTRACT

The objectives of this study were to develop an ambient environment and feeding protocol for rearing scarlet ibis young under artificial conditions; intensify reproduction in captivity and increase the number of ibises in the colony; evaluate the protocol by monitoring the development of the artificially reared young; and evaluate the efficiency of artificial and natural rearing. Rearing was artificial during year I and natural during year II at one of the areas of Mangal das Garças Park to test the number of young obtained, the survival rate, and the mortality rate. The ambient environment and feeding protocol was evaluated based on the clinical observations, body condition, and weight gains of 20 young. The mortality rate was lower and the number of births and survival rate were higher during artificial rearing. All of the young exhibited increased weight and weight gain ($P<0.05$) and good nutritional status, and no dystrophies were observed during artificial rearing. The artificial rearing protocol provided an adequate ambient environment and feeding strategy, resulting in intensified reproduction, an increased number of scarlet ibises in the park, and normal growth of the young. Artificial rearing was more efficient than natural rearing in the number of young obtained, the survival rate, and the mortality rate.

Keywords: Artificial enclosure; Artificial feeding; Artificial rearing; Intensified reproduction; Offspring growth; Wild bird.

INTRODUCTION

Although the conservation status of the scarlet ibis is 'Least Concern', its population is declining (Birdlife International, 2012). The scarlet ibis is considered extirpated in various regions where it was once sighted (Sick, 1997; Ebird, 2015) and is officially protected by Brazilian legislation as an endangered species (Ibama, 1989). Captive breeding techniques are complementary tools for species conservation because managed colonies in fragmented habitats and those in captivity can represent a large group for preservation and reduce losses of the species (Fontenelle, 2007).

Scarlet ibises are found in zoos in Brazil and other countries. However, there is no efficient reproductive management strategy for this species in captivity, and the few times that the animals have reproduced in zoos, the young have remained exclusively dependent on parental care. In the wild, the young can be lost because of predation by other animals, falling from nests, and parental desertion (Olmos and Silva, 2001). At Mangal das Garças Park, chicks that fall from nests made by the parents are rescued and artificially reared in a nursery. Additionally, at-risk young with unknown ages seized by environmental agencies are constantly received at the park.

There is no protocol in the scientific literature for the artificial rearing of scarlet ibis young, and very little of their developmental biology has been described. These factors represent a limitation for rearing young under human care and for maintaining and breeding the species in captivity.

Olmos and Silva (2001) found that some wild scarlet ibis pairs laid replacement eggs after losing their young during the first nesting cycle. Thus, collecting eggs for artificial incubation in captivity may also stimulate the females to lay replacement eggs, thereby intensifying reproduction in captivity and increasing the birth rate. Additionally, the development of an adequate ambient environment and feeding protocol would enable artificial rearing of young and thereby increase the number of individuals in captivity.

Thus, the objective of this study was to I- develop an ambient environment and feeding protocol for the rearing of scarlet ibis young under artificial conditions; II- intensify reproduction in captivity and increase the number of scarlet ibises in the colony; III- evaluate the protocol by monitoring the development of artificially reared young via daily clinical observations and weighings; and IV- evaluate the efficiency of artificial and natural rearing.

MATERIALS AND METHODS

Study site

The study was conducted at Mangal das Garças Park located in Belém, Pará State, Brazil (1°27'48.9"S 48°30'17.8"W) (Figure 1). A total of 111 ibis adults inhabit the park and are distributed among three areas: the Aningas Aviary (11 males and 8 females), Cavername Lake (34 males and 17 females), and the park's Extra Sector (41 unsexed individuals). Water and commercial extruded feed[1] are provided *ad libitum* from 7 am to 4 pm at all of the areas. Mangal das Garças Park has Authorization for the Management of Native Wildlife (no. 1501.8612/2014-PA) for rearing *Eudocimus ruber* (scarlet ibis). All of the birds receive daily technical assistance from a veterinarian and a biologist.

Figure 1 - Aerial view of Mangal das Garças Park. Source: http://www.mangalpa.com.br

[1] Feed FL 32 (Megazoo Betim, Minas Gerais, Brazil) – **Guaranteed analysis:** 110 g/kg moisture (max.), 320 g/kg crude protein (min.), 60 g/kg ether extract (min.), 45 g/kg fiber (max.), 110 g/kg mineral content (max.), 22 g/kg calcium (max.), 18 g/kg calcium (min.), 3,000 mg/kg sodium (min.), 9,000 mg/kg phosphorus (min.), 2,200 mg/kg omega 3 (min.), 400 mg/kg mannooligosaccharides (min.), 440 mg/kg beta-glucans (min.), 1.95 mg/kg milk thistle extract (min.), 7,000 mg/kg DL-methionine (min.), 19 g/kg L-lysine (min.), 3,000 mg/kg toxin adsorbent additives (min.). **Ingredients:** ground whole corn, fish meal, poultry offal meal, soybean meal, dry beer yeast, crude soybean oil, limestone, vitamin mineral premix, sodium chloride (table salt), natural annatto dye, prebiotic (mannooligosaccharide), fungistatic additive (propionic acid), DL-methionine, adsorbent additive (esterified glucomannan yeast), antioxidant (BHA).

Evaluating the efficiency of the artificial rearing

The study was divided into the following steps to evaluate whether artificial rearing intensified reproduction in captivity and increased the number of ibises in the colony: Year I (2012) – the egg-laying period began in June and lasted until May 2013. Eggs from the three park areas were collected and artificially incubated; and Year II (2013) – the egg-laying period began in August and ended in January 2014. Only eggs from the Aningas Aviary were not collected; these eggs were naturally incubated, and the young were reared under parental care. It was not possible to record the number of eggs under natural rearing because it was impossible to access the nests. The number of incubated eggs and hatching rates, number of young hatched, number of survivors and survival rates, number of dead young, and mortality rates were recorded.

Egg management

Nests were inspected two times per day (morning and afternoon), and eggs were collected whenever they were encountered. Eggs were manually collected and transported to the nursery in a plastic egg container. Each collected egg was sanitized with gauze and moistened with saline solution. After evaluation, broken, cracked or punctured eggs were discarded. The date and site of collection were recorded with a graphite pencil on each egg.

Eggs were incubated in a digital incubator, with automatic egg turning programmed at two-hour intervals (IP 130 PS, Premium Ecológica Ltda, Belo Horizonte, Minas Gerais, Brazil). The temperature and humidity in the incubator were 37.4 ºC and 60%, respectively. Eggs in the incubator were inspected two times per day (morning and afternoon), and when the hole made by the hatchling hours before hatching was observed, the egg was transferred to a bird treatment unit (UTA, TD, Premium Ecológica Ltda, Belo Horizonte, Minas Gerais, Brazil) and kept under the same temperature and humidity conditions as the incubator until the end of hatching.

Selecting and managing the young

Twenty clinically healthy scarlet ibis young were selected to develop the artificial rearing protocol. All of the animals were housed under the same artificial environmental conditions. The young were identified by adhesive bandage tape bands numbered from one to twenty.

After hatching, the young were housed in artificial nests made of straw baskets lined with hay (Figure 2A). These baskets were used to provide better environmental comfort for the young because they mimicked the natural nests composed of dry twigs or green branches with leaves made by adult scarlet ibises (Hass et al., 1999). The young remained at the bird treatment unit until they were 2 days old. At 3 days old, the nest containing the young was transferred to a fiberglass brooder (1.18 x 0.59 x 0.50 m) containing clay heaters with 25-watt light bulbs (Figure 2B). The heat source was used to provide environmental comfort for the young because in nature, the parents take turns keeping the chicks warm (Hancock et al., 1992; Sick, 1997; Olmos and Silva, 2001). The temperature and humidity in the nests were maintained at approximately 32ºC and 58%, respectively. Upon leaving the nests, the young were housed only in the brooders containing hay and the heat source (Figure 2C).

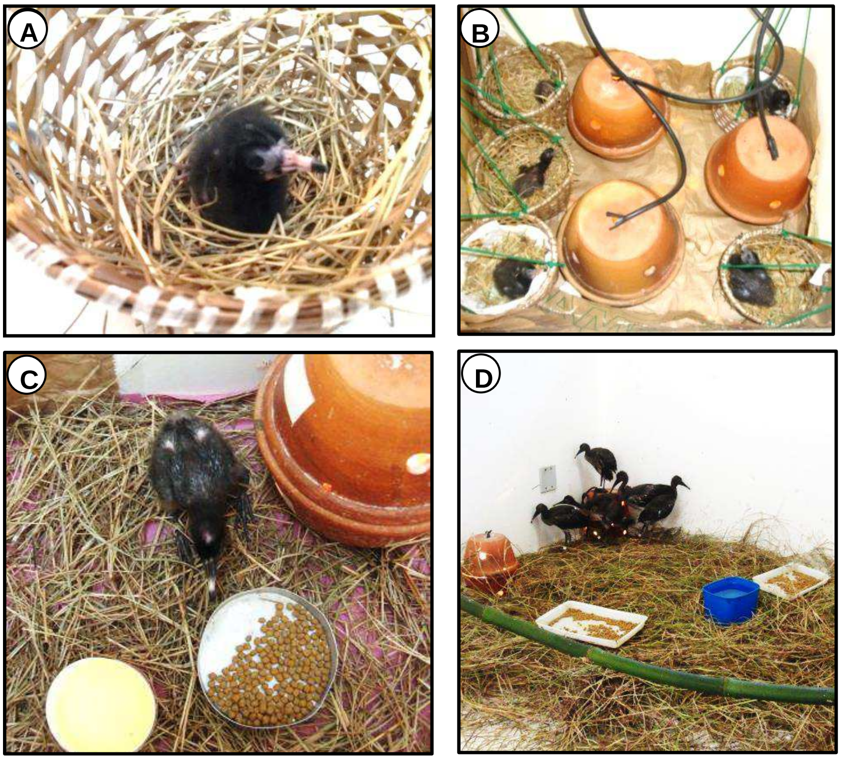

Figure 2 – Six-day-old scarlet ibis young (A) in an artificial nest constructed with a straw basket and hay bedding. (B) Individual nests with scarlet ibis young heated by clay pots with 25-watt light bulbs. (C) Twenty-day-old scarlet ibises with no nest kept on hay bedding and heated. (D) Group of scarlet ibises in the nursery with hay bedding, heating, perch, and natural lighting.

Starting on day 3 of life and continuing until they left the nursery, the young were exposed to direct sunlight daily for one hour before 9 am and received a daily mineral vitamin supplement at[2] a dose of two drops per young.

After leaving the nursery, the young were transferred to an 18 m^2 enclosure equipped with two clay heaters with 60-watt light bulbs, hay bedding, 15-cm diameter wood perches, and a skylight that provided ventilation and natural light. Perches were installed in the enclosure because Olmos and Silva (2003) demonstrated that in nature, the young walk about branches and gather in groups at the tops of the trees after becoming independent from their nests. In the enclosure, the animals were housed in groups of up to ten young (1.8 young/m^2; Figure 2D).

Feeding protocol

A paste comprising a mixture of 15 g of ground flamingo commercial feed (Feed FL32[1]) and 100 ml of fish broth was prepared to feed the birds. The fish broth was obtained by blending 100 g of mullet (*Mugil* spp.) fillets with 300 ml of water in a blender and then filtering it through a sieve. The fish broth was chosen as an ingredient based on Sick (1997) and Olmos et al. (2001). The feed was selected because it was originally developed for flamingos, which are birds with feeding habits similar to the scarlet ibis (Tobar et al., 2014). Additionally, adult scarlet ibises within the park have adapted to this feed and exhibit positive responses in terms of reproduction and feather coloration.

The fish broth was prepared twice daily (morning and afternoon). The paste was prepared prior to each feeding and heated in a microwave oven until it reached 40ºC. The young were first fed 12 hours after hatching, i.e., after the depletion of the yolk reserves.

The paste was administered orally directly into the entrance to the esophagus using a no. 10 gastric tube cut to 5 cm in length and coupled to a disposable syringe (Figure 3A). The head of the animal was kept elevated at 90º during feeding, and this position was maintained for at least ten seconds after administering the paste (Figure 3B) to avoid reflux and choking. According to Stanek (2009), in nature, an adult supports the chick's bill, causing it to raise its head so that the adult can regurgitate into the mouth.

[2] Avitrin Cálcio Plus (Coveli, Duque de Caxias, Rio de Janeiro, Brazil) – guaranteed analysis (kg): 125,000 IU vitamin A (min.), 800,000 IU vitamin D3 (min.), 2,000 mg magnesium (min.), 5,865 mg calcium (min.), 7,168 mg calcium (max.), 2,000 mcg vitamin B12 (min.).

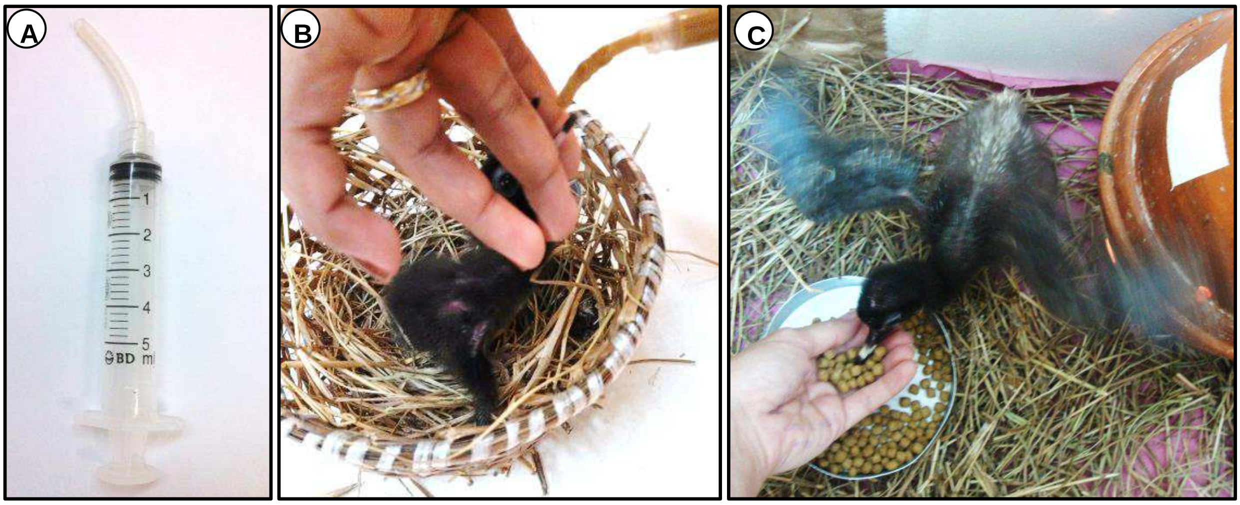

Figure 3 - Feeding the scarlet ibis young. (A) A no. 10 gastric tube was cut to a 5 cm length and coupled to a disposable syringe. (B) The paste was directly administered into the entrance of the esophagus. (C) A 20-day-old ibis being encouraged to feed itself.

The total number of meals per day, intervals, volume administered at each meal, and the total daily volume were defined according to the chick's age as described in Table 1. The young were encouraged to feed alone after they left the nest. Commercial extruded feed (Feed FL32[1]) was provided in a feeder and water was provided *ad libitum* (Figure 3C). After each paste supply, the maintenance technician encouraged the bird to eat the commercial feed in the feeder. On day 20 and onwards, the feeding intervals of paste supply were increased every four days until only commercial feed in the feeder was offered (Table 1). At this stage, to encourage younger chicks to eat the feed, the young were transferred to the enclosure and housed together with at least one older chick that was already feeding alone.

Table 1 – Feeding protocol developed to provide nutrition to 20 scarlet ibis chicks raised under artificial conditions on their 1st through 39th days of life.

Age (days)	Total feedings/day	Interval (hr)	Volume/feeding (ml)	Volume/day (ml)
1-2	13	1/1	0.5	6.5
3	13	1/1	1	13
4-7	13	1/1	2	26
8-11	13	1/1	3	39
12-15	13	1/1	4	52
16-19	13	1/1	5	65
*20-23	7	2/2	6	42
24-27	5	3/3	7	35
28-31	3	6/6	8	24
32-35	2	12/12	9	18
36-39	1	24/24	10	10

*Reductions in total feedings per day and in volume per day. Increase in feeding intervals and volume per feeding.

Evaluating the artificially reared young

To evaluate the scarlet ibis young during artificial rearing, individual clinical examinations were performed to monitor the following: limb development, body condition, and weight. The limbs were inspected daily to observe possible developmental abnormalities such as bone dystrophies.

The body condition was evaluated daily by inspecting and palpating the pectoral muscles and sternum and was scored from one to three (Harrison and Ritchie, 1994): 1 – reduced pectoral musculature and prominent sternum, indicating poor body condition; 2 – rounded pectoral musculature with a mild depression on both sides of the sternum, indicating good body condition; and 3 – pectoral musculature covering the entire sternum, indicating excess weight.

The weight of each young bird was monitored every five days. The birds were weighed with a digital balance (Actlife Superinox-5, Balmak Indústria and Comércio Ltd., Cidade Industrial Santa Bárbara d'Oeste, São Paulo, Brazil) starting on 1 day of life soon after birth and always in the morning thereafter. All data were recorded in an individual case report form.

Statistical analysis

The egg hatching rates, survival rates, and mortality rates of the young are expressed as percentages. Weight and weight gain are expressed as the mean ± standard error. Analysis of variance was used to assess the effect of age on weight. The differences between the mean weights were determined using Fisher's post hoc test. Exponential regression analysis was used to test the relationship between the age and weight of the young. All analyses were performed in Statview 5.0 (SAS Institute Inc., Cary, North Carolina, United States), and the results were considered significant when $P<0.05$.

RESULTS AND DISCUSSION

The egg hatching rates, number of eggs incubated, number of births, survival rates, number of survivors, mortality rates, and number of dead young are shown in Table 2. The high hatching rates of the artificially incubated eggs in years I and II (Table 2) suggested that the temperature and humidity conditions were most likely efficient for artificial incubation. In nature, Olmos and Silva (2001) reported hatching rates between 20 and 28% (0.20 to 0.28 young/egg) and Martínez and Rodrigues (1999) found a hatching rate of 32% (0.32 young/egg).

The incubation periods had mean durations of 23.3 ± 0.26 days in year I and 22.46 ± 0.14 days in year II, which were similar to the periods cited by other authors in observations in the wild: 25.8 ± 2.3 days (Hass 1996), approximately 23 days (Brouwer and Van Wieringen, 1990), between 21 and 24 days (Sick, 1997; Olmos and Silva, 2001), approximately three weeks (Heath et al., 2003) and between 19 and 23 days (Moochan, 2011). Thus, the proposed egg management strategy was adequate for artificially rearing scarlet ibises based on the high egg hatching rates obtained over two years and the incubation periods that were similar to those described in nature in other studies.

Table 2 – Egg hatching rates and number of eggs, number of young hatched, survival rate, number of survivors, mortality rate, and number of deaths recorded in artificial and natural reared scarlet ibises in Mangal das Garças Park.

Park Area		**Artificial Rearing (n)**	**Natural Rearing (n)**
Aningas Aviary	Hatching rate	77.77% (9)	*
	Number of young	7	3
	Survival rate	100% (7)	66.67% (2)
	Mortality rate	0% (0)	33.33% (1)
		Artificial Rearing (n)	**Natural Rearing (n)**
Cavername Lake and Extra Sector	Hatching rate	87.75% (49)	85.10% (47)
	Number of young	43	40
	Survival rate	88.38% (38)	77.50% (31)
	Mortality rate	11.62% (5)	22.5% (9)

* It was not possible to record the number of eggs.

The number of scarlet ibis births obtained by artificial rearing was higher (Table 2), suggesting that natural rearing demanded the parents' time to hatch the eggs and then take care of the young. By removing the eggs for artificial incubation, the parents most likely returned to mating, and the females laid replacement eggs, as described in nature by Olmos and Silva (2001). Additionally, when the births were compared with the total number of adult scarlet ibises in Mangal das Garças Park (111 birds), 0.45 young were obtained per adult individual in year I and 0.43 young were obtained per adult individual in year II. In nature, this ratio was 0.17 young per adult individual during the first laying cycle and 0.09 young per adult individual during the second laying cycle of the same year (Olmos and Silva, 2001).

The survival and mortality rates indicate that the losses of young in artificial rearing were lower than those in natural rearing (Table 2). Additionally, artificial rearing may have prevented the young from falling from the nests, which represents 19% to 49% of the scarlet ibis young losses in nature (Martínez and Rodrigues, 1999; Olmos and Silva, 2001). There was one fall from a nest and one young death in the natural rearing (Table 2). Because the birds were reared in a semi-free environment at one of the Mangal das Garças Park areas, artificial rearing most likely prevented losses due to predation. Predation represents the cause of 31% to 75% of the losses of scarlet ibis young in the wild (Martínez and Rodrigues, 1999;

Olmos and Silva, 2001). Therefore, the artificial rearing protocol was efficient for maintaining the survival of the young.

Thus, the hatching rates of the artificially incubated eggs, survival rates, young mortality rates, and number of births confirmed the hypothesis that artificial rearing intensified reproduction and was more effective than natural rearing in increasing the number of individuals in captivity.

The young left the nest at a mean age of 14.66±1.34 days. According to Olmos and Silva (2001), young between 11 and 13 days old in nature are able to move about the branches around the nest and climb to nearby nests but only become independent of the nests when they reach 20 days of age. At a mean age of 41.28 ± 1.32 days, the young fed only on the feed offered in the feeder. In nature, the young become self-reliant between 74 and 78 days of age when they are able to forage alone (Olmos and Silva 2001; Moochan 2011). Thus, the artificially reared young became independent earlier compared to the captive young reared by their parents, which could also enhance reproduction because the earlier chicks would most likely be able to reproduce at an earlier age.

The 20 young selected to evaluate artificial rearing exhibited 100% survival and normal limb development, with no bone dystrophies observed. This result demonstrated that the artificial ambient environment most likely provided environmental comfort and promoted correct hindlimb development, thereby avoiding dystrophies. Thus, the environment was efficient for rearing scarlet ibis young under human care.

All of the artificially reared young exhibited body scores of 2 when they were between 1 and 36 days old, indicating good nutritional status. Table 3 shows the mean weights and weight gains of the artificially reared young in years I and II. There was no effect of the year on the chick weights ($P>0.05$). The mean weights increased from 6 to 36 days of age ($P<0.05$), suggesting that a weight gain occurred during this period (Table 3).

Table 3 – Means ± standard errors of the weights and weight gains of 20 scarlet ibis young artificially reared and monitored every five days from 1 to 36 days of life.

Age (days)	Weight (g)	Weight gain (g)
1	28.50 ± 1.25[a]	-
6	43.12 ± 1.69[ab]	14.62 ± 1.10[a]
11	76.87 ± 5.06[b]	33.75 ± 4.62[a]
16	100.75 ± 6.82[c]	33.75 ± 4.62[a]
21	159.87 ± 16.02[d]	23.87 ± 3.99[a]
26	224.12 ± 22.63[e]	66.28 ± 11.37[b]
31	300.14 ± 24.83[f]	64.25 ± 10.27[b]
36	378.28 ± 17.99[g]	74.62 ± 1076[b]

[a-g] Letters indicate the difference in means among days (*P*<0.05).

Figure 4 shows the relationship between the age and weight of the 20 artificially reared scarlet ibis young. The curve was best fitted using an exponential model in terms of its coefficient of determination (R^2=0.95), intercept values (*P*<0.0001), and regression coefficient (*P*<0.0001). The coefficient of determination indicated that weight had a high correlation with age and that there was most likely no growth restriction.

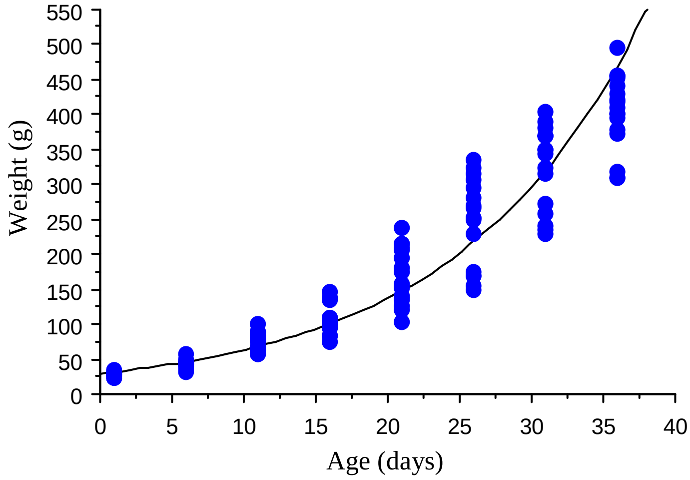

Figure 4 – Exponential regression analysis showing the relationship between age and weight of 20 scarlet ibis young artificially reared from 1 to 36 days of life.

Equation: Weight = 29.188 x e^(0.077 x Age)

Starting at 21 days of age, a higher variation in weight was demonstrated by the increased standard error (Table 3 and Figure 4). This variation most likely occurred as a result of the onset of independent feeding because some of the birds started to consume feed early compared to the other young and thus gained more weight. Therefore, the gradual reduction in the paste supply frequency was efficient in promoting a significant increase in weight, even with the reduced total volume of paste provided per day. In this sense, the developed diet and the meal supply protocol appeared to have met the dietary needs of the young from 1 to 36 days of age.

Hancock et al. (1992), Frederick and Bildstein (1992), Sick (1997), Olmos and Silva (2001; 2003), Stanek (2009), and Moochan (2011) described several characteristics of scarlet ibis young based on observations in the wild. However, no study on chick development based on weight has been published, most likely because of the difficulty in accessing the nests and the risks of losing the chicks as a result of handling in nature. According to Olmos and Silva (2003), the chicks quickly climbed through the branches towards the top of the tree when the nests were approached in the wild. Thus, artificial rearing facilitates chick handling, reduces the risk of loss, and enables better study of the species.

The artificial rearing protocol may contribute to the maintenance of *Eudocimus ruber* in the wild and may also serve as a tool for conservation studies in captivity (e.g., reintroducing groups born in captivity to sites where the species is extirpated or endangered). Additionally, this study will most likely contribute to rearing scarlet ibis young seized or rescued from nature and serve as the basis to create protocols for other species of the family Threskiornithidae.

CONCLUSION

The artificial rearing protocol for scarlet ibis young provided an adequate ambient environment and feeding strategy, which resulted in intensified reproduction, an increased number of scarlet ibises in the park, and normal growth of the young. Moreover, artificial rearing was more efficient than natural rearing in the number of young obtained, the survival rate, and the mortality rate.

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6. CAPÍTULO III

EQUATIONS AND METHODS FOR ASSESSING THE GROWTH OF SCARLET IBIS (*Eudocimus ruber*) YOUNG RAISED AT MANGAL DAS GARÇAS PARK

EQUATIONS AND METHODS FOR ASSESSING THE GROWTH OF SCARLET IBIS (*Eudocimus ruber*) YOUNG RAISED AT MANGAL DAS GARÇAS PARK

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ABSTRACT

The objective of this study was to develop growth estimation equations to evaluate the development of artificially reared scarlet ibis young using individual weights and biometrics, as well as to describe their feather coloration, beak pigmentation and the timing of developmental stages such as eye opening, locomotion and nest-leaving under artificial conditions. Specific measurements were recorded during each chick's development, including its weight and the biometry of its radius, tibia, tarsus and the unpigmented portions of its beak. The chicks opened their eyes at 4.73±0.12 days of age, began moving in the nest at 6.31±0.18 days of age and left the nest at 15.3±0.68 days of age. The mean body weight and radius, tibia and tarsus lengths increased over time, while the mean length of the unpigmented portion of the beak decreased over time ($P<0.05$). On the 7th day of life, the beaks began to gain pigmentation, and by the 35th day, the beaks were fully pigmented. The chicks' age, body weight and biometrics were strongly correlated, and the coefficients of determination for the regression equations were found to be high. We herein describe our resulting growth estimation equations as well as the developmental stages of scarlet ibis young raised under artificial conditions.

Keywords: Artificial Rearing; Beak Pigmentation; Biometrics; Bird; Development; Weight.

INTRODUCTION

The species *Eudocimus ruber* (scarlet ibis) can be found in various zoos throughout Brazil and around the world. However, the effective reproductive management of scarlet ibis in captivity has not been established. In the rare cases in which they were successfully bred in zoos, the chicks were exclusively dependent on parental care. At Mangal das Garças Park, it is common for chicks that have fallen from their parental nests to be rescued and artificially raised in the nursery. It is also common for the park to receive at-risk chicks of unknown age that were seized by environmental agencies.

The ability to determine the age of scarlet ibis young and establish parameters to assess their growth is important for the raising of these animals under artificial conditions and is also a useful tool for the conservation of the species. Despite its “Least Concern” conservation status, the scarlet ibis population is currently in decline (Birdlife International, 2012), and the species is considered to be extinct in several regions (Sick, 1997; Ebird, 2015).

Olmos and Silva (2001) described specific phenotypic characteristics of scarlet ibis offspring in the wild, such as molting and beak color at hatching, as well as the behavioral aspects of their development, such as their timing of locomotion, nest-leaving, progression of flight ability and food independence. However, the physical parameters of scarlet ibis young obtained at regular intervals, such as body weight and other age-associated measurements, are unavailable. This limits the determination of their age, feeding protocol development, developmental evaluation and the diagnosis of growth impairment under artificial conditions. Furthermore, certain parameters, such as the age at which scarlet ibis chicks open their eyes and the timing of beak pigmentation, have never been described.

Thus, weighing scarlet ibis chicks and measuring the radius, tibia, tarsus and the unpigmented portion of the beak at regular intervals would help to determine the age of scarlet ibis young and evaluate their development. This information would likely contribute to the improvement of artificial rearing in captivity. With daily monitoring, it is possible to describe the specific stages of chick development, such as the opening of the eyes and the progression of beak pigmentation, and to observe behavioral and phenotypic changes that have been described in the wild, such as the initiation of locomotion, nest-leaving and feather coloration, under artificial conditions.

The objectives of this study were to develop growth estimation equations to assess the development of scarlet ibis young reared artificially by weighing individuals and taking biometric measurements of the radius, tibia, tarsus and the unpigmented portion of the beak and to describe the feather coloration, pigmentation of the beak and stages of development, such as eye opening, the initiation of locomotion and the age of nest-leaving, under artificial conditions.

MATERIAL AND METHODS

Study site

The study was conducted at Mangal das Garças Park, located in the city of Belém, State of Pará, Brazil 1°27'48.9"S 48°30'17.8"W (Figure 1). A total of 111 scarlet ibis adults live in three areas of the park: Aningas Aviary (11 males and 8 females), Cavername Lake (34 males and 17 females) and the Extra Sector (41 unsexed individuals). In all three areas, water is provided *ad libitum* and commercial extruded feed[1] is available from 7:00am to 4:00pm. The Mangal das Garças Park possesses Authorization for the Management of Native Wildlife no. 1501.8612/2014-PA for rearing *Eudocimus ruber* (scarlet ibis). All the animals receive daily technical assistance from a veterinarian and biologist.

Egg handling

The nests were inspected twice daily (morning and afternoon), and all the discovered eggs were collected. The eggs were manually collected and transported to the nursery in a plastic egg carton. The collected eggs were sanitized with gauze moistened in saline solution. Any broken, cracked or punctured eggs were discarded. The date and place of collection were written onto each egg with a graphite pencil.

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[1] Feed FL 32 (Megazoo Betim, Minas Gerais, Brazil) – **Guaranteed analysis:** 110 g/kg moisture (max.), 320 g/kg crude protein (min.), 60 g/kg ether extract (min.), 45 g/kg fiber (max.), 110 g/kg mineral content (max.), 22 g/kg calcium (max.), 18 g/kg calcium (min.), 3,000 mg/kg sodium (min.), 9,000 mg/kg phosphorus (min.), 2,200 mg/kg omega 3 (min.), 400 mg/kg mannooligosaccharides (min.), 440 mg/kg beta-glucans (min.), 1.95 mg/kg milk thistle extract (min.), 7,000 mg/kg DL-methionine (min.), 19 g/kg L-lysine (min.), 3,000 mg/kg toxin adsorbent additives (min.). **Ingredients:** ground whole corn, fish meal, poultry offal meal, soybean meal, dry beer yeast, crude soybean oil, limestone, vitamin mineral premix, sodium chloride (table salt), natural annatto dye, prebiotic (mannooligosaccharide), fungistatic additive (propionic acid), DL-methionine, adsorbent additive (esterified glucomannan yeast), antioxidant (BHA).

Figure 1- Aerial view of Mangal das Garças Park. Source: http://www.mangalpa.com.br

The eggs were incubated in a digital incubator with automatic egg turning at two hour intervals (IP 130 PS, Premium Ecológica Ltda, Belo Horizonte, Minas Gerais, Brazil). The temperature and humidity in the incubator were kept at 37.4ºC and 60%, respectively. The eggs in the incubator were inspected twice daily (morning and afternoon), and when the hole created by the chick was observed hours before hatching, the egg was transferred to a bird treatment unit (UTA, TD, Premium Ecológica Ltda, Belo Horizonte, Minas Gerais, Brazil) and kept at the same temperature and humidity as the incubator for the completion of hatching.

Selection and management of the chicks

Fifteen clinically healthy scarlet ibis chicks were selected for the study. The animals were kept under identical artificial environmental conditions. The chicks were identified with bands made with adhesive bandage tape.

After hatching, the chicks were kept in artificial nests made of straw baskets and hay. The chicks remained in the bird treatment unit until their second day of life, and on the third day of life, the nest holding the chick was transferred to a fiberglass brooder (1.18 x 0.59 x 0.50 m) containing clay heaters with 25-watt bulbs. The temperature and humidity in the nests were kept at approximately 32ºC and 58%, respectively. When the chicks left the nests, they were kept in brooders containing hay and a heating source.

From their third day of life until they left the nursery, the chicks were placed under direct sunlight for one hour per day before 9:00am, and received a daily two-drop vitamin and mineral supplement[2] .

After leaving the nursery, the chicks were transferred to an 18 m^2 enclosure equipped with two clay heaters with 60-watt bulbs, hay bedding, 15 cm diameter wooden perches and a skylight providing ventilation and natural light. The animals were kept in groups of up to ten chicks (1.8 chicks/m^2).

Chick feeding

To feed the animals, a paste consisting of 15 g of ground commercial flamingo feed (Feed FL32[1]) and 100 ml of fish broth was made. The fish broth was made by blending 100 g of mullet (*Mugil* spp.) fillet with 300 ml of water and straining it in a sieve. The selection of mullet as a dietary ingredient was based on the information provided in Sick (1997) and Olmos, Silva and Prado (2001). The commercial feed was selected because it was developed for flamingos, whose eating habits are similar to those of the scarlet ibis (Tobar et al., 2014). In addition, scarlet ibis adults from the park had previously adapted to this diet, displaying a positive response in terms of reproduction and feather coloration.

The fish broth was prepared twice daily (morning and afternoon). The paste was prepared before each feeding and heated in a microwave oven to 40ºC. The chicks were started on the feed 12 hours after hatching, prior to which they lived off yolk reserves.

The paste was directly administered orally into the entrance of the esophagus, with a no. 10 gastric tube cut to 5 cm and coupled to a disposable syringe. The animals were kept with their heads elevated at 90º during feeding; this position was maintained for at least ten seconds after the paste was administered to prevent reflux and choking.

The total number of feedings per day, intervals, volume administered at each feeding and the total daily volume were based on the age of the chick, as described in Table 1. After leaving the nest, the chicks were provided with extruded commercial feed (Feed FL32[1]) in a feeder and water *ad libitum* and encouraged to begin feeding on their own. After each paste feeding, a technician encouraged the chick to eat the food in the feeder. Beginning on day 20,

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[2] Avitrin Cálcio Plus (Coveli, Duque de Caxias, Rio de Janeiro, Brazil) – guaranteed analysis (kg): 125,000 IU vitamin A (min.), 800,000 IU vitamin D3 (min.), 2,000 mg magnesium (min.), 5,865 mg calcium (min.), 7,168 mg calcium (max.), 2,000 mcg vitamin B12 (min.).

the frequency of paste feeding was reduced every four days until only the extruded commercial feed (Feed FL32[1]) in a feeder was offered (Table 1). At this stage, the chicks were transferred to the nursery and housed with at least one independently feeding older chick to stimulate them to consume the feed.

Table 1 – Feeding protocol developed to provide nutrition to 15 scarlet ibis chicks raised under artificial conditions on their 1st through 39th days of life.

Age (days)	Total feedings/day	Interval (hr)	Volume/feeding (ml)	Volume/day (ml)
1-2	13	1/1	0.5	6.5
3	13	1/1	1	13
4-7	13	1/1	2	26
8-11	13	1/1	3	39
12-15	13	1/1	4	52
16-19	13	1/1	5	65
*20-23	7	2/2	6	42
24-27	5	3/3	7	35
28-31	3	6/6	8	24
32-35	2	12/12	9	18
36-39	1	24/24	10	10

*Reductions in total feedings per day and in volume per day. Increase in feeding intervals and volume per feeding.

Chick development

To describe the development of the scarlet ibis chicks, their feather coloration, beak pigmentation, time of eye opening, initiation of locomotion, and the age at which they left the nest were monitored daily. The beak photographs, which were taken every seven days, were cataloged and scored to estimate the age of the animals.

The chicks were weighed daily using a digital scale (Actlife Superinox-5, Balmak Industry and Commerce Ltda, Santa Bárbara d'Oeste, São Paulo, Brazil), and biometric measurements were obtained every seven days, always by the same technician. For the biometric evaluation, measurements were taken of the right radius, tibia and tarsus, as well as the unpigmented portion of the right side of the beak, using a 150 mm plastic caliper (Marberg Limited, Toronto, Ontario, Canada), as shown in Figure 2.

Weight and body biometrics are parameters of body development. The radius, tibia and tarsus, long bones under developmental pressure in birds due to flight (Sick, 1997), are easily measured in live animals, making them useful growth markers. The chicks were evaluated on their 1st day of life, soon after hatching, and every day thereafter, always in the morning.

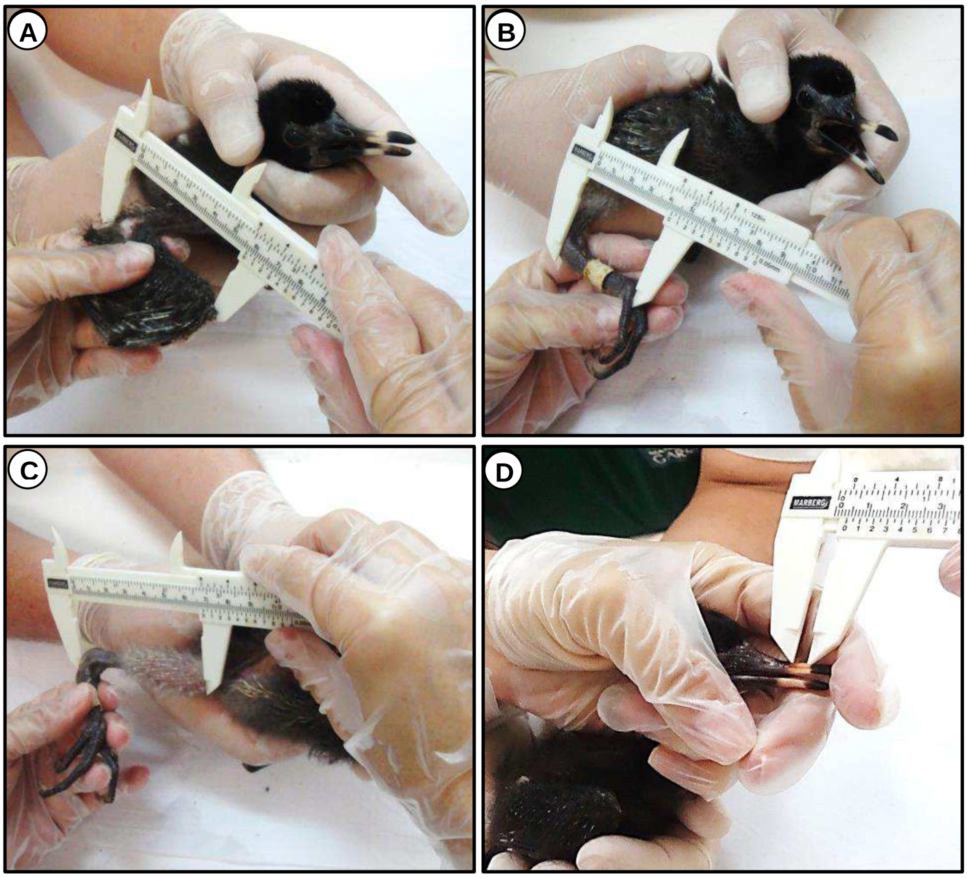

Figure 2 – Biometry of the scarlet ibis young. (A) Biometry of the radius. (B) Biometry of the tarsus. (C) Biometry of the tíbia. (D) Biometry of the unpigmented portion of the beak.

Statistical analysis

The survival rate of the scarlet ibis young was represented as a percentage. The data were rendered as the mean ± the standard error. Exponential regression analysis was used to show the relationship between the age of the chicks and their body weight and bone lengths. Polynomial regression analysis was used to show the relationship between chick age and the length of the unpigmented beak portion. Analysis of variance was used to show the effect of chick age on the weight and body measurements. Differences in mean body weight and the biometric measurements over time were determined using Fisher's post hoc test. A Pearson correlation was calculated using chick age, body weight, and the lengths of the radius, tibia, tarsus and unpigmented portion of the beak. All the analyses were performed using Statview 5.0 (SAS Institute Inc., Cary, North Carolina, United States), and the results were considered significant at $P<0.05$.

RESULTS AND DISCUSSION

All of the selected chicks reached adulthood (100% survival). The chicks hatched with black plumage, corroborating the findings of Hancock et al. (1992).

The beak of a newly hatched bird was rectilinear and lightly colored with a small black distal portion (Figure 3A), also as described by Hancock et al. (1992). On the 7th day of life, the proximal portion of the beak became pigmented (Figure 3B), extending into the distal portion (Figure 3C, 3D and 3E) until it became completely pigmented at day 35 (Figure 3F). Olmos and Silva (2001) found that scarlet ibis chicks in the wild had completely dark beaks at only 29-31 days of life. Beak pigmentation has not yet been described in detail in these animals, and it has not yet been related to age for the development of a scoring system. Thus, the beak images obtained at regular intervals in this study enable the estimation of age in scarlet ibis young in captivity. In addition, the beak images can be used to estimate chick age in the wild via a scoring system without the need to approach the nest and manipulate the chicks.

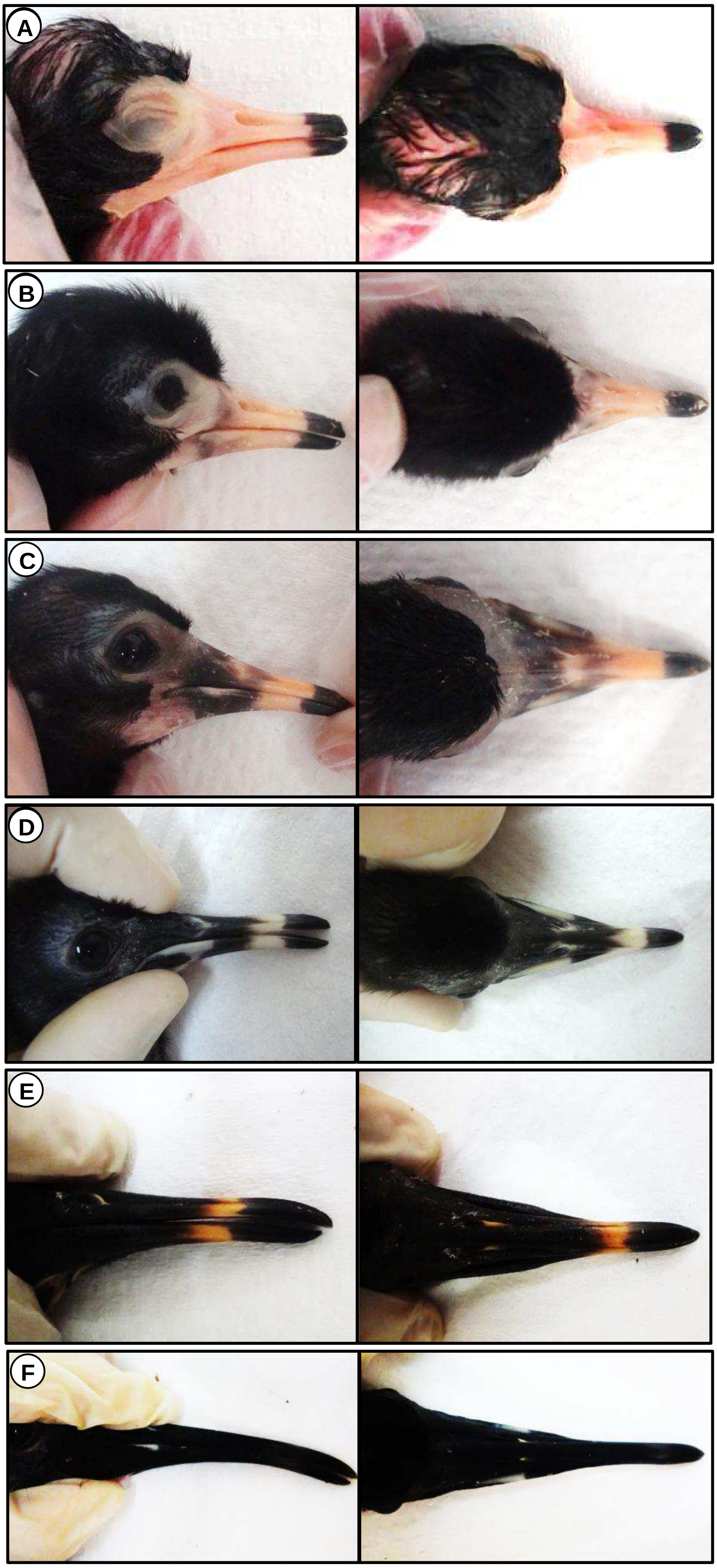

Figure 3 – Images of scarlet ibis chick beaks. (A) A 1-day-old scarlet ibis exhibiting a light beak with black pigmentation in the distal portion only. (B) A 7-day-old scarlet ibis exhibiting the initation of black pigmentation in the proximal region of the beak. (C) A 14-day-old scarlet ibis. (D) A 21-day-old scarlet ibis. (E) A 28-day-old scarlet ibis. (F) A 35-day-old scarlet ibis exhibiting a fully pigmented beak.

For the first time, it was determined that the chicks opened their eyes at 4.73±0.12 days of life. The chicks left the nest, on average, at 15.3±0.68 days of life. According to Olmos and Silva (2001), scarlet ibis chicks in the wild are able to move through the branches surrounding the nest and climb to nearby nests at 11-13 days of life; however, they only become independent of the nest at 20 days of life. Therefore, artificially reared scarlet ibis chicks become nest-independent earlier than wild chicks that were raised by their parents. These parameters – the time of eye opening and behavior – are important for estimating the age of scarlet ibis chicks and evaluating any potential vision or mobility abnormalities during their development.

The scarlet ibis young were weighed daily from hatching until their 42nd day of life, after which the chicks become very active, making it difficult to weigh them. Their mean body weight increased from the 4th to 42nd days of life, with significant weight differences found between days, confirming their weight gain (Table 2). Prior to the 4th day of life, it was likely that the chicks did not gain weight because their physical conditions were still similar to those in the egg, and only after the 4th day of life did food begin to influence their development. A decrease in mean body weight was only observed on the 2nd day of life, but this decrease was not significant and may have been related to yolk absorption.

Table 2 - Means ± standard error of the weights of 15 scarlet ibis chicks monitored from their 1st to 42nd days of life.

Age (days)	Weight (g)	Age (days)	Weight (g)	Age (days)	Weight (g)
1	28.23 ± 0.86^{a}	15	105.40 ± 4.53^{i}	29	338.25 ± 10.19^{q}
2	26.93 ± 0.82^{a}	16	111.40 ± 4.78^{ij}	30	349.69 ± 8.74^{q}
3	27.33 ± 0.74^{a}	17	123.20 ± 6.01^{j}	31	366.08 ± 9.12^{qr}
4	32.73 ± 0.99^{b}	18	142.00 ± 5.80^{k}	32	383.66 ± 9.34^{r}
5	38.42 ± 1.54^{c}	19	152.69 ± 7.91^{kl}	33	393.27 ± 10.88^{r}
6	44.07 ± 1.53^{d}	20	170.38 ± 8.06^{l}	34	407.00 ± 11.15^{rs}
7	50.53 ± 1.89^{e}	21	190.81 ± 8.67^{m}	35	409.63 ± 10.60^{rs}
8	55.86 ± 1.91^{e}	22	208.00 ± 10.44^{mn}	36	436.00 ± 18.79st
9	64.66 ± 2.46^{f}	23	227.53 ± 9.78^{n}	37	447.11 ± 12.30^{t}
10	73.20 ± 2.48^{g}	24	252.38 ± 9.84^{no}	38	456.16 ± 18.70^{tu}
11	80.00 ± 2.57^{gh}	25	265.07 ± 9.79^{op}	39	456.83 ± 14.64^{tu}
12	85.73 ± 2.61^{h}	26	285.30 ± 9.96^{p}	40	478.60 ± 16.89^{tu}
13	95.80 ± 3.16^{i}	27	310.75 ± 9.72^{pq}	41	480.60 ± 11.13^{u}
14	100.60 ± 4.51^{i}	28	313.46 ± 11.12^{q}	42	485.57 ± 19.57^{u}

$^{a-u}$Different letters indicate differences among the means (P<0.05).

In addition to weight gain, the mean radius, tibia and tarsus lengths also increased significantly and were used to characterize the chicks' development (Table 3). The mean unpigmented beak portion decreased (*P*<0.05) during chick development, and beak pigmentation was complete at day 35 (Table 3).

Table 3 - Means ± standard error of length of the radius, tibia, tarsus and unpigmented portion of the beak of 15 scarlet ibis chicks monitored from their 1st to 42nd days of life.

Age (days)	**Radius (mm)**	**Tibia (mm)**	**Tarsus (mm)**	**Beak (mm)**
1	18.92 ± 0.17[a]	25.76 ± 0.23[a]	15.50 ± 0.20[a]	11.0 ± 0.33[a]
7	27.08 ± 0.39[b]	37.53 ± 0.52[b]	22.25 ± 0.37[b]	8.80 ± 0.72[b]
14	41.07 ± 0.95[c]	53.58 ± 0.72[c]	31.83 ± 0.79[c]	3.85 ± 0.49[c]
21	59.76 ± 1.26[d]	70.60 ± 1.02[d]	43.58 ± 0.69[d]	2.40 ± 0.47[d]
28	85.57 ± 1.63[e]	89.16 ± 1.05[e]	57.72 ± 0.97[e]	0.80 ± 0.24[e]
35	103.00 ± 1.06[f]	104.25 ± 1.32[f]	69.50 ± 1.13[f]	0[f]
42	107.62 ± 1.01[g]	115.00 ± 1.27[g]	80.66 ± 1.38[g]	-

[a-g]Different letters indicate differences among the means (P<0.05).

Table 4 shows the equations that relate chick age to body weight, the lengths of the radius, tibia, tarsus and unpigmented portion of the beak. The curves for body weight and bone length were best expressed by the exponential curve model, and the curve for the length of the unpigmented beak portion was best expressed by a second-order polynomial model using the coefficients of determination, intercept values and regression coefficient (*P*<0.05). The relationship between these parameters was found to be significant and highly correlated with age, as indicated by the coefficients of determination (Table 4).

Table 4 – Regression analysis showing the relationship between the age of 15 scarlet ibis chicks and body weight, and the lengths of the radius, tibia, tarsus and unpigmented portion of the beak obtained from their 1st to 42nd days of life.

Regression analysis	**Equation**	**R^2**
Exponential	Age = 5.66 x e^(0.005 x Weight)	0.94
	Age = 1.887 x e^(0.031 x Radius)	0.95
	Age = 1.113 x e^(0.035 x Tibia)	0.95
	Age = 1.424 x e^(0.049 x Tarsus)	0.96
Polynomial	Age = 33.219 - 4.216 x Beak + 0.134 x Beak^2	0.94

R^2 = coefficient of determination.

P<0.05 was used for all the analyses.

The age, body weight and length of the radius, tibia, tarsus and unpigmented beak portion exhibited a high, positive and significant correlation (Table 5), i.e., all the parameters increased with age and thus can be used to estimate the age of scarlet ibis young and evaluate their growth. The unpigmented beak portion is an important parameter for estimating age, particularly if the feeding history of the animal is unknown, as food does not affect beak pigmentation, which is a phenotypic characteristic of chicks.

The high coefficients of determination of the regression analyses (Table 4) and the high correlations found between age, body weight, and radius, tibia, tarsus and unpigmented beak length (Table 5) indicate that these parameters can be used to assess the growth of scarlet ibis chicks and diagnose clinical abnormalities such as growth restriction. Because birds are required to fly as soon as possible, these bones are suitable markers of growth due to the developmental pressure that is exerted on them from flight (Sick, 1997).

Table 5 – Pearson correlation between age, weight and the lengths of the radius, tibia, tarsus and the unpigmented portion of the beak of 15 scarlet ibis chicks monitored from their 1st to 42nd days of life.

	Correlation	**p**
Age, Weight	0.95	<0.0001
Age, Radius	0.98	<0.0001
Age, Tibia	0.99	<0.0001
Age, Tarsus	0.99	<0.0001
Age, Beak	0.96	<0.0001
Weight, Radius	0.97	<0.0001
Weight, Tibia	0.96	<0.0001
Weight, Tarsus	0.97	<0.0001
Weight, Beak	0.85	<0.0001
Radius, Tibia	0.99	<0.0001
Radius, Tarsus	0.99	<0.0001
Radius, Beak	0.93	<0.0001
Tibia, Tarsus	0.99	<0.0001
Tibia, Beak	0.95	<0.0001
Tarsus, Beak	0.93	<0.0001

Hancock et al. (1992), Frederick and Bildstein (1992), Sick (1997), Olmos and Silva (2001; 2003), Stanek (2009) and Moochan (2011) described several phenotypic and behavioral characteristics of scarlet ibis young in the wild. However, previous studies have not described the body weight and biometric measurements of scarlet ibis chicks nor the relationship of these parameters to age, likely due to the difficulty of accessing nests and the risk of chick loss due to handling chicks in the wild. In this sense, artificial rearing facilitated the manipulation of the chicks and reduced the risk of chick loss, which allowed for enhanced study of the species. The results of the present study make it possible to evaluate the growth of artificially raised chicks and estimate the age of scarlet ibis young that have fallen from nests or been rescued by environmental agencies.

CONCLUSIONS

Growth estimation equations were developed to assess the development of artificially reared scarlet ibis chicks by relating chick age to body weight and measurements of the radius, tibia, tarsus and unpigmented portion of the beak. Currently, these are the only such equations available in the literature. Moreover, we have described the feather coloration, beak pigmentation and developmental stages, such as eye opening, initiation of locomotion within the nest and nest-leaving, of scarlet ibis chicks under artificial conditions. Beak pigmentation was found to be a useful parameter for estimating the age of scarlet ibis young from a distance, which has the benefit of not requiring the perturbation of the nest.

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7. CONCLUSÃO GERAL

As dietas com peixe e camarão apresentaram composições nutricionais semelhantes e em maior concentração, garantindo o crescimento dos filhotes. Contudo, os indivíduos que receberam a dieta com peixe atingiram peso e comprimentos dos ossos maiores ao final do trabalho, sendo considerada a dieta mais adequada para criação artificial de filhotes de guarás. A pigmentação do bico revelou-se um parâmetro não influenciado pela alimentação, diferente do peso e ossos.

Os filhotes de guarás foram criados em condições artificiais e o protocolo mostrou-se eficiente proporcionando ambientação e dieta adequadas, o que resultou na intensificação da reprodução, no aumento do número de guarás do parque e no crescimento normal dos filhotes.

A coloração das penas, a pigmentação do bico e fases de desenvolvimento como a abertura dos olhos, a capacidade de locomoção e a saída do ninho foram descritas em condições artificiais. A pigmentação do bico mostrou-se um parâmetro de grande utilidade para estimar a idade de filhotes de guará a distância, não sendo necessária a interferência no ninho. Além disso, foi possível elaborar equações para estimar a idade e avaliar o crescimento de filhotes de guarás criados artificialmente por meio da relação da idade com o peso e as medidas do rádio, da tíbia, do tarso e da porção despigmentada do bico.

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