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Reproductive Ecology of the Brazilian Merganser (*Mergus octosetaceus*) in Serra da Canastra National Park and Adjacent Areas, Minas Gerais, Brazil

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Abstract.—The Brazilian Merganser (*Mergus octosetaceus*) is globally classified as a Critically Endangered species and is one of the world's rarest waterbirds. The breeding ecology of this species was studied between 2005 and 2016 in the region of the Serra da Canastra National Park, Minas Gerais, Brazil. Between two and six nests were followed each year, with mean of 4.1 (n = 18 nests). Mean clutch size was 6.7 ± 0.9 (n = 31 clutches) with a range of five to eight eggs per nest. Average incubation constancy was 88.3% (n = 3 nests) and ranged from 86.7% to 90.7%. Mean incubation temperature and humidity were obtained from three nests and ranged from 33.6 °C to 33.8 °C and 65.9% to 70.2% respectively. The nest success was 77.1%, and the duckling survival (up to 8 weeks) was 53.8%. Nest predation was relatively low at 7.9%, and the annual reproductive output was 4.7 ducklings/female. Data on breeding ecology is fundamental in guiding conservation strategies, both in the field and in captivity. *Received 16 May 2017, accepted 14 July 2017.*

Key words.—Brazilian Merganser, breeding success, clutch size, incubation constancy, incubation rhythm, *Mergus octosetaceus*, nest success.

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The Brazilian Merganser (*Mergus octosetaceus*), the only member of the Mergini tribe still occurring in the Southern Hemisphere, is globally classified as Critically Endangered and is one of the world's rarest waterbirds (International Union for Conservation of Nature 2016). The global population is estimated to be around 250 individuals, and it is likely that a population decline has occurred in recent times due to degradation and habitat loss (Benstead *et al.* 2017) as the species has disappeared from many sites in south central Brazil and nearby regions in Paraguay and Argentina, where it was once found (Collar *et al.* 1992).

One of the few waterfowl adapted to rivers of mountainous regions (Baldassare and Bolen 2006), Brazilian Merganser occurs in low densities in clear waterways, interspersed by rapids and waterfalls, with gallery forest, at altitudes of up to 1,300 m, in both subtropical forest and Brazilian savanna (*Cerrado*) regions (Hughes *et al.* 2006). The species is highly vulnerable to habitat alteration, in particular, water quality degradation through siltation of rivers, which may have been a major cause of the Brazilian Merganser's decline (Hughes *et al.* 2006). Being a visual predator that feeds on fish and invertebrates in clear water streams (Partridge 1956), increased water turbidity is likely to negatively impact food harvesting, ultimately affecting energy budgets and, possibly, essential life history functions.

Current distribution of the species is restricted to three localities in Brazil: Serra da Canastra National Park (NP) (Silveira and Bartmann 2001; Lamas 2006; Lins *et al.* 2011), Chapada dos Veadeiros NP (Bianchi *et al.* 2005) and Jalapão State Park (Braz *et al.* 2003; Barbosa and Almeida 2010). The region of the Serra da Canastra NP is of particular importance as a key area for the Brazilian Merganser, boasting the largest population with an estimated 140 individuals (Benstead *et al.* 2017).

The Brazilian Merganser is a monogamous, sedentary and territorial species (Partridge 1956; Bartmann 1988) and it nests in cavities on river banks (Lins *et al.* 2011). The first nest was recorded by Partridge (1956) in a tree hollow in Misiones, Argentina. Almost half a century later, Lamas and Santos (2004) found the second nest in a rock wall cavity in Serra da Canastra NP. The Serra da Canastra NP has since become an important research area for the species' ecology (Silveira and Bartmann 2001; Lamas 2006; Bruno *et al.* 2010; Lins *et al.* 2011; Ribeiro *et al.* 2011), and especially since 2005, a period when eight nests were recorded, mainly found in ground cavities (Lins *et al.* 2011). Although these records have been fundamental in improving knowledge of the reproductive ecology of this species, several other aspects, such as reproductive success and nest site selection, are still poorly understood.

Our objectives were to present data on the breeding ecology of the Brazilian Merganser and to provide background information to assess future monitoring data within the Serra da Canastra NP region in southeastern Brazil.

Methods

Study Area

Data were collected in Serra da Canastra NP and surrounding areas, Minas Gerais state, Brazil (20° 18′ 16″ S, 46° 35′ 56″ W). The Serra da Canastra NP presents a variety of plant formations typical of the Brazilian savanna (*Cerrado*), such as open savannas, grasslands, rupestrian grasslands and gallery forests. Outside the Serra da Canastra NP, the landscape includes a few mesophyll forests and savanna patches surrounded by pastures and croplands.

The study region consists of a drainage network with numerous tributaries and springs at headwaters of two important Brazilian river basins, the São Francisco and Paraná. The altitude ranges from 700 m to over 1,400 m, the average annual temperature ranges between 22 °C and 23 °C and the average annual rainfall varies between 1,200 mm and 1,800 mm (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis 2005).

Data Collection

Between 2005 and 2016, a total of 18 nests were recorded (Table 1). In these nests, 31 clutches and 14 broods were monitored. We collected data with respect to egg laying, incubation, hatching and fledging. These data were collected mainly through direct observations taken from a blind. The broods were observed from the river's edge and identified from their marked parents. Attempts to locate the birds were made at least weekly. First laid egg dates were obtained either from direct observations or by back-dating. Incubation temperature and humidity were obtained at 5-min intervals using a data logger (Egg Temp-RH; MadgeTech), which was inserted into the oologic chamber during the first days of incubation, and throughout the nesting period ($n = 3$ nests). In the first nest with the data logger (nest M; Table 1), data were recorded between the 2nd and the 33rd day ($n = 32$ days), the second data logger nest (nest P) was recorded between the 7th and the 18th day ($n = 12$ days), and the third data logger (nest Q) was recorded between the 3rd and the 33rd day ($n = 31$ days). We evaluated logger data for four different scenarios: 1) entire duration, including the period the female remained inside the nest and the

Table 1. Activity and reuse of Brazilian Merganser nests in the Serra da Canastra National Park region, Brazil, between 2005 and 2016, where 'Ac' indicates active nest, 'x' inactive nest and 'hyphen' without information. Nests in bold are the nests that were monitored using a data logger.

Nest	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
A	Ac	Ac	Ac	Ac	Ac	x	x	x	x	x	x	x
B	Ac	—	Ac	Ac	Ac	—	—	Ac	—	—	Ac	—
C	—	Ac	x	x	x	x	x	x	x	x	x	x
D	—	Ac	x	x	x	x	x	x	x	x	x	x
E	—	—	Ac	Ac	Ac	x	x	x	x	x	x	x
F	—	—	Ac	Ac	Ac	Ac	Ac	Ac	Ac	x	x	x
G	—	—	Ac	Ac	Ac	Ac	Ac	x	x	x	x	x
H	—	—	—	—	Ac	Ac	x	Ac	x	x	x	x
I	—	—	—	—	—	Ac	x	x	x	x	x	x
J	—	—	—	—	—	—	Ac	x	x	x	x	x
K	—	—	—	—	—	—	Ac	x	—	—	x	x
L	—	—	—	—	—	—	Ac	x	x	x	Ac	x
M	—	—	—	—	—	—	—	Ac	Ac	Ac	Ac	Ac
N	—	—	—	—	—	—	—	Ac	Ac	Ac	x	x
O	—	—	—	—	—	—	—	Ac	x	x	x	x
P	—	—	—	—	—	—	—	—	—	Ac	x	x
Q	—	—	—	—	—	—	—	—	—	—	Ac	Ac
R	—	—	—	—	—	—	—	—	—	—	—	Ac

recess (entire incubation period); 2) duration the female remained inside the nest, excluding recess and the first 30-min duration post entry to the nest (incubation excluding recess); 3) duration the female was outside the nest (recess); and 4) initial 30-min duration post entry to the nest (entry). The length and width of the eggs (*n* = 25 eggs, 3 nests) were measured with a digital caliper, and the volume was calculated according to Hoyt's equation (Hoyt 1979): *volume = 0.51 x (length) x (width)*^{2}. Some of these eggs (*n* = 12 eggs, 2 nests) were marked and weighed with an electronic scale before and after incubation began (weekly weighing) and subjected to weekly egg candling after incubation started. Rainfall data were obtained during the reproductive season (Agritempo 2016). We captured birds using mesh mist nets stretched across the river channel and weighed them with a dynamometer. The mean was calculated from these results, and a value for standard deviation (SD) was produced.

Reproductive Success

We calculated reproductive success based on five different estimates: 1) nest success: the probability that at least one egg in a nest survives the entire incubation period (33 days); 2) egg hatching rate: the probability that an egg that is present at hatching time will hatch successfully; 3) duckling survival: the probability of a duckling surviving for 8 weeks post hatching; 4) brood survival: the probability that at least one duckling in a brood survives for 8 weeks post hatching; and 5) descendant success (from egg to duckling at 8 weeks): the probability that an egg at the start of incubation will produce a chick that survives for 8 weeks post hatching (*descendant success = egg survival probability x egg hatching probability x duckling survival probability*). Eight weeks was defined as the limiting age because in this phase it was still possible to identify each brood from their marked parents, when the ducklings had not yet been observed forming mixed groups of juveniles. All these estimates were calculated as suggested by or adapted from Mayfield (1961, 1975). Daily and period survival rates were calculated for nests and ducklings. The daily survival rates variance was calculated according to Johnson (1979), and the period survival rate variance was obtained using the delta method, as described in Powell (2007). The values are presented with the associated standard error (SE). We estimated dates for unobserved losses under the assumption that they occurred after 40% of the interval, when this interval was greater than 15 days (Miller and Johnson 1978; Johnson 1979). The annual reproductive output per female was calculated from the total number of chicks that left the nest in relation to the number of nesting females. The same female nesting in different years was counted separately.

RESULTS

Egg Laying

From a total of 18 nests recorded during the study period, some were active for more than a single reproductive season (*n* = 10 nests); for example, one nest was used for seven consecutive years (nest F; Table 1), supporting a total of 31 clutches. Between two and six nests were followed each year ($\bar{x}$ = 4.1 ± 1.3). Brazilian Merganser females only nest once a year, and for the duration of the study we did not observe any attempts at renesting. Egg laying occurred on alternate days (*n* = 23 clutches; *n* = 9 nests) and commenced between 12 May and 2 July, with a peak occurring in May (82.6%) during the dry season, when the average rainfall was 35 mm.

In those nests where it was possible to access the oologic chamber (*n* = 16 nests), clutch size was recorded: Range = 5-8, color = light cream to white eggs ($\bar{x}$ = 6.7 ± 0.9; *n* = 31 clutches). Eggs belonging to three of the nests measured from 57.5 mm to 62.5 mm in length ($\bar{x}$ = 60.5 ± 1.2 mm; *n* = 25 eggs) by 40.7 mm to 43.5 mm width ($\bar{x}$ = 42.3 ± 0.7 mm; *n* = 25 eggs). Their volume varied from 51.8 cm^3 to 59.8 cm^3 ($\bar{x}$ = 55.3 ± 2.0 cm^3; *n* = 25 eggs). The egg weight obtained during egg laying ranged from 57.0 g to 60.0 g ($\bar{x}$ = 59.0 ± 0.9 g; *n* = 12 eggs), equivalent to an average approximately 7.9% of an adult female's weight ($\bar{x}$ = 747.3 ± 46.9 g; *n* = 11 females).

Incubation

The weight loss of fertile eggs (*n* = 11) during embryonic development, from egg laying up to four weeks development, averaged 7.0 g, corresponding to 11.9% of the average egg weight during egg laying. The incubation period was recorded from five nests, between 32 days to 34 days ($\bar{x}$ = 33.1 ± 0.7; *n* = 10 clutches). Incubation (*n* = 13 nests) started between May and July, with a mean date of 4 June ± 3 days (SD). Only the female was observed incubating the eggs, at which stage she usually leaves the nest twice a day. The first exit of the day occurred between 06:19 hr and 09:40 hr ($\bar{x}$ = 07:17 hr ± 12 min; *n* = 148 first exits; 15 nests). During the nesting season, the sun rises around 06:40 hr in the Serra da Canastra NP region. The time of the second exit had a greater variation, between 10:12 hr and 15:11 hr ($\bar{x}$ = 12:30 hr ± 30 min; *n* = 102 second exits; 14 nests; Fig. 1). The duration of the first exit

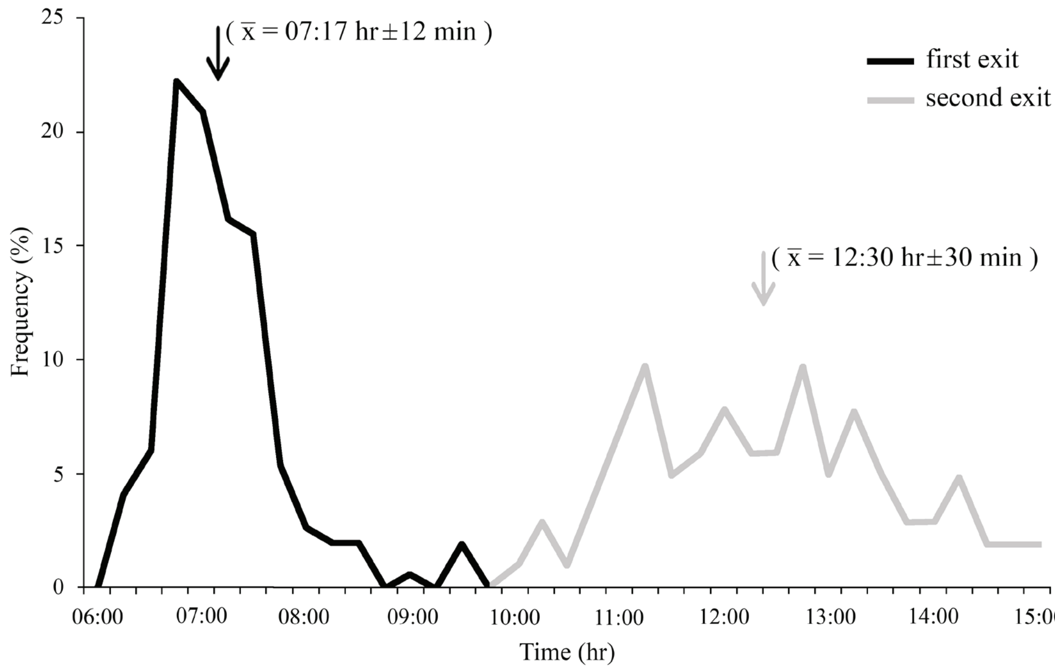

Figure 1. Frequency of female of Brazilian Mergansers exiting nests in the Serra da Canastra region, Brazil: first exit (*n* = 148; 15 nests) and second exit (*n* = 102; 14 nests).

ranged from 28 to 206 min ($\bar{x}$ = 88.2 ± 32.6 min; *n* = 127 first exits; 15 nests), whereas the second exit varied from 35 to 161 min ($\bar{x}$ = 72.1 ± 24.4 min; *n* = 84 second exits; 14 nests).

The incubation rhythm of three females was obtained using data loggers and direct observations (Table 2). One of these females (nest "M") was documented as having a gular tongue protrusion, which is seen when the gular region is pierced and the tongue protrudes through this new opening. Incubation was successful on all three occasions (*n* = 18 ducklings). Mean incubation temperature and humidity of these three nests ranged from 33.6 to 33.8 °C (Table 3) and 65.9 to 70.2% humidity (Table 4), respectively, when considering all logger data registered.

Egg Hatching and Fledging

Hatching success was 89.1% (139/156 eggs, *n* = 23 clutches; 10 nests). A nest reused by the same female during four breeding seasons showed an increasing hatching rate of 37.5%, 57.1%, 75.0% and 85.7%, respectively, from the first to the fourth year. Nest hatching (*n* = 25 events) was between 27 June and 14 August with a peak in July (*n* = 19 events) and a mean date of 13 July ± 11 days. The ducklings left the nest between 06:50 hr and 10:50 hr ($\bar{x}$ = 08:09 hr ± 3 min; *n* = 21 events; 8 nests).

Table 2. Summary of female incubation rhythm in Brazilian Merganser, obtained using data loggers ('M' and 'Q' nests, *n* = 30 days/nest) and direct observation ('A' nest, *n* = 12 days) based on female entry and exit data in the Serra da Canastra National Park region, Brazil.

		Recess Duration (min)			Recess Duration/Day (min)	
Nest	Incubation Constancy (%)	Range (min-max)	Mean ± SD	Recess Frequency/Day	Range (min-max)	Mean ± SD
A	87.6	51-129	93.4 ± 21.8	1.9	102-257	179.0 ± 44.6
M	86.7	45-165	73.5 ± 21.6	2.6	150-255	191.8 ± 27.6
Q	90.7	35-150	69.3 ± 23.4	1.9	70-205	134.0 ± 31.7

Table 3. Brazilian Merganser incubation temperature in the Serra da Canastra National Park region, Brazil. The mean, standard deviation, and minimum and maximum values of each situation are reported. Temperature (°C) was obtained with data loggers.

Nest	Entire Incubation Period	Incubation Excluding Recess	Recess	Entry
M	33.7 ± 2.2 (23.0-37.6)	34.6 ± 0.9 (28.7-37.6)	30.1 ± 2.8 (23.0-35.9)	30.5 ± 2.2 (23.3-34.6)
P	33.6 ± 1.7 (21.2-36.2)	34.1 ± 0.8 (30.4-36.2)	30.2 ± 2.6 (22.8-35.7)	30.9 ± 2.1 (21.2-34.2)
Q	33.8 ± 2.2 (20.9-36.9)	34.4 ± 0.9 (29.2-36.9)	29.5 ± 3.4 (20.9-36.5)	30.3 ± 2.6 (20.9-34.7)

Using data loggers, we recorded an increase of humidity in two nests. Despite the abrupt variation in humidity indicating the hatching event, it was not possible to determine exactly when this alteration occurred, whether at post partial rupture of the eggshell or when the chick completely disengaged from the shell. In nest 'M', hatching appeared to have started at 03:40 hr, when humidity ($\bar{x}$ = 70.0 ± 5.7%; incubation excluding recess) began to rise, reaching 94.0% humidity approximately 3 hr later. At 08:50 hr, with direct observations, it was noted that five out of six chicks hatched. The following day, all of the hatchlings fledged successfully. In nest 'Q', hatching appeared to have started at 10:15 hr, when humidity ($\bar{x}$ = 65.4 ± 5.6%; incubation excluding recess) began to increase, reaching 88.2% humidity 1 hr later. As the female left the nest after this period, we cannot exclude the influence of her returning to the nest 2 hr later, when the highest level of humidity (90.6%) was observed in the nest. The next day, five chicks successfully left the nest.

Reproductive Success

Nest success was 77.1% (Mayfield 1961, 1975; Table 5). The exposure time used in nest success calculations was 764.5 nest-days. During the incubation period, the nest daily survival rate was 0.992 ± 0.003 and the nest survival rate per period was 0.772 ± 0.082. Throughout the study period, we did not observe partial egg losses during the incubation period. Six clutches were totally lost during the incubation phase: three were the result of predation, two were due to the collapsing of the basal portion of the nest where the eggs were solely laid on vegetation deposited in a crack in the rock, and one was lost to human egg collection. Nest predation was 7.9%. Partially lost clutches were not observed. Two other nests were found abandoned during the incubation phase and excluded from the calculations, as these nests were only visited once they were deemed unsuitable for mortality and survival records (Mayfield 1975).

Duckling survival was 53.8% (Mayfield 1961, 1975). The exposure time used in duckling survival calculations was 2,723 chick-days. During the duckling rearing period, the chick daily survival rate was 0.989 ± 0.002 and the chick survival rate per period (reaching 8 weeks of life) was 0.538 ± 0.061. Throughout the study period, we did not observe broods that were completely lost during the 8-week period, generating a brood survival of 100.0%. The descendant success (from egg to duckling at 8 weeks) was 35.9%. Thirty chicks were lost during the rearing period due to unknown causes.

We recorded three predation attempts on Brazilian Merganser adults by the Great

Table 4. Brazilian Merganser incubation humidity in the Serra da Canastra National Park region, Brazil. The average, standard deviation, and minimum and maximum values of each situation are reported. Humidity (%) was obtained with data loggers.

Nest	Entire Incubation Period	Incubation Excluding Recess	Recess	Entry
M	70.2 ± 6.8 (53.5-95.4)	70.0 ± 5.7 (54.7-91.1)	64.9 ± 5.1 (53.5-79.7)	83.5 ± 4.5 (70.6-95.4)
P	69.9 ± 4.6 (56.0-83.4)	69.9 ± 4.1 (57.1-82.2)	65.3 ± 4.0 (56.0-76.5)	77.3 ± 3.1 (67.2-83.4)
Q	65.9 ± 6.9 (49.0-94.7)	65.4 ± 5.6 (51.4-91.1)	62.2 ± 5.7 (49.0-79.8)	83.8 ± 5.1 (70.4-94.7)

Table 5. Brazilian Merganser reproductive success (Mayfield 1961, 1975) in the Serra da Canastra National Park region, Brazil. The numbers for the descendant success estimate are related to observed eggs and ducklings and to losses of eggs and ducklings.

Estimates	Observed	Losses	Reproductive Success (%)
Nest success	38	6	77.1
Egg hatching rate	156	17	89.1
Duckling survival	82	30	53.8
Brood survival	14	0	100.0
Descendant success	204	72	35.9

Black Hawk (*Urubitinga urubitinga*) based on direct observations (n = 2) and images captured by motion video cameras (n = 1; Fig. 2). A total of 179 ducklings from 37 nesting events resulted in an annual reproductive output of 4.7 ducklings/female.

Discussion

The Brazilian Merganser has the smallest clutch size within the genus; other species lay more eggs, ranging from 8-12 eggs in Scaly-sided Merganser (*M. squamatus*; Zhengjie *et al.* 1995) and 9-10 eggs in Common Merganser (*M. merganser*) and Red-breasted Merganser (*M. serrator*; Johnsgard 2010). The existence of long-lasting bonds in breeding pairs, the male actively contributing to parental care, the sedentary behavior and the relatively high duckling survival rate could explain the smaller clutch size of Brazilian Merganser.

It is not possible to make inferences about egg size variation among females from distinct populations, or within the same pop-

Figure 2. Distant (A) and close-up (B) images of a Brazilian Merganser nest in the Serra da Canastra region, where a motion camera trap recorded a Great Black Hawk trying unsuccessfully to access the interior nest cavity for two consecutive days (C and D).

ulation of Brazilian Merganser, as very little is documented in the literature concerning egg size (Lamas and Santos 2004; Barbosa *et al.* 2011). Nevertheless, results obtained in this study are fundamental to creating a database for the species and to investigate further whether intraspecific variation in clutch size, egg size and mass exist.

Total egg weight loss (11.9%) recorded in Brazilian Mergansers between egg laying and the 4th week of incubation, was slightly lower than the average range of 14% to 18% (Afton and Paulus 1992) for birds in general. Nest type and the climatic conditions to which eggs are subjected are thought to play an important role in weight loss. Nests located in cavities, such as those of the Brazilian Merganser, have a milder microclimate, which could account for these results.

Brazilian Mergansers exhibited a high rate of hatching success (89.1%), which reflects the high incubation capacity of the females and the low number of infertile eggs. The increasing hatching rates recorded in one nest reused by the same female could be related to this female's increased incubation experience, as the initial low hatching rate recorded in the first clutch was not due to egg infertility (non-hatched eggs contained embryos that were at about 30 days of development).

Brazilian Mergansers showed a high nest success rate, which in general is higher for waterbirds nesting in cavities in relation to other types of substrate (Baldassarre and Bolen 2006). Many authors calculated nest success including the egg-laying and incubation phases (Grand and Flint 1997; Kellett and Alisauskas 1997; Quakenbush *et al.* 2004), which certainly provide lower estimates, because a significant amount of losses occur during the egg-laying phase (Craik and Titman 2009). We did not record nest loss throughout the egg-laying stage, but this may have occurred in undetected nests. If these losses are infrequent, which seems to be the case, an even higher nest success could be expected for the species if calculated for the egg-laying and incubation periods.

Renesting attempts were not recorded during the study period, although they are commonly observed in many Mergini species (Johnsgard 2010). This may be related to the female's difficulty in finding a suitable new cavity or to the fact that all nests were abandoned or destroyed during the egg incubation phase, when most of the nesting process had already taken place and the female's energy investment is much higher.

Observed nest predation was low, at less than 10%, and may not have a significant impact on the Brazilian Merganser population in the Serra da Canastra NP region, especially when associated with high egg hatching rates. Estimates of reproductive success obtained from this study represent a first step toward future research on species demographics and can facilitate a better understanding of population dynamics and possible stability deviations within species populations, which are key to predicting extinction risk (Saether and Bakke 2000). Considering the threats to Brazilian Mergansers, such research is of paramount importance in providing information to policy makers and developing plans for efficient management strategies.

Despite the relatively small clutch size, the high hatching rate, high nest and duckling survival rates, and low nest predation that was observed in this study, the overall result was a relatively high annual reproductive output per female. These strong vital statistics are important for a species to be successful. However, water quality degradation, in particular from soil erosion and silting of rivers and streams, is widespread and is likely the single most prevalent factor impacting the Brazilian Merganser throughout its range. Clear stretches of streams and rivers have become quite rare outside national parks and nature reserves as a result of the fast agricultural development throughout the Brazilian savanna (Bartmann 1988). Hydrological impacts from river dams are also considered threat factors of critical importance to the conservation of the species. Therefore, the greatest obstacle to population growth of Brazilian Mergansers appears to be related to increasing habitat loss, which could limit the establishment of new territories by offspring.

Incubation rhythms described in this study were similar to those reported by Afton and Paulus (1992) for Mergini, with incubation constancy of 86.7%, 2.4 nest exits per day and 191 min of daily recess. Intraspecific differences in duration and/or frequency of recess are likely related to abundance and distribution of food resources in each territory, as well as the ability to obtain these resources, as most of the recess is spent feeding (an average of 63% for Mergini; Afton and Paulus 1992). Therefore, higher daily recess frequency of the female of nest "M" is probably related to its physical condition.

The 35.6 °C average internal egg temperature of 22 waterbird species (Afton and Paulus 1992) is similar to the mean temperature recorded for Brazilian Mergansers in this study (33.7 °C). Information on the abiotic environment within nests (temperature, humidity, incubation constancy) is fundamental for the implementation of effective species conservation, particularly in helping to facilitate the Brazilian Merganser captive-breeding program, initiated in 2011, as an important conservation tool for such a critically endangered species.

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Literature Cited

Afton, A. D. and S. L. Paulus. 1992. Incubation and brood care. Pages 62-108 *in* Ecology and Management of Breeding Waterfowl (B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec and G. L. Krapu, Eds.). University of Minnesota Press, Minneapolis, Minnesota.

Agritempo. 2016. Sistema de monitoramento agrometeorológico. Embrapa Informática Agropecuária and Centro de Pesquisas Meteorológicas e Climáticas Aplicadas à Agricultura (Cepagri), Universidade Estadual de Campinas, Campinas, Brazil. http://www.agritempo.gov.br/, accessed 1 July 2016. (In Portuguese).

Baldassarre, G. A. and E. G. Bolen. 2006. Waterfowl ecology and management. Krieger Publishing Company, Malabar, Florida.

Barbosa, M. O. and M. L. Almeida. 2010. Novas observações e dados reprodutivos do pato-mergulhão *Mergus octosetaceus* na região do Jalapão, Tocantins, Brasil. Cotinga 32: 40-45. (In Portuguese).

Barbosa, M. O., R. T. Pinheiro and V. F. Carvalho. 2011. Descrição de ninhos do pato-mergulhão *Mergus octosetaceus* em cavidade arbórea na região do Jalapão, Tocantins, Brasil. Cotinga 33: 71-75. (In Portuguese).

Bartmann, W. 1988. New observations on the Brazilian Merganser. Wildfowl 39: 7-14.

Benstead, P., J. Bird, S. Butchart, R. Calvert, D. Capper, R. Clay, J. M. Barnett, J. Pilgrim, C. J. Sharpe, A. Symes and others. 2017. Brazilian Merganser *Mergus octosetaceus*. BirdLife International, Cambridge, U.K. http://datazone.birdlife.org/species/factsheet/brazilian-merganser-mergus-octosetaceus/text, accessed 5 April 2017.

Bianchi, C. A., S. Brant, R. A. Brandão and B. F. Brito. 2005. New records of Brazilian Merganser *Mergus octosetaceus* in the Rio das Pedras, Chapada dos Veadeiros, Brazil. Cotinga 24: 72-74.

Braz, V. S., T. L. S. Abreu, L. E. Lopes, L. O. Leite, F. G. R. França, M. M. Vasconcellos and S. F. Balbino. 2003. Brazilian Merganser *Mergus octosetaceus* discovered in Jalapão State Park, Tocantins, Brazil. Cotinga 20: 68-71.

Bruno, S. F., R. D. Andrade, L. V. Lins, R. Bessa and S. E. Rigueira. 2010. Breeding behaviour of Brazilian Merganser *Mergus octosetaceus*, with a tree-cavity nest in Serra da Canastra National Park, Minas Gerais, Brazil. Cotinga 32: 27-33.

Collar, N. J., L. P. Gonzaga, N. Krabbe, A. Madroño Nieto, L. G. Naranjo, T. A. Parker and D. C. Wege. 1992. Threatened birds of the Americas: the ICBP/IUCN red data book. International Council for Bird Preservation, Cambridge, U.K.

Craik, S. R. and R. D. Titman. 2009. Nesting ecology of Red-breasted Mergansers in a Common Tern colony in eastern New Brunswick. Waterbirds 32: 282-292.

Grand, J. B. and P. L. Flint. 1997. Productivity of nesting Spectacled Eiders on the lower Kashunuk River, Alaska. Condor 99: 926-932.

Hoyt, D. F. 1979. Practical methods of estimating volume and fresh weight of bird eggs. Auk 96: 73-77.

Hughes, B., B. Dugger, H. J. Cunha, I. Lamas, J. Goerck, L. Lins, L. F. Silveira, R. Andrade, S. F. Bruno, S. Rigueira and Y. Barros. 2006. Action plan for the conservation of the Brazilian Merganser *Mergus octosetaceus*. Brazilian Environmental Ministery (MMA)/Brazilian Environmental Agency (IBAMA), Brasília, Brazil.

Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA). 2005. Plano de manejo do Parque Nacional da Serra da Canastra. Unpublished report, Ministério do Meio Ambiente (MMA)/Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), Brasília, Brazil. (In Portuguese).

International Union for Conservation of Nature (IUCN). 2016. The IUCN red list of threatened species, v. 2016-3. BirdLife International, Gland, Switzerland. http://www.iucnredlist.org/, accessed 5 April 2017.

Johnsgard, P. A. 2010. Ducks, geese, and swans of the world. University of Nebraska Press, Lincoln, Nebraska.

Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96: 651-661.

Kellett, D. K. and R. T. Alisauskas. 1997. Breeding biology of King Eiders nesting on Karrak Lake, Northwest Territories. Arctic 50: 47-54.

Lamas, I. R. 2006. Census of Brazilian Merganser *Mergus octosetaceus* in the region of Serra da Canastra National Park, Brazil, with discussion of its threats and conservation. Bird Conservation International 16: 145-154.

Lamas, I. R. and J. P. Santos. 2004. A Brazilian Merganser *Mergus octosetaceus* nest in a rock crevice, with reproductive notes. Cotinga 22: 38-41.

Lins, L. V., R. D. Andrade, F. Ribeiro and S. E. Rigueira. 2011. Distribuição e biologia reprodutiva do pato-mergulhão (*Mergus octosetaceus*) na região da Serra da Canastra, Minas Gerais. MG Biota 4: 4-33. (In Portuguese).

Mayfield, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73: 255-261.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87: 456-466.

Miller, H. W. and D. H. Johnson. 1978. Interpreting the results of nesting studies. Journal of Wildlife Management 42: 471-476.

Partridge, W. H. 1956. Notes on the Brazilian Merganser in Argentina. Auk 73: 473-488.

Powell, L. A. 2007. Approximating variance of demographic parameters using the delta method: a reference for avian biologists. Condor 109: 949-954.

Quakenbush, L., R. Suydam, T. Obritschkewitsch and M. Deering. 2004. Breeding biology of Steller's Eiders (*Polysticta stelleri*) near Barrow, Alaska, 1991-99. Arctic 57: 166-182.

Ribeiro, F., L. V. Lins, V. M. Gomes, F. H. Nery and E. S. Reis. 2011. Dispersão e maturidade sexual de *Mergus octosetaceus* Vieillot 1817 na região da Serra da Canastra, Minas Gerais, Brasil. Revista Brasileira de Ornitologia 19: 391-397. (In Portuguese).

Saether, B.-E. and O. Bakke. 2000. Avian life history variation and contribution of demographic traits to the population growth rate. Ecology 81: 642-653.

Silveira, L. F. and W. Bartmann. 2001. Natural history and conservation of the Brazilian Merganser *Mergus octosetaceus* at Serra da Canastra National Park Minas Gerais, Brazil. Bird Conservation International 11: 287-300.

Zhengjie, Z., X. Han, S. Zhang, J. Wu and Z. Piao. 1995. Breeding ecology of the Chinese Merganser in the Changbai Mountains, China. Journal of Field Ornithology 66: 54-59.