
VOL. 280 NOS. 1–4, 1 AUGUST 2008
ISSN 0044-8486
ELSEVIER
Aquaculture

Aquaculture 280 (2008) 264–266

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

Short communication

Broad snouted caiman (*Caiman latirostris*) growth under different rearing densities

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ARTICLE INFO

Article history:
Received 17 December 2007
Received in revised form 19 April 2008
Accepted 20 April 2008

Keywords:
Crocodiles
Caiman latirostris
Raising density
Growth rate
Ranching

ABSTRACT

The effect of density on growth in body mass (BM) and total length (TL) of *Caiman latirostris* hatchlings raised in small pens (area 0.36 m^2), for 3 months, was investigated. Twelve animals from each of three clutches were randomly distributed (1, 2 or 3 individuals) to two replicates at low rearing density (LRD: 0.12 m^2/individual), medium rearing density (MRD: 0.06 m^2/individual) and high rearing density (HRD: 0.04 m^2/individual. Growth at LRD [BM: 150.75±43.83 g (SE); TL: 11.58±0.93 cm] and MRD (BM: 141.96±22.55 g; TL: 8.38±1.26 cm) was significantly more than at HRD (BM: 57.19±14.38 g; TL: 4.61±0.89 cm; $p<0.001$). Density is important to achieving optimal growth and maintaining the well-being of *C. latirostris* in commercial ranching programs.

1. Introduction

Crocodilians are components of Latin America's tropical wetlands which have both ecological and economic values. Excessive exploitation has led to population declines and increased risks of extinction for many crocodilian species worldwide (Ross, 1995, 1998), however, sustainable use of strategies have encouraged the rebuilding and conservation of wild crocodilian populations and their habitats (Messel et al., 1995; Ross, 1995). Over the last 20 years, unregulated exploitation and illegal trade of crocodilians has been largely replaced by managed sustainable exploitation and legal trade.

Two crocodilian species are found in Argentina, *Caiman latirostris* (Broad-Snouted Caiman) and *Caiman yacare* (Yacare Caiman). These species share most of their distribution in the northeastern region of Argentina, but *C. latirostris* extends further south than *C. yacare* because it exhibits a greater tolerance of low temperatures and occupies a greater diversity of environments (Siroski, 2004). In Argentina, *C. latirostris* inhabits the provinces of Jujuy, Salta, Formosa, Santiago del Estero, Entre Ríos, Santa Fe, Corrientes, Chaco and Misiones (Yanosky, 1990; Siroski, 2004).

Since 1990, a conservation program for *C. latirostris* called Proyecto Yacaré (PY; Conv. Gob. Santa Fe/MUPCN) has been active in Santa Fe Province. It involves sustainable use through ranching, in which wild eggs are harvested, artificially incubated and the hatchlings are raised in captivity. A percentage are reintroduced into the wild at ten months of age being approximately seven times larger (BM) than wild animals of the same age. The remainders are used for commercial purposes (Larriera and Imhof, 2006).

All animals housed in artificial habitats are confronted by a wide range of potentially problematic environmental challenges (Morgan and Tromborg, 2007). With captive crocodilians, avoiding environmentally induced "stress", particularly in the first year of life, is critical to the maintenance of good health, high survivorship, high and normally distributed growth rates, and resistance to parasites and pathogens (Shotts et al., 1972; Brisbin, 1982; Hutton and Webb, 1993; Smith and Marais, 1994; Turton et al., 1997; Rooney and Gillette, 2000; Franklin et al., 2003). Density has been demonstrated as an important species-specific aspect of the rearing environment (Webb et al., 1983; Elsey et al., 1990a, 1990b), with crowded conditions generally favoring poor growth performance (Lance, 1990; Elsey et al., 1990a; Guillette et al., 1995), and higher rates of both injuries from biting and mortality (Siroski et al., 2006), which affects the value of the skin (Webb et al., 1983; Elsey et al., 1990a). This study quantifies for the first time the effects of different rearing densities (the density of individuals held within an enclosure, called here 'rearing density', RD′) on growth of *C. latirostris*.

2. Materials and methods

The study was carried out in six plastic chambers (80 cm long, 45 cm wide and 30 cm high), each with a surface area of 0.36 m^2 and fitted with a plastic lid. The chambers were tilted to give 70% dry and 30% water surface areas, with a maximum water depth of 15 cm, approximately. Water temperatures were maintained at 31±0.5 °C

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doi:10.1016/j.aquaculture.2008.04.032

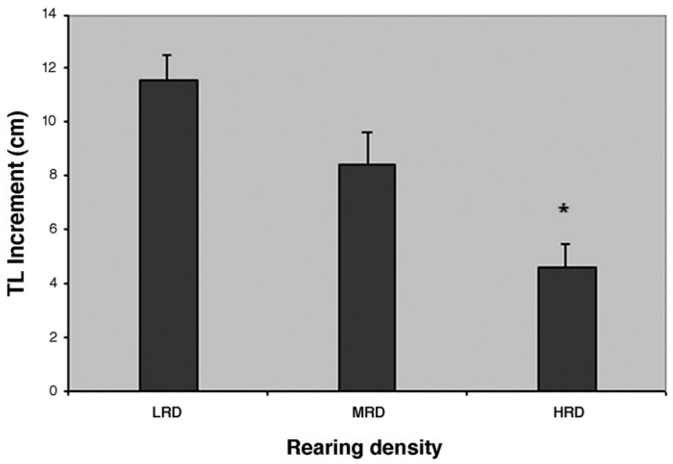

Fig. 1. Increase in total length (TL) of juveniles *C. latirostris* maintained at different rearing densities over three months. LRD: low rearing density, MRD: medium rearing density, HRD: high rearing density. Error bars represent standard error of the mean.*Statistically significant relative to LRD (p=0.002) and MRD (p=0.037). There was not significant difference among LRD and MRD (p=0.241). ANCOVA–Tukey's *post hoc* test.

with thermostatically-controlled aquarium heaters in the water, and were monitored with Hobbo Temperature recorders (Onset Computer Corporation, Pocasset, MA, USA).

Thirty six *C. latirostris* approximately five months old, from three different artificially incubated clutches, were selected for the study. They were similar in size and apparently healthy. All the conditions used for the rearing of the caimans since hatching in pools at PY commercial husbandry facilities (temperature, food composition, food and cleaning regimes, etc.; Larriera and Imhof, 2005) were maintained identically during the experiment except for the rearing density. Each animal was individually marked with webbing tags (Monel Natl Band and Tag CO., Newport, Kentucky, USA, 1005-1), and one, two or three from each clutch were assigned to each of two replicates of low raising density (LRD; N=3; 0.12 m^2 per individual), medium raising density (MRD; N=6; 0.06 m^2 per individual) or high raising density (HRD; N=9; 0.04 m^2 per individual).

Animals were fed three times a week with a mixture of 60% minced chicken heads and 40% dry pellets. Excess food was offered to each density group depending on the number of animals in them to ensure that all had the opportunity to feed. The amount of food given was increased as the experiment progressed and animals grew, and the tanks were cleaned after feeding. Body mass (BM, nearest 0.1 g) and total length (TL, nearest 0.5 cm) were measured at the beginning and the end of the study. None of the caimans lost the tip of the tail during the study, so TL was an appropriate measure of length.

Data were tested for normality with Kolmogorov–Smirnov test and homogeneity of variances between groups was verified by Levene test. The initial size of animals was analyzed using a one-way ANOVA with density and clutch as grouping variables, and BM and TL as response variables. The growth of BM and TL (final minus initial values) were was analyzed by ANCOVA, with density and clutch as grouping variables, initial BM and TL as co-variables, and the change in BM and TL as response variables. Significant differences among groups were detected by Tukey's Test. Results are expressed as means ± standard error. BM units are in grams and TL in centimetres (SPSS for Windows, 2005).

3. Results

There was no significant difference between treatments in the initial BM (p=0.492) or TL (p=0.432), and nor were there any significance clutch effects on initial BM (p=0.969) or TL (p=0.722).

Neither mortality nor injuries caused by caimans biting each other were observed during the experiment in any of the three density groups. The mean increases in BM and TL after three months were inversely correlated with density (Figs. 1 and 2). At HRD (growth in BM: 57.19 ± 14.38 g; growth in TL: 4.61 ± 0.89 cm) growth was significantly less (p<0.05) than at MRD (BM: 141.96 ± 22.55 g; TL: 8.38 ± 1.26 cm) or LRD (BM: 150.75 ± 43.83 g; TL: 11.58 ± 0.93 cm) which were not significantly different from each other (BM: p=0.971; TL: p=0.241).

No significant clutch effects were apparent on the increase in BM or TL (p>0.05), and no interaction between raising density and clutch was observed in either BM or TL (p>0.05). Nor was the growth in BM or TL significantly influenced by initial BM or TL (p>0.05).

Most of the animals increased in both TL (88.8%) and BM (88.8%) over the 3 months, but some (N=4; 11.2%) lost weight. This occurred in the HRD (N=3; 16.66% of the animals in the group) but also in the LRD in the same percentage of animals (N=1; 16.66%). It was noted that the skin coloration of some individuals in all three treatments became lighter as the experiment progressed, but the change in color was not quantified.

4. Discussion

Within the context of the experimental raising chambers used here, density of *C. latirostris* was inversely correlated with growth of BM and TL. At HRD the growth in BM and TL was significantly retarded relative to LRD and MRD. The same trends were apparent between LRD and MRD treatments, but they did not reach statistical significance. This may in part reflect the small sample sizes and the increased variance in the results due to some individuals, in the LRD and HRD, failing to thrive and losing weight. Elsey et al. (1990a) reported that growth in juvenile *A. mississippiensis* was inversely proportional to stocking density, although Joanen and McNease (1987) found no difference between two groups of juvenile female *A.mississippiensis* raised at different densities. Webb et al. (1983, 1992) reported a similar inverse relationship between growth rate and rearing density in Australian freshwater crocodiles (*C. johnstoni*) and saltwater crocodiles (*C. porosus*) respectively.

Elsey et al. (1990a) recommended a density not less than 0.18 m^2/animal for rearing juvenile alligator (7–10 months old) which is lower than those densities considered acceptable in our study for the rearing of *C. latirostris* at the same age (0.06–0.12 m^2/ind.). Probably, these differences are due to the fact that *A. mississippiensis* are larger than *C. latirostris* at the same age. According to our results, Joanen and McNease (1987) suggested an optimum raising density of 0.1 m^2/alligator during the first year of life while Webb et al. (1983) recommended a density of 0.06–0.1 m^2/ind. for *C. johnstoni* in the first three months of life and then reduce it to 0.1–0.2 m^2/ind. until the first year. On the other hand, Webb et al. (1992) reported a density not less than 0.09 m^2/animal for rearing

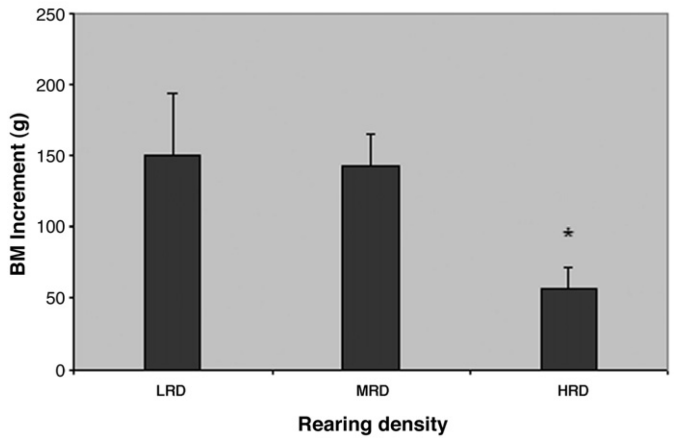

Fig. 2. Increase in body mass (BM) of juveniles *C. latirostris* maintained at different rearing densities over three months. LRD: low rearing density, MRD: medium rearing density, HRD: high rearing density. Error bars represent standard error of the mean. *Statistically significant relative to LRD (p=0.036) and MRD (p=0.015). There was not significant difference among LRD and MRD (p=0.971). ANCOVA–Tukey's *post hoc* test.

C. porosus during the first month of life. Although this density is similar to those producing better growth in *C. latirostris* at 6–7 months of age in our study, there is again an important difference in size between the two species.

The observation is commonplace that in any crocodilian clutch, some hatchlings grow much slower than others. With *A. mississippiensis*, Elsey et al. (1990a) reported all juveniles at three density treatments they tested showing positive growth. Yet this was not the case with *C. johnstoni* (Webb et al., 1983), *C. porosus* (Webb et al., 1992) nor with the *C. latirostris* tested here. In all three species some individuals failed to thrive and lost weight. With *C. latirostris*, the number of non-growing animals was higher in the HRD ($N=3$) than in the LRD ($N=1$). However, this different distribution of non-growing animals cannot totally explain the less growth reached at the HRD group, because both HRD and LRD groups had exactly the same percentage of non-growers (16.66%) and the absence of them in the MRD group did not produce a significantly higher growth compared to the LRD. Social interactions between individuals are involved, and with *C. porosus* (Webb et al., 1992), the density treatments that give the fastest growing individuals also give the highest proportion of animals that do not thrive. With *C. johnstoni*, lower densities are also associated with higher food conversion rates (Webb et al., 1983). Conversion of food to body weight is a variable that appears to be compromised for a number of species when housed in small enclosures (Morgan and Tromborg, 2007).

In our study, animal growth was not influenced by either clutch effect or initial size of the animals. Likewise, Webb et al (1983) found no relation between growth rate of juvenile *C. johnstoni* and initial size. Contrary to these results two studies made in *C. porosus* have shown that growth of animals under controlled conditions is closely related to initial size and shows a pronounced clutch effect (Riese, 1991 in Webb et al., 1992; Webb et al., 1992).

With *C. latirostris* and other species, selecting optimal densities for promoting fast growth is advantageous from both conservation and commercial perspectives. Fast-growing healthy individuals released back to the wild can rapidly reach a size at which they are less vulnerable to predators, thereby enhancing survival (Brandt, 1991; Elsey et al., 1992; Larriera et al., 2004; Larriera and Imhof, 2006). In commercial raising, increasing growth rates reduces the time animals need to be maintained in captivity, which reduces the extent of facilities and costs of maintenance.

The lack of a significant difference in *C. latirostris* growth at the LRD and MBD treatments here may indicate confounding effects as a consequence of an increased variance produced by the negative growth of one caiman at the LRD. However, the possibility that a density threshold exists, where crowding has major and minor effects on growth, cannot be rejected.

5. Conclusion

Our findings indicate that rearing density is an important factor to consider when rearing caimans in order to obtain optimal growth. Of the three densities tested, one individual per 0.12 m^2 provided the highest mean growth rates and 0.04 m^2 per individual the lowest. However there was little difference between densities of 0.12 m^2 and 0.06 m^2 per individual and so it may constitute the best economic option for raising in the short-term.

Acknowledgments

This study was supported by Yacarés Santafesinos/Proyecto Yacaré (Min. Prod./MUPCN). We would like to thank all other members of Proyecto Yacaré for their help in this study. We appreciate comments made by Mark Merchant, PhD on the original English version of the manuscript. We are also grateful to the anonymous referees for their constructive comments on the manuscript. G.L.P. is a doctoral fellow from CONICET, Argentina.

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