DEFINING BREEDING OBJECTIVES FOR SALTWATER CROCODILE GENETIC IMPROVEMENT PROGRAMS

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SUMMARY
Genetic improvement of crocodilians is a novel concept. Here, breeding objectives for such a program are proposed and discussed in relation to the biological constraints inherent within the production system. The main source of income is the sale of skins, with meat as the major by-product. Skins are sold according to a grading system. Objectives to increase the production efficiency of crocodile farms include: number of hatchlings per female per year, survival rate, food conversion efficiency, and age to slaughter (growth rate). In the future, skin “quality” (scale row number and regularity, shape and thickness) could also become important.
Keywords: Breeding objectives, *Crocodylus porosus*, crocodile

INTRODUCTION
Crocodile production for the lucrative skin trade is an emerging industry. To date, research in the industry has concentrated on improved management and husbandry techniques, such as nutrition and housing, to improve production efficiency. No research has yet been conducted into the possibility of genetic improvement in captive breeding populations. This paper represents a first attempt to identify breeding objectives. It also aims to sustain the enthusiasm for such an initiative indicated in a recent (unpublished) industry survey.

MacNamara *et al.* (2003) recently reviewed the Australian crocodile industry. Briefly, it is based on the production of skins from the saltwater crocodile (*Crocodylus porosus*), with meat produced as a by-product. Stubbs (1998) estimated the total value of production at A$5 million per annum, with skins contributing A$4 million of this total. Producers are paid per cm belly width with the industry-accepted optimum belly width ranging between 32-42cm (at 1.3-2.0m total length) (MacNamara *et al.* 2003). It takes between two and five years for crocodiles to reach this size. Skin prices are determined through a grading system: skins with no blemishes are classified as 1st grade, while skins with imperfections such as bite marks, abrasions and knife holes are classified as 2nd, 3rd and 4th grade, depending on the extent of imperfections. Currently, the Australian industry is small in relation to world trade (MacNamara *et al.* 2003). Webb (1989) stressed the importance of improving the efficiency of the industry.

DISCUSSION
Here we attempt to identify breeding objectives as a prelude to estimation of relevant genetic and phenotypic parameters, as well as economic values for the breeding objectives. As part of a larger

study to evaluate the potential of implementing genetic improvement programs on saltwater crocodile farms, the following breeding objectives were identified in relation to gross returns and costs.

Gross Returns. Gross returns are determined primarily by skin grade, as assessed by commercial buyers. Skin grade mainly reflects physical damage to the skin (bites and abrasions). The quantity of meat produced per animal is also a breeding objective, although it contributes substantially less return per animal than skins.

Skin Grade. The largest concern of buyers of crocodile skins is the high proportion of skins failing the requirements for 1st grade classification (Manolis *et al.* 2000). Typically, only around 30% meet this grade, although MacNamara *et al* (2003) reported up to 50%. It is essential to improve the average grade to meet market demand.

The issue of skin grades is complex. Since the industry is still developing, much of the downgrading of skins is likely to be caused by inappropriate husbandry/management techniques, such as inappropriate stocking densities and pen designs. It is possible that crocodile behaviour, especially fighting, could also affect skin grade. Anecdotal evidence suggests that some clutches are more "aggressive" than others, even at the time of hatch, implying a familial and possibly genetic basis for the differences in aggressive behaviour.

Quantity of Meat Produced. A 1.5m crocodile will yield around 4-5 kg of boneless flesh. Treadwell *et al.* (1991) reported a yield of 7-10 kg, but this is probably based on whole (bone-in) carcases, the form in which meat was marketed at that time. The majority of fat is contained in the inner portion of the tail and as a "fat body" in the abdominal cavity (Richardson *et al.* 2002). Fat levels are difficult to measure on live animals, although measuring tail girth has been proposed as a possible selection criterion for future investigation. The quantity of meat produced is also perceived as antagonistic to skin production. However, selection indexes are designed to accommodate such antagonisms.

Costs. Breeding objectives aimed at minimising the costs of production are: high offspring output from breeder stock, high survival, food conversion efficiency and decreased age to slaughter. Since the industry is still at a developmental stage, research has concentrated on improving nutrition (for example, pelletised food) and improved environmental raising conditions (for example, appropriate water temperatures), again with no investigation into genetic sources of variation.

Breeder Output. The maintenance of breeding stock is a substantial cost in crocodile production. Pen construction is a major cost item, particularly where breeding pairs are maintained to optimise hatchling production per female. Females can produce between 25 and 30 hatchlings per year (Treadwell *et al.* 1991). Of course, the actual clutch size laid is greater than the number of live hatchlings produced, due to egg infertility and embryonic mortality. If higher hatch rate could be realised, this would allow a reduction in breeder overheads.

Again, no investigation has been completed into selection criteria for annual breeder output of finished animals. This is a complex trait requiring evaluation of fertility, age of female and male at breeding, environmental conditions prior to hatch and survival of the embryo to hatching.

Survival. Webb (1989) recommended that survival should be at least 95% in the first year (between hatching and one year) and at least 95% between one year old and slaughter (~3.5 years). In reality, very few farms achieve such high survival rates, and there is large variation in this trait. This large variation is definitely affected by management regimes and husbandry factors, but genetic effects may also impact.

Food Conversion Efficiency. It has been estimated that 42-45% of the operating costs of crocodile production is accounted for by feed (Treadwell *et al.* 1991). Therefore, an increase in food conversion efficiency should be a major breeding objective. Treadwell *et al.* (1991) also reported that on average, a crocodile harvested at 1.5m should have consumed a total of 120kg of food. Feed costs themselves are extremely variable between farms mainly due to the location and source of cheap protein. Although food conversion efficiency has been estimated in biological and production-based studies, it has not been genetically analysed in relation to growth rate.

Age to Slaughter. The majority of juveniles reach harvest size in captivity within 3.5 years (Treadwell *et al.* 1991), and most of the variation in age to slaughter has been reported to occur through clutch-specific effects (for example Manolis *et al.* 1989). Treadwell *et al.* (1991) determined that a decrease in the average age of slaughter by one year from 3.5 to 2.5 years would increase the internal rates of return by 250% using a small breeding farm model. Although there are no genetic parameter estimates yet available, there does appear to be sufficient genetic variation among animals to begin selecting for faster growth rates (unpublished data).

Skin quality- a trait of future importance? Skin quality, reflecting inherent properties of the hide such as shape and thickness, is subjectively determined and is not rewarded under the current marketing system. Saltwater crocodile skins, with their relatively small scales, evenly distributed belly-scale pattern, lack of bone deposits in the belly scales, attract a premium price in comparison to other crocodilian skins. This implies that improvements in these characteristics would be desirable within saltwater crocodiles. Manolis *et al.* (2000) conducted a survey of persons involved in all aspects of the crocodile skin industry in an effort to understand the issues that face producers of saltwater crocodiles to enhance their product. Four "quality" concerns that could be influenced by genetic selection were raised: skin shape, skin thickness, regularity of scale pattern and number of scale rows between the vent and the neck.

Wild-harvested crocodiles are considered by buyers to have a superior skin shape and skin thickness compared to their captive counterparts (Manolis *et al.* 2000). They are narrower per unit length and have less wastage during product manufacture (Manolis *et al.* 2000). By comparison, captive-raised crocodiles can be obese and show signs of stretching between the ventral scales. Extensive experience in other animal industries has shown that obesity is very amenable to selective improvement. Captive crocodiles grow faster than those in the wild, which may affect the thickness of the skin.

At present, a premium price is not offered for skins with superior scale pattern regularity or number of scale rows. Manolis *et al.* (2000) investigated the inheritance of the number of scale rows but did not report any genetic parameter estimates. It is likely that scale row number and regularity could be considered as future selection objectives although there is currently no market reward for these traits.

CONCLUDING REMARKS

Feedback from the industry so far has been extremely positive (unpublished survey results) with most producers welcoming the concept of a genetic improvement program and its potential benefits. Some producers have expressed concerns that improving efficiency through genetic selection is premature and that the research focus should remain on husbandry-related issues. However, optimal improvement of productivity within the industry can best be achieved by simultaneous improvement of the genetic value of the stock and their husbandry. This paper represents the first attempt anywhere to comprehensively define breeding objectives for the crocodile industry and is thus an important first step towards improving the basic resources and productivity of this industry.

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