

Despite many predictions to the contrary, one outstanding result of the market-driven conservation of crocodilians is that illegal trade has all but been eradicated by supply from well-regulated legal trade. Both government and business have worked against illegal trade as it compromises investment in management, production and conservation (Anon, 1998).

## THE RACE TO REGULATION

The exploitation of crocodilian resources is largely a sovereign national issue, but although the wild resources most often originate in developing countries, processing and the markets for finished products are located mainly in the more affluent industrialised nations (Brazaitis, 1989) most of which are OECD members. International trade is fundamental to programmes and thus CITES<sup>7</sup>, the convention that controls international trade in wild species in order to prevent them from becoming endangered, impacts on all operations. Enthusiasts of CITES as a conservation tool point to crocodilians as a success story for the convention. Others question whether the gains have been made because of CITES or despite it (e.g. Kievit, 2000). Regardless, there is no doubt that the way that the way in which CITES has impacted upon crocodilians is central to any discussion of the regulated exploitation of these animals. Country after country has had to experience the rigours of international scrutiny before their crocodilians could be transferred from Appendix I to Appendix II of CITES so that market mechanisms could be mobilised for conservation.

Although empirical information is limited, conventional wisdom holds that, as recently as the early 1970s, over two million crocodilian skins were traded each year. The vast majority, perhaps as many as 1.5 million, were caiman *Caiman crocodilus*<sup>8</sup> originating in Bolivia, Brazil, Paraguay and Venezuela. The balance was made up of alligator skins from the USA and crocodile skins from many other parts of the world (e.g. Brazaitis, 1989). When CITES came into force in 1975, all crocodilians were listed on the Appendices even though the true status of many was unknown and there were no explicit criteria to guide the listing process (Kievit, 2000). In what was seen as a precautionary move, most species were included in Appendix I which prohibited commercial international trade, and the remainder in Appendix II where trade could take place if the exporting country made certain findings and implemented trade controls (Luxmoore, 1992).

In reality, Appendix I listing in 1975 did not stop commercial trade. Trade was often able to continue through several different mechanisms. Firstly, at that time a number of important producer and consumer nations were not Parties to CITES (including Zimbabwe, France and Italy) and continued to trade. Secondly, as more and more countries did join CITES in the 1970s and 1980s, many took 'reservations'<sup>9</sup> on crocodilian species, which protected their harvesting and industry programmes (including, for example, Botswana, Zambia, Zimbabwe, France, Italy and Japan). In addition, Appendix I still allowed products from animals that were bred in captivity for commercial purposes to be traded. Perhaps most importantly, illegal trade continued to thrive because of a combination of continuing high demand for crocodilian hides and poor national controls and regulation in several countries.

During the 1980s, loopholes were gradually tightened. With more countries in CITES the scope for trading amongst non-members declined rapidly. Member countries came under pressure to withdraw their reservations<sup>10</sup> and it was decided that 'bred in captivity' excluded specimens taken from the wild when young, which was the basis of several important new market-driven conservation programmes such as that in Zimbabwe (Kievit, op cit.). Finally, CITES began to make some headway against the widespread unregulated or illegal trade (Anon, 1998). With the closure of these loopholes the attention of many countries, especially those with newly developed exploitation programmes, turned to ways in

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<sup>7</sup> The Convention on International Trade in Endangered Species of Wild Fauna and Flora.

<sup>8</sup> The taxonomy of the caiman is subject to considerable debate. For the purposes of this paper the term 'caiman' includes all variations of *Caiman crocodilus* including what is sometimes known as *Caiman yacare*.

<sup>9</sup> A country that takes a 'reservation' against the listing of a species in CITES is not bound by that listing decision.

<sup>10</sup> For example, the EC required member nations to withdraw their reservations.

which crocodilians could be transferred from Appendix I to Appendix II to allow legal, well regulated trade to continue. Others focused on captive breeding that could benefit from the exemptions afforded to Appendix I species under such programmes.

During the early days of CITES the only mechanism for transferring species from Appendix I to Appendix II was the Berne Criteria<sup>11</sup>, but this required evidence that species had recovered sufficiently to allow trade. Since there had been no data on the status of most crocodilian species at the time of listing it was often impossible to prove that the species had recovered. The only crocodilian ever downlisted pursuant to these criteria was the American alligator in 1979. CITES overcame this problem for crocodilians by introducing the concept that came to be called ‘ranching’. Implicit within this was the recognition that exploitation based on the collection of young life-stages (ranching)<sup>12</sup> was both biologically safe and could provide economic incentives for conservation.

A new CITES resolution was adopted that allowed the transfer of individual national crocodilian populations from Appendix I to Appendix II if it could be demonstrated that a ranching programme was in place, and that it was contributing positively to the conservation of the species. Zimbabwe was the first country to achieve an Appendix II listing based on ranching of its Nile crocodiles. It was followed by Australia which transferred its saltwater crocodile *Crocodylus porosus* to Appendix II under the ranching scheme a few years later. However, ranching proved technically complex and expensive in terms of infrastructure and management, and start-up difficulties prevented many other countries, particularly less developed countries, from following suit. To deal with this problem, CITES introduced an interim system of quotas through which crocodilian populations could be transferred to Appendix II on a temporary basis. Eventually the Berne Criteria were abandoned in favour of new, scientifically-based criteria for listing on the Appendices which allowed both ranching and quotas to be used as precautionary measures in a management programme.

**Table 1.** List of countries with crocodilian production programmes indicating mode of use. Wild harvest is direct harvest of adults or sub-adults from the wild. Ranching is collecting eggs from the wild for hatching and raising in captivity. Captive breeding is the production of eggs from adults held in captivity

Country	Species	Mode of use
United States	<i>A. mississippiensis</i>	Ranching, wild harvest and captive breeding
Mexico	<i>C. moreletii</i>	Captive breeding, ranching under development
Honduras	<i>C. acutus</i>	Captive breeding
Nicaragua	<i>Caiman crocodilus</i>	Wild harvest
Cuba	<i>C. rhombifer</i>	Captive breeding
Colombia	<i>Caiman crocodilus</i>	Captive breeding
Venezuela	<i>Caiman crocodilus</i>	Wild harvest and captive breeding
Guyana	<i>Caiman crocodilus</i>	Wild harvest
Brazil	<i>Caiman crocodilus</i>	Captive breeding, Ranching under development
Bolivia	<i>Caiman crocodilus</i>	Wild harvest
Paraguay	<i>Caiman crocodilus</i>	Wild harvest
Argentina	<i>Caiman latirostris</i>	Ranching
South Africa	<i>C. niloticus</i>	Captive breeding, ranching

<sup>11</sup> Laid out in Resolution Conf. 1.2

<sup>12</sup> Ranching is considered a highly precautionary and biologically “safe” method of harvesting because it relies on harvesting of the youngest life stages that regularly experience high mortality in the wild.

Country	Species	Mode of use
Mozambique	<i>C. niloticus</i>	Ranching
Botswana	<i>C. niloticus</i>	Ranching
Malawi	<i>C. niloticus</i>	Ranching
Zimbabwe	<i>C. niloticus</i>	Ranching, captive breeding
Zambia	<i>C. niloticus</i>	Ranching
Uganda	<i>C. niloticus</i>	Ranching
Kenya	<i>C. niloticus</i>	Ranching, captive breeding
Tanzania	<i>C. niloticus</i>	Wild harvest, ranching
Ethiopia	<i>C. niloticus</i>	Ranching
Madagascar	<i>C. niloticus</i>	Ranching, captive breeding
Thailand	<i>C. siamensis</i>	Captive breeding
China	<i>Alligator sinensis</i>	Captive breeding
	<i>C. porosus</i>	Captive breeding
Cambodia	<i>C. siamensis</i>	Captive breeding
Indonesia	<i>C. porosus</i>	Captive breeding, wild harvest
	<i>C. novaeguineae</i>	Wild harvest
Malaysia	<i>C. porosus</i>	Captive breeding
Singapore	<i>C. porosus</i>	Captive breeding
Papua New Guinea	<i>C. porosus</i>	Ranching, wild harvest
	<i>C. novaeguineae</i>	Ranching, wild harvest
Australia	<i>C. porosus</i>	Ranching, captive breeding
	<i>C. johnsoni</i>	Ranching, captive breeding

CITES was central to the gradual replacement of unregulated crocodilian exploitation with exploitation based on sustainable resource management. Today, CITES allows at least 30 countries to use wild harvests, ranching and captive breeding to produce crocodilians of 12 species for international trade (Table 1), but only on the understanding that these programmes do not threaten the future of any of the species in the wild. This proviso is by no means cosmetic. For example, it is quite possible to find examples where one species found in eight countries is much sought after by the market, but only one country is considered by CITES to have met the requirements for legal export.

## PATTERNS OF PRODUCTION

The articles and regulations of CITES have marked effects on trade in both raw and manufactured crocodilian products. CITES influences which species can be sold, when they can be sold, to whom they can be sold, and in what form they can be sold. In determining the terms of trade in this way, CITES has a fundamental impact on the traditional crocodilian leather industry in which the relative occurrence of different species in trade has always been of critical importance. The American alligator and most crocodiles are considered to have high value ‘classic’ belly skins because they are free of osteoderms<sup>13</sup>, while the belly skins of caimans, especially the larger sized ones traditionally taken from the wild, are strongly ossified and less valuable, and only the flanks are used to produce leather goods (e.g. Thorbjarnarson, 1999). Even within the classic species there are differences in value based on

<sup>13</sup> Boney plate-like growths within the skin

various perceived skin characteristics or supply differences, with saltwater crocodiles traditionally being favoured ahead of other species.

In the early 1980s, CITES began severely to impact both the number and composition of species in trade.

By 1989, the total volume of crocodilian skins in trade had been reduced from an estimated high of 1.5 million a year to a low of about 500,000. Thereafter it began to rise again until it reached a new peak of almost 1.2 million skins in 1999 creating a U-shaped historical supply. This pattern broadly mirrors the end of unregulated exploitation, dominated by illegal trade, and the ushering in of sustainable use. However, things become more complicated when the composition of species in trade and the mode of their production (and in association with this, their size) are considered.

The total number of “classic” skins from crocodiles and alligators entering trade before 1977 is unknown. The best known estimate of 300,000 is largely speculative (Ashley & David 1985). Figures for legal trade are available from 1977 when 40,000 skins entered trade, almost all from cropping in the wild, until 1999 when 390,000 skins entered trade. The number of animals taken from the wild hardly changed over the period. Almost all the increase came as a result of production from ranching, which rapidly increased from 6,500 in 1983 to 263,000 in 1999, and captive breeding, which increased from 5,600 in 1988 to 73,000 in 1999 (MacGregor, 2001, in prep.).

The data show a very different pattern for South American caimans. Here wild harvesting remained the dominant form of production until 1985, when more than 1.4 million wild-taken skins were reported in trade. Thereafter the number of wild skins in trade dramatically decreased to as few as 34,000 by 1999, principally from just one country, Venezuela. Amazingly, over the same period the number of caiman skins produced by captive breeding (principally in Colombia) increased from zero to over 770,000 (Table 1) (MacGregor, 2001 in prep.).

The marked changes in the source of skins reflect two paradigms within crocodile conservation that have been supported by the evolving regulations of CITES. For some years it was held as conventional wisdom that the preferred conservation strategy for crocodilians, and many other species, was “captive breeding” in which adult animals were held in farms to produce eggs so that production could be completely independent of wild populations. The usual justification for this approach was that, in situations where demand for wildlife products persisted, the production of captive bred specimens would take the pressure off wild populations.

The feathers of this dogma were severely ruffled in the late 1980s when it became clear that the effective conservation of crocodilians often depended on giving wild populations an economic value in order to provide conspicuous and tangible incentives for their long-term sustainable management. Not only was captive breeding eroding the pivotal link with the wild, but production was beginning to move *ex-situ*, from the Range States<sup>14</sup> to important consuming countries, or even to countries that hitherto had played no role in the crocodilian industry. As noted by Thorbjarnarson (1999) this had the effect of “reducing the potential for developing sustainable-use programmes based on native species and increasing the likelihood of introducing exotic species through escapes.” Colombia commenced the captive breeding of caiman in the late 1980s and by 1995 was producing over 700,000 skins a year in what is, essentially, a new agricultural business. The industry no longer impacts on the wild, but nor does it provide obvious incentives for conservation. A similar situation exists in Thailand, where virtually all the production of Siamese crocodiles *Crocodylus siamensis* is based on captive breeding, and the wild population, reduced to a few individuals at best, benefits little if at all. Today, commercial production through captive breeding remains controversial as it is often perceived as a threat to incentive-based conservation, although an element of captive breeding may be needed to sustain the business elements of a ranching programme, providing security of through-put and insurance against regulatory and other changes out of the investor’s control.

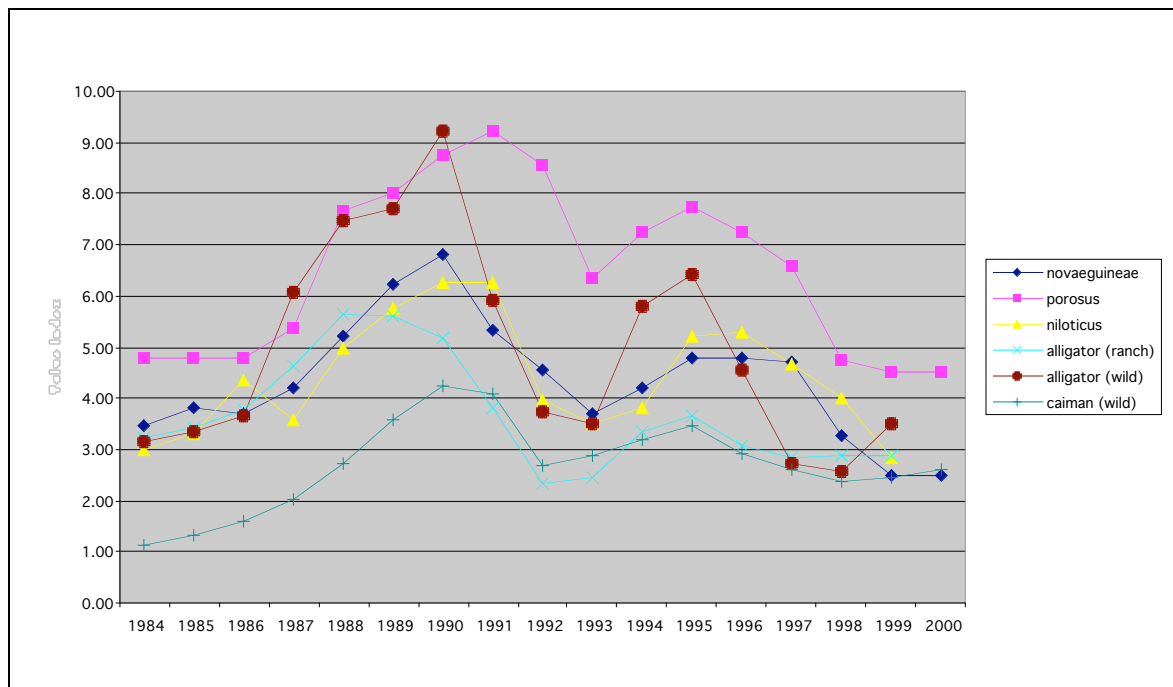
As our experience mounts, flexibility and a willingness to change are emerging as the essential ingredients of successful market-driven conservation programmes for crocodilians. It is not simply a

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<sup>14</sup> The countries in which the resource occurred naturally.

matter of implementing a prescriptive programme and letting it operate indefinitely without change. Rather, it is one of implementing a programme that can adapt rapidly and smoothly to changed circumstances. Unfortunately, the machinery of CITES is not designed to adapt rapidly to change. It tends to force new programmes of economic consumptive use into a narrow range of fixed options, such as captive breeding and ranching<sup>15</sup>. Market-driven conservation programmes based on ranching require a major investment in infrastructure to collect and incubate eggs, and to grow the young animals. In times of weak markets, governments and investors have often wished to switch to less expensive forms of production to maintain incentives for conserving wild stocks: options such as the export of eggs and hatchlings or the cropping of larger, market-ready animals directly from the wild. But the export of eggs or hatchlings is generally frowned upon, partly because it is assumed that value-adding of the resource benefits a nation, even if it is not economically viable to do so. Direct cropping from the wild may be the only viable option for poorer countries to participate in the market, and generate incentives for conservation, but despite compelling economic arguments, it is commonly resisted because it is less precautionary in biological terms.

Because the economics of the market-driven conservation of crocodilians has never been examined in any detail, the nature of the relationship between conservation objectives and financial returns is largely speculative. However, preliminary examination of the economics of the crocodilian industry has suggested that demand is elastic and supply is relatively inelastic (Woodward, Dennis and Degner, 1993). As a result, the market is characterised by marked price fluctuations. During the 1980s prices steadily increased as the demand for legal classic hides exceeded supply. It appears that some traders, tanners and manufacturers responded to the rising market by increasing their stocks, without fully considering the many new production facilities coming online. In 1990, prices started to fall and then crashed as speculators tried to cut their losses (Figure 1). The downturn was less severely felt by the producers of saltwater crocodiles, a species which has traditionally been in short supply, than by the producers of other species, where prices often fell to uneconomic levels and remained there for several years.



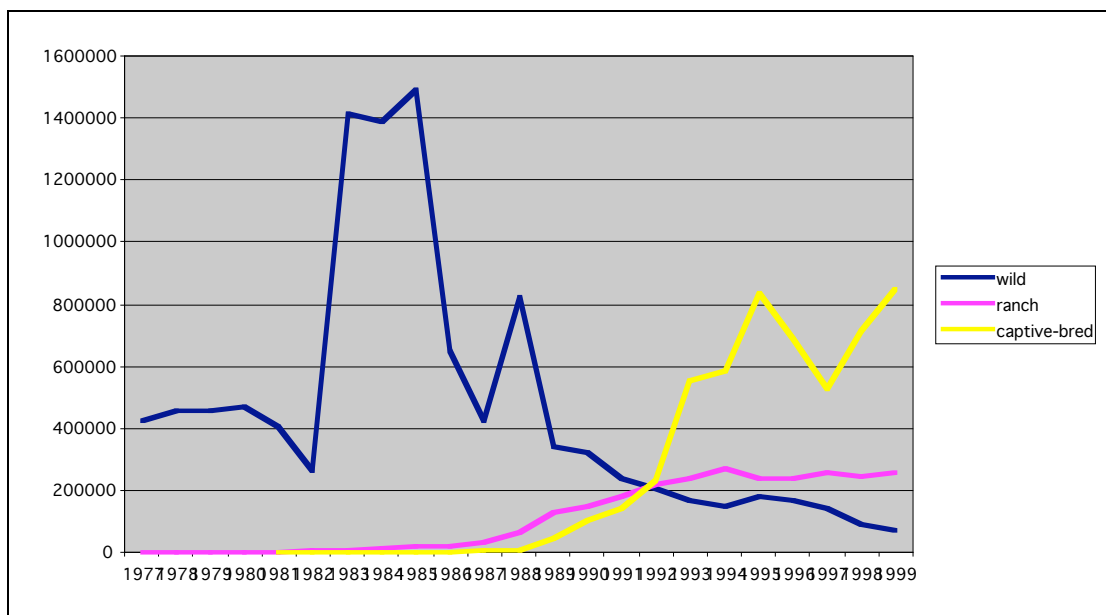
**Figure 1.** Producer Price Indexes for Crocodilian Skins, 1984–2000

Prices started to rise again in 1993, but crashed again in 1996 – almost certainly in response to the Asian economic crisis. Asia is the principal end-market for luxury goods, including leather goods

<sup>15</sup> The terminology in crocodilian production can be confusing. In terms of the wild population there is a major distinction between ‘captive breeding’ and ‘ranching’, but this distinction is not always made clear. The term ‘farming’ is commonly used to describe both forms of production.

made from crocodilians (Woodward, Dennis and Degner, 1993). The price for crocodilian raw materials is determined largely by the economic status within consuming nations, although superimposed on this are the unpredictable vagaries of the fashion industry. During these two difficult periods a number of individual producers went out of business and several national market-driven conservation operations (particularly in Africa, which had a number of new programmes in which the costs of investment had not yet been amortised) were reduced to holding-operations, or closed altogether. This created conservation crises in some instances (Thorbjarnarson, 1999). However, global production continued to increase (Figure 2) as producers increased efficiency and adopted new strategies to produce economies of scale within the industry.

It has long been recognised that one of the potential problems with market-driven crocodilian conservation is that considerations of sustainability may be set aside in order to overcome short-term, economic problems (e.g. Loveridge, 1996; Thorbjarnarson, 1999; Woodward, Dennis and Degner, 1993). The responses to a weaker market in the early 1990s were varied. There were attempts to better control market fluctuations through producers working together to reduce costs, restrict supply and increase demand. Attention to production efficiency on most farms resulted in more production or profit from the same level of harvest. In some countries producers tended to swing towards captive breeding rather than ranching, which although more secure economically, eroded conservation advantages.



**Figure 2.** Estimated Trade in Crocodilian Skin by Method of Production, 1977–99

It appears that producers and conservationists met little success in controlling either supply or demand. On the supply side, the concept of an international producers' cartel to restrict production was neither researched in depth nor implemented. Indeed, some producers reacted to falling prices by increasing production in an effort to maintain profitability. In some developing countries, the subsidised export of raw crocodilian materials continued, regardless of viability, because there was an acute need for foreign exchange. In a positive vein, on at least one occasion producers were provided with a subsidy in recognition of the conservation value of production<sup>16</sup> (Loveridge, 1996).

On the demand-side, producers tended to have such a poor understanding of the dynamics of the traditional luxury crocodilian leather industry that they were unable to exert any influence. While trade over the last 20 years has seen a reduction in the number of the intermediaries between producers and consumers, vertical integration has consolidated the critical role of tanneries which have become the

<sup>16</sup> Crocodile farmers in Zimbabwe were preferentially issued permits to catch fish to feed crocodiles on farms.

principal buyers and wholesalers. The number of tanneries has also declined, partly due to environmental regulation, but their capacity has increased. While there is not yet a monopoly, the few remaining tanneries probably exert the largest single influence on the market. The concept that producers, tanners, manufacturers and retailers could work together to influence demand, remains embryonic; it would require levels of transparency unlikely to be forthcoming.

Finally, when considering the economics of production it is appropriate once again to visit CITES as it affects the final price of items in numerous ways. Regulation and control systems create costs and these are largely borne by the producer. Even the price of the permits and skin tags that are required by CITES can be a significant part of the profit margin with some species. As larger and larger numbers of specimens are produced, the resources needed for regulating trade at the level of the individual animals or even parts of individuals (such as teeth and other curios), as required by CITES, may increase out of all proportion to the value of the resource and to the conservation priorities that spawned the need for regulation.

## **BIOLOGY, BUSINESS AND BENEFITS**

Although many, if not most, crocodilian production programmes started with strong conservation objectives, it has often been difficult to adhere to these over the long-term. For example, even where programmes have been well planned in biological terms, the high value of wild crocodilian resources has not always resulted in re-investment in the resource. Government agencies have sometimes preferred to use revenues for other priorities.

Most of these difficulties could have been predicted if broader expertise had been included in the development of programmes, because the success or failure of these programmes has ultimately proved to be governed largely by economic and institutional factors. Key questions that should be considered are: Is the programme profitable for those investing? Is the structure of incentives likely to deliver the desired results?

These elements are largely ignored by CITES which emphasises the biological determinants of sustainability. This is not surprising, because most of the 'actors' in wildlife management are biologists or aspiring biologists. However, it has resulted in the biological elements of market-related programmes being subjected to close scrutiny while the social, cultural and economic elements have often been ignored. With crocodilians, biologists have tended to play the leading role in developing market-driven conservation programmes despite most of them having limited skills in marketing, animal production, economics, or the socio-economic constraints on business. With the benefit of hindsight, biology has proved to be one of the least relevant (and most easily addressed) factors in achieving sustainability, despite the disproportionate emphasis given to it by CITES. In contrast, conservation benefits ultimately depend on the socio-economic context and the institutional mechanisms in place. Yet business risk and uncertainty analysis are not involved in most proposals to CITES.

One important lesson from crocodilian management is that success has always hinged on the establishment and maintenance of good relations between the government regulators and business interests, from the planning stages onwards. Business may not understand the conservation focus of management programmes as much as governments, but tends to tolerate expenditure during start-up phases even if it considers it cosmetic or unnecessary. But investment has proved to be a powerful political tool and once programmes are established, economic interests have often conflicted with, and sometimes prevailed over, conservation interests. The financial stress of falling markets in the early 1990s provides an extreme example. It resulted in pressures to reduce the costs associated with resource monitoring and other regulation in many countries. In some cases, it promoted efforts to bypass regulation completely (illegal harvesting), and some wild-caught animals probably entered trade under the guise of farm-raised animals.

On the other hand, government regulators often have little understanding of, or sympathy for, the needs and realities of sustaining a business. They have sometimes compromised the conservation objectives of programmes themselves, by inappropriate actions that directly affect the interests of the business partner. In some instances the state regulator has introduced uncertainty over long-term

access to wild resources. The principal lesson here is that compromises between conservation and business interests are commonplace, and they need to be accepted as a normal part of any market-linked programme. If short-term business interests are put before sound long-term conservation gains, sustainability can be compromised, but it can equally be compromised by the reverse situation. There is no easy answer to this problem, although building in transparency - where changes have to be justified publicly - may perhaps be one step in the right direction.

Long-standing and effective partnerships between government and business have sometimes been compromised by staff changes and loss of institutional memory. Any programme trying to achieve sustainability will have to confront an array of new and unpredictable problems born of the interaction between social, cultural, economic and biological variables. Yet as staff change in regulatory institutions, the experience of resolving these complex issues is often lost. This difficulty is perhaps most critical in small and poorly financed institutions within developing countries, where changes in personnel and record-keeping protocols occur at a much faster rate than would normally be the case in any business operation. New regulators facing experienced business interests for the first time often face a series of difficulties in rebuilding partnerships based on confidence. The original conservation focus may have changed over time, perhaps for sound reasons, but if these are not well understood by both parties, distrust can be created and programmes compromised. The results of these difficulties sometimes benefit business interests in the short-term, but are often costly in the longer term. Governments typically have problems with:

- Keeping track of the changes in policy and management plans that have been implemented over time, and of the original reasons for those changes;
- Training staff so that programmes are not compromised by individuals leaving or being promoted;
- Maintaining long-term monitoring programmes with the necessary levels of accuracy and precision;
- Making commitments for long-term monitoring in say, three or five year cycles;
- Maintaining a stable relationship between business and regulatory interests;
- Maintaining a clear understanding of the interactions between social, cultural, economic and biological variables that govern success or failure;
- Maintaining records in such a way that past experience can be readily called upon.

Unfortunately, government regulators have been known to compromise sustainable use programmes for political or personal gain. Where impoverished government agencies have the opportunity to receive significant revenues from crocodile production there have been instances where the regulator has raised unrealistically high “taxes” on business, issued harvest quotas beyond levels likely to be sustainable, tried to enter the production business as a competitor to private investment, or used potential financial benefits as a political tool (e.g. Loveridge, 1996). There are also examples of rent-seeking on the part of individual bureaucrats. All of these have detracted from the sustainability of management programmes.

Despite these negative observations, the economic importance of crocodilians has usually led directly to stronger institutional arrangements for their sustainable management, largely because governments are often obvious beneficiaries and have a strong incentive for conservation. The benefits that flow to a handful of crocodilian producers or traders create a potentially powerful supporting constituency and many programmes rely on this dualism. Often, however, the State is not the ‘owner’ of the resource or the land on which it is found. In Australia the state claims ownership of wildlife including crocodiles (e.g. Webb *et al.*, 2000), but the situation varies from country to country. In Papua New Guinea, crocodiles are owned legally by rural communities (e.g., Fernandez and Luxmoore, 1996), whereas effective ownership is bestowed upon private land-owners in a number of countries, for example Venezuela (Thorbjarnarson and Velasco 1998). Unfortunately, with a few well-known exceptions, it has often proved to be a challenge to design schemes in which crocodilians become a significant economic asset to private or community landholders who live with them, and on whose goodwill their survival will ultimately depend (e.g., Loveridge, 1996).

## THE MISSION TO MARKET

Conservationists, particularly those who focus on the biological and regulatory aspects of management, often assume that the marketing of products is a strictly private, commercial element of the programme, with little relevance to management of the resource. Yet marketing, sales and profitability are absolutely fundamental to the success of these conservation schemes. There can be no economic incentive without profitable sales, and conservation interests can be eroded. For example, in the early years of a market-driven conservation programme in Tanzania in the 1990s, the poor marketing of crocodile skins resulted in the a request to take off twice as many crocodiles from the wild - something that could have been avoided had the true value of the final product - the cured skin - been returned to the correct authorities (Hutton, 1992). Thus, there are sound reasons for regulatory authorities to embrace marketing as one of the variables associated with sustainability.

Marketing and technical knowledge has itself become a tradeable commodity in the crocodilian industry, with mixed results. Significant improvements in production efficiency have been gained from research, and in most cases investment in market research has resulted in better market prices, mostly due to improved quality and eliminating “middlemen” from the trading chain. However, in each case a recurrent problem has been the conflict between transparency and the protection of the intellectual property rights associated with market and technical research. In the early 1970s, research results tended to be available for all to use, but this has changed over time and it can be argued that secrecy has been a major impediment to progress in some countries, partly because it has constrained the ability of those receiving information to validate it. The impacts of poor or uninformed advice, or advice given by people who did not necessarily have the credentials to give it, is difficult to evaluate. There are clear cases where ‘expert’ advice has resulted in unrealistic expectations amongst both the government and private sector and, as a consequence, has been directly implicated in poor investment strategies. For example, ranching or captive breeding programmes were inappropriately developed for certain species or populations. As a result, a number of national programmes have shrunk dramatically, or closed altogether, and the whole concept of market-based conservation has suffered when unrealistic expectations, based on poor advice, have not been met.

In the absence of effective information allowing producers to influence the demand for traditional high-value crocodilian leather goods, producers commonly investigate value-added production, diversification and creating new markets. On the whole these are regarded as positive outcomes, but it has not proved easy to add value to the raw product in producer countries. Not only has there been strong opposition from vested interests, but the technology is expensive and expertise is not freely available. It has proved difficult for developing countries to produce the high quality required by a market specialising in luxury items. Attempts by government regulators to force value-adding have also had dubious results. For example, Indonesia insisted that skins be partly tanned before export, but the price was often higher for raw skins than for partly tanned ones (Jenkins, pers. comm.).

Most successes in value-adding have come from joint ventures between producers or groups of producers and established processing businesses. However, the principal result has not been penetration of the luxury market, but rather the creation of new markets, often of a domestic nature, providing goods of lesser distinction to ordinary consumers. In terms of diversification, crocodilian meat is an important by-product and in some species it may be worth as much, or more than the raw hide. Other by-products include curios and a variety of products made locally from low grade skins. These all generate income and stimulate secondary businesses, and are typically oriented towards domestic sales to tourists, who subsequently export the items.

It is not only tourist souvenirs that are moved across borders. The principal manufactured end-products of the crocodilian industry, luxury leather clothing and accessories, are commonly carried from country to country. Although CITES itself may exempt these legally-held personal possessions from inconvenient controls, such as permits and tags, many of the key consuming countries have adopted domestic trade control measures for wildlife products that are stricter than those under the Convention. It results in difficulties and inconveniences for the final consumer. Added to this,

campaigns by NGOs and governments, such as those at many airports, often urge citizens to avoid buying any wildlife products, or at the very least, to exercise extreme caution. Travellers are urged to be aware of the strict regulatory requirements associated with any movement of wildlife products across international borders, and are often confronted with impressive penalties. While these exhortations and difficulties may be valid for some wildlife products, they rarely apply to crocodilians today - yet buyers are naturally discouraged from purchasing crocodilian products.

This situation persists, at least in part, because the commercial use of wildlife disturbs many conservationists, perhaps with considerable justification. History is littered with examples of where market forces have resulted in over-exploitation and declines in wild species. The widely held opinion that economically driven consumptive use of wildlife is incompatible with conservation lingers on, despite dramatic changes in our understanding of the reasons why this occurred so commonly in the past. Over-exploitation almost invariably occurred in situations of “open access” without appropriate institutional arrangements, and without any incentives to conserve or use sustainably. Thus, despite situations which rectify these problems today, wildlife trade is, at least in some cultures, now considered undesirable and even immoral.

## **DISCUSSION AND CONCLUSIONS**

Markets have created economic incentives for crocodilian conservation in a diverse range of circumstances and contexts. There is no doubt that the most successful crocodilian programmes are those that have used a broad range of inputs during their preparation and implementation, and were flexible enough to adapt to changing circumstances. These are programmes that have been mindful of the socio-economic environment, and have ensured that the institutions of regulation could operate in an environment relatively free of perverse incentives.

It is also clear from the global experience that the development and maintenance of successful programmes requires effective partnerships between regulators and all other stakeholders. Not least to prevent the loss of institutional memory, which is the substance of building long-term partnerships. Policy and management are best developed cooperatively, so that all sides understand the conservation elements and the way business is expected to contribute to them. To ensure consistency with respect to conservation objectives, long-term management plans should be supported by precise and long term contracts to achieve the goals required. Management programmes should stipulate transparent procedures for developing and allocating quotas, to constrain the ease with which they can be manipulated. To avoid unrealistic expectations it is desirable to increase transparency in research, marketing and the provision of advice, even though there are important issues to tackle with respect to the balance between openness and the protection of commercially sensitive information.

CITES has always been the biggest international influence on the commercial use of crocodilians because most programmes were developed before Agenda 21 and the introduction of the Convention on Biological Diversity (CBD). As a result, there has been little attention paid to issues of equity and benefit-sharing which are important considerations with respect to sustainable use in the context of the CBD, but of lesser concern within CITES. In fact, experience suggests that it is difficult to extend benefit sharing beyond business and the government regulator, down to the landholder and others who live with crocodilians. One difficult issue to consider is how conservation benefits of the market can be maintained in the face of a seemingly inexorable drift towards the domestication of crocodilians in some countries: a trend which reduces the link between business investment and wild populations. The issue of long-term access to crocodilian resources is much more important and fundamental to business interests than would appear from most management programmes, and has often resulted in the pursuit of captive breeding. The ecology of wild crocodilians introduces significant variation in the numbers of eggs and hatchlings available from the wild each year, making life unpredictable for business interests. It is important to seek ways to ensure that supplementary production through captive breeding can add security to operations based on wild harvest without making captive breeding the most cost-effective option for obtaining stock.

While the market-driven conservation of crocodilians has its problems, many of these could have been predicted at the time of planning had there been any honest and objective assessment of the market environment. Far too much emphasis was placed on biological variables and far too little on economic factors. A large share of the responsibility for this lies with the biologists<sup>17</sup> who played a central role in the design of most programmes, as they typically sought little input and involvement from specialists in economics, business and marketing – a situation exacerbated by CITES. There is no doubt that CITES, which has been the most critically important instrument fostering the sustainable management of crocodilians, would benefit from the inclusion of standard economic issues in its deliberations. At the moment, it attempts to regulate trade in commodities without any detailed considerations of the market. As a result, it receives no warning of major economic problems, and its inflexible structure constrains its ability to respond to them when they arise. Unnecessary and burdensome regulation, often cosmetic and typically costly to implement, are of continual concern. CITES may have been the principal tool for change and improvement in the sustainable commercial use of crocodilians, but it has not been the driving force behind those changes. The impetus has been provided by strong national interests that have been supported by a strong constituency of voluntary crocodilian ‘experts’, particularly those under the auspices of the Crocodile Specialist Group which is part of the Species Survival Commission of IUCN – the World Conservation Union.

Price fluctuations cause major problems for businesses and ultimately threaten conservation of the resource. The question must be addressed as to whether or not there are any appropriate interventions that can be made to support the conservation premium where this exists? Producers, traders and some conservationists are calling for the endorsement of programmes of market-driven conservation by international conservation agencies and have suggested the introduction of certification and/or eco-labelling schemes. A number of initiatives endorse sustainably-harvested marine and forest products and these could, perhaps, be models for crocodilian harvesting regimes. In addition, given that Appendix II of CITES is supposed to act to prevent commercial international trade from threatening wild species, there may be potential for CITES itself to develop a certification role. These possibilities merit detailed investigation, though it is far from clear where the lead will come from. This is something that the IUCN Crocodile Specialist Group might consider further.

Of more importance, as far as the market is concerned, is the disincentive to business created by the burden of regulation imposed over recent years, regardless of the good intentions involved. Eco-labelling may be a far less important issue than removing restrictions on the movement of personal possessions, and amending information which discourages the public from buying products that are directly linked to better conservation. The practice of many OECD countries of adopting domestic control and regulation measures that are more restrictive than CITES adds a further tier of complexity. These issues must be addressed as a matter of urgency to ensure that the gains made from the market-driven conservation of crocodilians over the last decade or so are not lost over the next.

## ACKNOWLEDGEMENTS

This review has been produced on behalf of a Working Group of the IUCN/SSC Crocodile Specialist Group (CSG) and we are grateful to all the members of the CSG who have given their time to contribute to the process. We would like to thank John Caldwell at UNEP-WCMC for his help with crocodile trade data and Don Ashley, Steve Broad, Rosie Cooney, Ruth Elsey, Richard Fergusson, Lee Fitzhugh, Dietrich Jelden, Hank Jenkins, James MacGregor, Alvaro Velasco and Allan “Woody” Woodward for their critical comments on earlier versions of this manuscript. Any remaining errors must be laid at our door. We are grateful to the ResourceAfrica and Wildlife Management International for their support to this project during its inception and throughout its implementation.

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<sup>17</sup> Possibly including some of those who have contributed to this paper.

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**Accumulation of Radionuclide and Metal Contaminants  
in Flesh and Osteoderms of  
Estuarine Crocodiles (*Crocodylus Porosus*):  
Pathways and Histories of Catchment-Specific Exposure**

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**ABSTRACT:** Flesh and osteoderms of estuarine crocodiles (*C. porosus*) from Kakadu National Park, Northern Australia were analysed for a range of metals, including uranium, to assess their capability for accumulation, in relation to their catchment-specific exposure to i) uranium mine effluents and mineralisation, and ii) Pb shot ammunition through their consumption of fauna shot by the traditional owners of the Park. Uranium in osteoderms was significantly ( $P < 0.05$ ) elevated in the East Alligator River catchment, that contains the Ranger and Jabiluka uranium mine sites, relative to two other adjacent catchments. The mean concentrations of various other elements in flesh and osteoderms were also significantly ( $P < 0.05$ ) different between catchments. Linear discriminant analysis was used demonstrate that multi-element signatures in both flesh and osteoderms could be used to classify individual crocodiles to their respective catchments. This approach may be useful for the identification of source catchments of itinerant 'nuisance crocodiles' that find their way into Darwin Harbour, close to dense human habitation. Pb concentrations were significantly ( $P < 0.05$ ) enhanced in both tissues of crocodiles sampled within areas hunted with Pb ammunition. Enhanced ratios of Pb:Ca in the annual laminations of their osteoderms are consistent with their history of continual exposure to elevated anthropogenic Pb sources. Subsequent experimental studies have demonstrated the ability of the crocodilian stomach to retain ingested Pb shot, that is readily solubilised and absorbed into the blood and then archived in the contemporary osteodermal lamination.

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**Molecular Cloning of Steroid Hormone  
Receptors of the American Alligator**

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In all species of crocodilians, sex is determined not by genetic mechanisms alone, but also by the temperature at which the egg is incubated. In the American alligator (*Alligator mississippiensis*) the thermosensitive period (TSP) for sex determination is a 7- to 10-day window within stages 21-24 of development. Treating embryos with estrogen during the TSP produces female offspring, even at male incubation temperatures. Therefore, it has been suggested that estrogens play a role in determining sex in the alligator. However, the mechanisms of estrogen action on sex determination in the alligator are still uncertain. Further, studies of contaminant-exposed alligators have shown alterations in steroid action. Whether these abnormalities are due, in part, to alterations in steroid receptor expression is

unknown. To begin to understand the mechanism of steroid action in alligators, we isolated cDNA encoding the estrogen receptors (ER) and the progesterone receptor (PR). Degenerated primers specific to ER were designed according to a comparison of nucleotide sequences of ERs from other species. Partial DNA fragments were amplified by PCR using alligator ovary RNA. Two DNA fragments (ER<sub>a</sub> and ER<sub>b</sub>) were obtained, and the RACE technique was utilized to clone full-length alligator ER<sub>a</sub> cDNA in the 5' and 3' directions. Comparison of the amino acid sequence from the alligator ER<sub>a</sub> with that of human, chicken and zebrafish ER shows that alligator ER is very similar to chicken ER (91 %). We also isolated a DNA fragment encoding a partial progesterone receptor (PR) of the alligator. We examined the expression levels of three steroid receptors (ER<sub>a</sub>, ER<sub>b</sub> and PR) in the ovary of juvenile alligators. Thirty hours after a single E<sub>2</sub> (270 mg/kg) injection, total RNA was extracted from the ovary. cDNA was synthesized, and the expression levels of each of the above receptors were analyzed with quantitative RT-PCR. Intriguingly, ER<sub>a</sub> transcript decreased significantly with E<sub>2</sub> treatment. ER<sub>b</sub> and PR transcripts were not changed. These results suggest that the expression of ER<sub>a</sub> is sensitive to estrogen in the ovary of the juvenile alligator. However, in this study the expressions of ER<sub>b</sub> and PR were not affected by estrogen treatment. Further study are underway to examine the expression of these receptors during embryonic development and reproductive cyclicity.

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### **Preliminary Surveys of American Alligators in Ephemeral Wetlands on Ichauway Plantation, Georgia, USA**

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Ichauway Plantation, an 11,600 hectare private reserve located in southwest Georgia, is comprised primarily of longleaf pine-wiregrass uplands that are interspersed with numerous shallow ephemeral lime-sink wetlands. The property is bounded on the east by 20 kilometers of the Flint River and is bisected by 22 kilometers of the Ichawaynochaway Creek. Eyeshine counts of American alligator populations in 1994, 2000, and 2002 were higher in ponds than on the creek or river by at least 64%. The pond populations also had higher concentrations of juveniles, indicating that the ponds may provide important breeding habitat and refuge for juvenile alligators. Preliminary data indicate that alligators are more likely to use wetlands with emergent vegetation during wet years versus forested wetlands during times of drought. In spring 2002, we began a mark-recapture study that focused on a pond basin with a high concentration of juvenile alligators. Between 3/30/02 and 8/22/02 we marked 27 individuals within this pond basin (TL: 54.9 cm to 105 cm). We found that the alligators dispersed among the pools when they all had water, but concentrated in the deepest manmade pool during months of severe drought. Future work will include using radio telemetry to study the movements of alligators among wetlands. Ultimately we hope to study the role that alligators play in ephemeral wetlands in a seasonally fluctuating environment.

## **Present Range and Habitats of the American Alligator (*Alligator mississippiensis*) in Texas**

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**ABSTRACT:** Survey results from a questionnaire circulated to area county biologist and from nuisance reports submitted by state wildlife staff and enforcement officers in Texas were used to document the current range and habitats utilized by the American alligator in the state of Texas. Range expansion from all-time population lows in the late 1970's is evaluated, and American alligator presence is reported for previously undocumented counties. Survey methods as used were found to have certain strengths and shortcomings that should serve as a basis in developing future surveys. Useful trends indicated by the survey aid in identifying areas with (1) increasing nuisance alligator problems, (2) American alligator populations from relocations outside of their historic range, (3) released exotic crocodilians, and (4) the ability to support an increased level of harvest.

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## **Improved Field Techniques for Containing, Transporting and Estimating Body Mass of American Alligators**

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**ABSTRACT:** Previously utilized methods of containing and transporting American alligators can be cumbersome, dangerous, extremely time consuming, and stressful to the animal. The use of baseball bags or army surplus style duffle bags for containment and transport of American alligators addresses some of these problems. Equipment for weighing American alligators in the field can be expensive and difficult to use. Morphometric measurements from wild-harvested, live nuisance, farm-reared, and live-captured American alligators were used in the development of an improved method to estimate the body mass of American alligators in Texas. Using total length to estimate the body mass of American alligators is generally less than optimal because of variations in body condition among years (e.g., drought versus wet years) or among habitat types. Preliminary results indicate that tail girth is a more accurate indicator of body mass than total length alone. Combining tail girth with other morphometric measurements may result in an even better indicator of body mass.

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**Status of the American Alligator (*Alligator mississippiensis*)  
in Southern Florida and its Role in Measuring  
Restoration Success in the Everglades**

Mazzotti, F.; Rice, K.; Brandt, L.; Abercrombie, C.; Zweig, C. and Cherkiss, M.

**ABSTRACT:** The American alligator (*Alligator mississippiensis*) was abundant in the pre-drainage Everglades. The largest populations occurred in the broad marl prairies to the east and west of the southern ridge and slough and in the freshwater mangrove zone. Development and water management practices have reduced the spatial extent and changed the hydropatterns of these habitats. As a result of these activities, alligator populations have decreased. Currently, restoration of hydrologic pattern and ecological function is beginning in the Everglades. Due to the alligator's ecological importance and sensitivity to hydrology, salinity, habitat and system productivity, the species was chosen as an indicator of restoration success. A number of biological attributes (relative density, relative body condition, nesting effort, and nesting success) can be measured, standard methods for monitoring have been developed, and historical information exists for alligator populations in the Everglades. These attributes can be used as success criteria at different spatial and temporal scales and to construct ecological models used for predicting restoration effects. Here, we discuss Everglades alligator population status and its role in evaluating restoration success of the Southern Everglades.

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**An Evaluation of Follicular Quality for American Alligators  
in Contaminated Florida Lakes.**

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**ABSTRACT:** Organochlorine pesticides (OCPs) in Florida lakes have been associated with decreased egg hatchability/quality and increased embryonic mortality in American Alligators (*Alligator mississippiensis*). Although levels in yolk and offspring do not correlate with hatchability, OCPs may decrease egg quality by altering maternal reproductive and ovarian function. To test this hypothesis, ovarian follicles and vitellogenin (Vtg) proteins were compared in female alligators collected during the peak follicular season from Lake Griffin, FL (n = 10) and Rockefeller Wildlife Refuge, LA (reference site, n = 10). Lake Griffin animals had two distinct follicular populations: 10-20cm and 21-35cm, with approximately 50 mature, pre-ovulatory follicles. Rockefeller animals had predominantly one population of follicles (16-25cm) with approximately 40 mature, pre-ovulatory follicles. SDS-PAGE of plasma revealed Vtg protein bands unique to follicular females at ~250, 300 & 350kD, which are similar to published molecular weights for Vtg or Vtg metabolites from other species. Two additional Vtg protein bands, ~150 & 230kD, were also identified and were more pronounced in Lake Griffin females. Follicular contents had similar protein profiles and showed similar site differences. These data suggest that there may be differences in the post-translational processing of Vtg in animals from Lake Griffin. (Funded by NIEHS-SFBRP).

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## **Predicting Contaminant Body Burdens and Evidence of Maternal Transfer in *Alligator mississippiensis***

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**ABSTRACT:** Noninvasive methods for determining contaminant body burdens are useful in risk assessments for endangered crocodilian species. The present study's objective was to evaluate the use of eggs as a predictor of maternal body burdens in adult alligators. Adult female alligators (n = 7) and their eggs were collected from two contaminated lakes in central Florida during June 2001. Egg yolks from each clutch and maternal tissues were screened for 30 organochlorine pesticides (OCPs). Mean cumulative OCP burdens (ppb wet weight) for Lake Apopka females were 44,650 (fat), 15,108 (yolk), 2,134 (liver), 1,501 (muscle), 900 (bile), and 55 (blood). Mean cumulative OCP burdens for Lake Griffin females were 2,689 (fat), 616 (yolk), 208 (muscle), 153 (liver), 87 (bile), and 31 (blood). For all females, the tissue with the most linear correlations with yolk was fat in which 14 of 15 detected chemicals showed significant correlations ( $p = 0.05$ ), followed by liver (11/13), muscle (7/13), bile (6/12), and blood (1/9) with R<sup>2</sup> values ranging from 0.67-0.99. We conclude that yolk burdens are predictive of maternal burdens for certain tissues and that selected OCPs are maternally transferred in the American alligator. (Funded by NIEHS-SFBRP).

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## **Relationship between Egg Thiamine Concentrations and Embryo Mortality in the American Alligator.**

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Thiamine deficiency has been linked to early mortality syndrome in salmonids in the Great Lakes. The present study was conducted to compare thiamine concentrations in alligator eggs from sites with high embryo mortality and high exposure to organochlorine pesticides (OCPs) (Apopka, Griffin, and Emerald Marsh) to that from a site that has historically exhibited low embryo mortality and low OCPs (Orange/Lochloosa). During 2000 and 2001, a total of 120 clutches were collected from these sites, and artificially incubated. Clutches were monitored for embryo mortality and hatch rates, and thiamine measured in one egg/clutch. Eggs from the reference site had two times the amount of total thiamine compared to the impacted sites (1603 pmol/g vs. 847 pmol/g), and clutches with > 65% hatch rates had twice the amount of total thiamine compared to clutches with < 64% hatch rates (990 pmol/g vs. 485 pmol/g). These results suggest that thiamine deficiency might be playing an important role in alligator embryo survival and development. Causes for this deficiency are unknown at this time, but might be related to differences in the nutritional value of prey items across the sites studied. In addition, it remains unknown what the role of OCPs are in the overall differences observed in egg nutritional quality across the sites studied (Funded by NIEHS-SFBRP).

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## **Prehistoric Presence, Alligators and the American Landscape**

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This proposal is to hang 20 to 30 large scale photographs (32" X 44") in areas where speakers and attendees will frequent throughout the conference; and to have a poster presentation space where one photograph will hang, and a video monitor will present a video presentation which runs two hours and then can be rerun numerous times for continuing viewing. In this same space a copy of the book, *Alligators, Prehistoric Presence in the American Landscape*, Martha A. Strawn, The Johns Hopkins University Press, 1977, will be made available for review and sale.

The content of the presentation offers a selection of 151 photographs in a unique book, video, and exhibition that tells a story of America's southern landscape and one of its most evocative creatures, the American alligator. The content combines art, science, history, folklore, land ethics, and literature to tell the story. Topics covered include mating and reproduction, hunting, loss of habitat, resource management, and the commercial meat and skin industries. The emphasis is on mutuality – when human beings and alligators live together in one habitat, each benefiting from the association -and the ethics involved.

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## **Preliminary Study of an Identification Method by the Use of Natural Tail Marks in the Orinoco Crocodile**

Suarez, A.

Ctra. de Andalucía, km.11 (C.L.H.) n° 2

Several artificial marking methods (tagging, cutting of scutes, ...) have been applied in the Orinoco Crocodile Conservation Program. A preliminary study was done to determine the feasibility of using a novel natural identification method in the Orinoco crocodile (*C. intermedius*). This method was developed by Swanepoel in the Nile crocodile (*C. niloticus*); it is based on the coding of natural marks located on a specific portion of both sides of the tail.

Tail sides were photographed and recorded from captive animals of Venezuelan breeding centers, ranging from hatchlings to adults.

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## **Economic analysis of broad-snouted Caiman (*Caiman latirostris*) farming in Sao Paulo, Brazil**

Tacon, A., L. M. Verdade & R. Shiota

**ABSTRACT:** Broad-snouted Caiman (*Caiman latirostris*) skin and meat present a considerable value at Brazilian markets. The natural distribution of the remnant wild populations of: broad-snouted Caiman in South-Eastern Brazil prevent the establishment of ranching and harvesting operations. Because populations are small and fragmented, they would not support hunting pressure or egg collection. Therefore, the only management option for this specie in South-Eastern Brazil is farming. The present study presents an economic evaluation of this system. The following indexes are presented: NPL, internal income rate, Payback period and analysis of sensitivity and risk.

# Conservation Status and a Progress Report of the Re-introduction Program of the Siamese Crocodile in Thailand

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**ABSTRACT:** Since the latest comprehensive survey of *Crocodylus siamensis* in Thailand was in 1993, the wild population status has just been reevaluated. Surveys revealed few remnant populations of less than 10 individuals together in four remote habitats – Kaeng Krachan National Park (KKNP), Pang Sida National Park (PSNP), Khao Ang Ru Nai Wildlife Sanctuary (KARNWS), and Phu Khieo Wildlife Sanctuary (PKWS). Geographically isolated population of crocodiles in all four areas draws an urgent need for augmentation of viable population. Habitat of KKNP and PSNP were demonstrated to meet requirements for Crocodile Habitat Suitability Index. The other two areas are being surveyed. The schedule for pilot release and monitoring program is set for upcoming dry season. Two groups of local conservationists in KKNP and KARNWS areas have been fully supporting the re-introduction program. That suggests help for community outreach and education program in the areas. However, local sustainable development seems far away since most study areas are restricted and remote. The DNA analysis awaits DNA samples from wild-caught animals in study areas and from Cambodia for a comparative test. The main obstacle for Thailand program has been inadequate government support and insufficient funding.

## INTRODUCTION

The Siamese crocodile has been widely distributed in the low altitude freshwater wetlands of central and eastern Thailand. They appeared to be reduced to non-breeding remnants in marginal habitats. The principal threats are habitat destruction, illegal hunting, and killing as vermin. They have been considered an endangered species based on the small number of specimens remaining in the wild. In IUCN Red List (1971), *C. siamensis* is categorized as CR: Critically Endangered, Criteria A.1.a. and c. severely decline in numbers and areas more than 80% decline in three generations (Ross, 1998). During a survey in November 1993, Ratanakorn *et al.* (1994) confirmed the presence of at least one wild adult *C. siamensis* in Pang Sida National Park and another in Ang Lue Nai Wildlife Sanctuary. Many sightings of *C. siamensis* in the wild were recorded at Pang Sida National Park. The most recent one was on April 25, 1993, which is an aerial photograph by M.L. Tossawan Tehwakul (Boonyakhajohn, 1999). In Yod-Dome area, a carcass of *C. siamensis* was discovered after fish bombing by fishermen. Platt *et al.* (in press) reported a recent photograph of a crocodile in Kaeng Krachan National Park. Historically, sightings of *C. siamensis* in the wild were common. In Me Yome, Me Ping, and Pasak rivers, it was fairly common, but it did not exist on the upper reaches of the Me Kong (Smith, 1919). Although wild populations are scarce, *C. siamensis* is abundant in captivity. Tens of thousands of captive populations of *C. siamensis* provide a significant resource for restoration (Temsiripong, 2001).

The ideal habitat proposed for restocking of endangered species must be within historical distribution of animals (IUCN, 1992). A limited number of papers describe the historical distribution of the species making it more difficult to locate potential release sites. It is apparent that this stage of survey is to locate any remaining crocodile populations in Thailand. A number of *C. siamensis* and *C. porosus* have been bred in captivity to provide a basis for recovery. However, the purity of captive-

bred animals is questionable especially in hybrids. No genetic analysis exists for any of the captive populations; the degree of heterozygosity within populations and the degree of relatedness between isolated populations are completely unknown.

As the Siamese crocodile disappeared from people's immediate surrounding, so did this experience and tolerance (Dijk, 1999). It is suggested that the crocodile is not a threat to humans as long as he is given ample room to escape. In fact, a leading herpetologist told swimmers and fishermen that they would be safe from a crocodile attack unless they molest the reptile. During the first decade of the re-introduction effort, the chance that a crocodile will injure a human is exceedingly small, due to the low density of crocodiles in the areas and no one is allowed in the release areas (Temsiripong and Ratanakorn, 2001).

## **METHODS**

### **Habitat Survey**

Four protected areas within historical distribution of *C. siamensis* are visited and assessed the habitat suitability index (HSI) for crocodiles. The potential criteria are the food availability, basking ground, nesting area, protection, nursery pond, and survival index. The spoil or sub-optimum habitats are not considered.

### **Crocodile Survey**

The technique involves a small team of observer who survey a section of waterway in one direction during the day, noting salient features and hazards, and then return over the same section in the reverse direction at night. The survey transect (the section of mainstream river or creek and any associated side creeks to be surveyed) has to be defined by a START POINT and a STOP POINT. Any side creeks off the mainstream, which are amenable to spotlight survey, must also have definitive stop points. Both banks of the mainstream and any side creeks are surveyed. Time of year and water level that is going to affect the number of crocodiles seen will be recorded. It is important to do surveys at the same time of year. For the best results, the cool dry season is the most suitable time to conduct surveys because the current is always too strong to conduct such survey. At this time of year crocodiles tend to be in the water at night because it is warm relative to the cool, night air. It is crucial to use the same type of light each time an area is surveyed. The choice of light used will be determined by the nature of the waterway to be surveyed. For small narrow creeks with thick vegetation fringing the water edge and a high frequency of bends, it is best to use a powerful hand torch as opposed to a 100W spotlight. Under these conditions, the area effectively scanned with the light is usually restricted to distances of 50 m or less. The use of a powerful spotlight creates a glare from light reflected off the vegetation. This may result in "eyeshines" going undetected as they tend to be obscured by the reflected light. Furthermore, crocodile eyes, like cat's eyes, close up in bright light. In wider, more open waterways, where the observer can scan 200-300 m ahead of the boat, a 100W spotlight is ideal. Locations in this study are reported in Universal Transmercator Units (UTM) Zone 47Q as eastings and northings.

### **DNA Analysis**

*Blood sample Collection:* Blood (5 ml) was collected without injury to individuals from either an anterior dorsal sinus using a syringe rinsed with heparin. All samples were collected in icebox and sent to laboratory for DNA extraction.

*DNA Extraction:* For blood, the equivalent of 100  $\mu$ l of crude blood was first suspended in ACK lysis buffer to a total volume of 1.5 ml. This was followed by a proteinase K digestion (62.5 U in 0.5 ml of 20 mM Tris-HCl pH 8.0) at 65°C for at least 3 hrs or overnight follow by two extractions with equal volumes of phenol: chloroform (PC) in a ratio of 1:1 and one extraction with chloroform. The DNA was then precipitated with 95% ethanol, rinsed with 75% ethanol and redissolved in 200  $\mu$ l, TE buffer.

*Quantity and quality' of DNA:* The quantity of DNA recovered from an extraction was determined from the absorbance of the sample at 260 nm. The estimate was refined by comparing the intensity of the fluorescence produced by the sample and by a standard sample of known DNA concentration running on a agarose electrophoretic gel containing 1  $\mu$ g ethidium bromide/ml, and visualized under shortwave UV light. These gels also allowed us to estimate the size range of the DNA fragments in the samples.

*DNA analysis:* PCR amplifications had final concentrations of 50 mM KCl, 10 mM Tris-HCl pH 8, 1% Triton X-100, 1.5-2.5 mM  $MgCl_2$ , 150  $\mu$ M of each dNTP, 0.5  $\mu$ M of specific primer, 1 unit *Taq* DNA polymerase and 50 ng of DNA. During optimization, annealing temperature was varied and/or bovine serum albumin (BSA; 250  $\mu$ g/ml) was added. Thermocycling parameters must be 94°C for 2 mm, follow by 30 cycles of 94°C for 1 mm, annealing temperature for 30 sec, and 72°C for 30 sec.

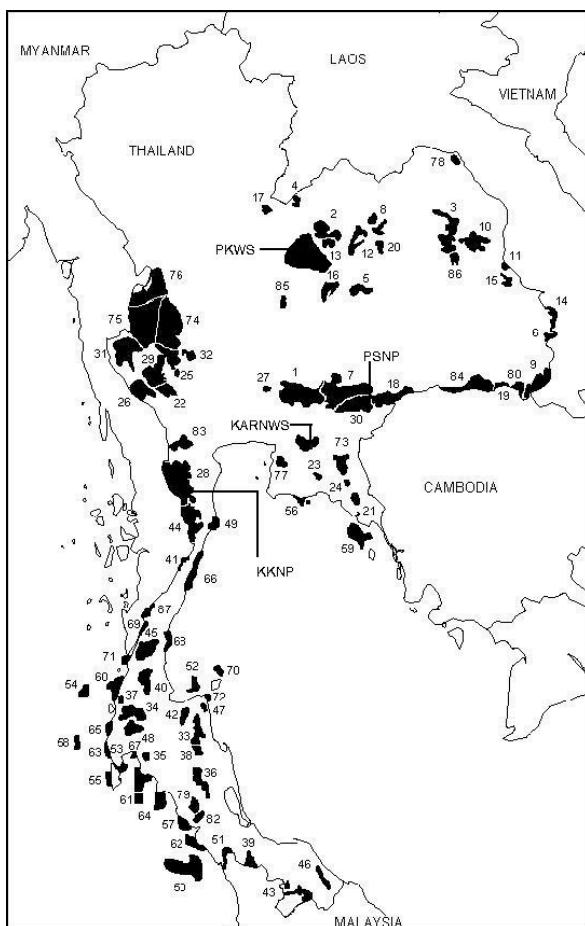
We tested the ability of the primers to produce specific PCR products from DNA of Siamese crocodiles. PCR conditions were identical to those used *C. siamensis*. Products were assayed 1.5-2% agarose gels. Tests were considered positive when one or two bands of similar size and intensity to those from *C. siamensis* are produced. Decreasing stringency of PCR increased taxonomic breadth of taxa amplified, but it also tended to increase presence of extra nonspecific bands and smearing.

## STUDY AREAS

**Kaeng Krachan National Park (KKNP)** is located in the Tenasserim Mountains along the Thai-Myanmar border in Petchburi and Prachuab Khiri Khan Provinces of southwestern Thailand (Fig. 1).

Encompassing 2,915 km<sup>2</sup>, Kaeng Krachan is Thailand's largest national park. The topography is characterized by steep mountain ridges with swift-flowing rivers in restricted valleys. Khao Phanoen Thung (1,207 m) is the highest point in the park. The steep topography and lack of roads make access to the crocodile habitat difficult. Semi-evergreen forest is the dominant vegetation with hill evergreen forest above 1,000 m. Surrounding lands are largely deforested, and KKNP protects the Petchburi River watershed, which supplies Kaeng Krachan Reservoir. The Petchburi River is swift flowing with numerous rapids with small number of Siamese crocodiles recently discovered.

**Pang Sida National Park (PSNP)** is located by The Khorat Hills in Srakaew Province, eastern Thailand (Fig. 1). With 845 km<sup>2</sup>, the park is dominated by deciduous and evergreen rain forest as well as lowland scrub and open grasslands at the foothills, which reflects past logging activities. Surrounding lands are deforested with agricultural use. The Houy Nam Yen Creek was selected as the survey site due to



**Figure 1.** Study areas – KKNP, PSNP, KARNWS, and PKNP

many evidences of *C. siamensis*. For example, a crocodile was sighted and photographed from a helicopter there in 1992. And poachers claimed that they used to harvest hatchling crocodiles from the creek as well. The creek located in the western part of the park flows out of the western boundary of the park into surrounding lowland country.

**Khao Ang Rue Nai Wildlife Sanctuary (KARNWS)** comprises of 108 km<sup>2</sup> and encompasses hills covered in evergreen and dry deciduous forests, with open grasslands in the lowlands. In most of the sanctuary, there are several watersheds that eventually flow into river systems well outside the sanctuary. Most creeks dry and break up to form series of small pools in dry season. Klong Ta Kraw Creek was surveyed once in 1993 by Ratanakorn et. al. (1994). The creek is shallow and narrow and superficially seems to be sub-optimum habitats for *C. siamensis*.

**Phu Khieo Wildlife Sanctuary (PKWS)** encompasses an area of 1,560 km<sup>2</sup> in Chaiyaphum Province, northeastern Thailand, approximately 550 km from Bangkok. The sanctuary comprises a steep-sided plateau ranging from 540 m at its base to 1,310 m at the highest peak. The plateau is drained by five watersheds: Lam Saphung, Lam Nam Chi, Lam Dok, Huai Sang, and Huai Nam Phrom Creek. The latter is the river reported to have a remnant crocodile population. Hill and dry evergreen and dry deciduous forests with open grasslands in lowlands are major types of forest.

## RESULTS

### Habitat and Crocodile Survey

#### Kaeng Krachan National Park (KKNP)

A series of survey carried out in the Petchburi River, Kaeng Krachan National Park from dry season 2001 to wet season 2002. The 30 km stretch of river from the watershed to a reservoir is a rapid flow system with couple deep pools. The sighting of *C. siamensis* in this river has been reported. Two animals were caught there some thirty years ago and put into a farm. However, no reliably positive identification has ever made until recently. A photograph of a 2-m crocodile was recovered from a camera trap. We are able to confirm three locations where signs of crocodiles were discovered.

First of all, the first camera-trap photograph of a Siamese crocodile from Thailand was taken in March 2001 by a field team from Royal Forest Department and WCS, in the course of a tiger survey. We visited and surveyed the area in early 2002 and found an old footprint at UTM coordinate 0531939 1425677. Next, the fresh sign of a crocodile is a drag mark and a footprint of approximately 2m crocodile at UTM coordinate 0533145 1416876. The size of the footprint is similar to the one previously reported by Platt et al. (in press). The location is approximately 13 km upstream from the site of the photo record. The footprint measures 175 x 125 mm. It was a right rear foot. It situated at the edge of the sandbar where sand is tiny grain. The left rear footprint was not shown distinctly because the substrate is the coarse grained sand. Tail drag lies next to the footprint with 40-mm width. This indicates that the animal is approximately 2m. The crocodile was observed a week before by a helicopter pilot and a wildlife photographer. Several efforts to try to capture a crocodile that was camera-trapped were carried out, but due to the fact that there was no fresh track found at the location. We got a water monitor in one of the live traps (Fig. 2). The species is extremely common in the area and its sign could confuse an inexperienced observer. We also used a combination of snare, rope trap and baited snare.



**Figure 2.** Live trap used in Kaeng Krachan National Park

From the surveys, we were able to verify the photo observation and to visit a fresh track spotted a week before. We could not capture one and that may be because a recent rain that obscure all tail drag and foot print. Observation and sampling of potential prey item prove that this area can support a population of *C. siamensis*. Protection is above average according to a large number of carnivore species. And the last but not least, a remnant population lives here. KKNP is, therefore, considered as a re-introduction site.

#### Pang Sida National Park (PSNP)

The first set of surveys provided an update information of a remnant population of *C. siamensis* in PSNP. The surveys on the main section (16.7 km) of Houy Nam Yen Creek was repeated several times. The whole section of the creek was walked, paddled, and some time just drift away on bamboo raft. Several basking sites were spotted, three of which could have been made by moderate-sized crocodiles or monitor lizards. With the size of 2 m<sup>2</sup>, these basking grounds are located between Wang Yao and Wang Mon (Start and stop point of line transects). Unfortunately, 72-hour observation failed to locate a positive sign of crocodiles. Two helicopter surveys for nesting activities in dry season were not able to locate a nest.

The surveys for hatchling crocodiles in wet season were carried out during July – August 2002 in the same area and beyond Wang Mon where never been surveyed before by any research team. We located a hatchling drift across the creek at UTM coordinate 0191145 1553582, but due to dense vegetation we were not able to capture it. We also located a footprint measured at 125 x 105 mm. The footprint could belong to a 1.2-m crocodile. We estimated that there is at least a breeding pair, a juvenile, and a pod of hatchling crocodiles. Habitat and food availability is sufficient to support a small population of crocodiles. Through out the entire creek, there are several deep pools, plus the water is running all year round. The depth of the bottom reaches 3.5 m while the range of the width is 2.5-30 m. The slope of the bank is minimum with abundant aquatic vegetation such as *Cyperus* sp. and *Sagittaria* sp.



**Figure 3.** A 2.8-m wild Siamese crocodile in KARNWS

#### Khao Ang Rue Nai Wildlife Sanctuary (KARNWS)

Several visits were paid to the basking sites (the location is confidential) which belong to one individual (Fig. 3) in Klong Ta Kraw Creek, KARNWS. We almost always find the animal by one of the basking areas. From 120-hour observation during both day and night, the animal usually surfaces quietly and does not panic when he realizes the presence of humans. He, then, submerges upon arrival and leaves only bubble trails on the surface. Twenty minutes thereafter, he comes back up to breathe for 2 minutes and

submerges again for another 20 minutes. Water level appeared low and seemed to be lower till the rain falls. In wet season vegetation on the basking ground is dense, which suggests that the animal had not used the site for a while or he basks only in the dry season. Line transects reveal two more basking sites normally used by the crocodile. A number of scatters collected from these sites proved that the animal has sought a much more secluded site to bask and hide away from us. Later analysis of the scatter uncovers the taxons, which normally being preyed upon by a wild crocodile. The majority of preys are freshwater fish such as *Probarbus* spp., *Channa* spp., and *Clarias* spp. Small mammals' fur

is accounted for only 5% w/w of the scatter. A skull of Pig-tailed macaque was discovered by a sanctuary ranger near the creek seemed surprised but not impossible that it was taken by *C. siamensis*. Upper stream is broken in dry season with only two small pools. Downstream the creek runs toward sanctuary border and end at the Si-Yad Dam near park border.

Observation data show that the crocodile lives mostly under water. He is highly secretive. He basks only in the morning after a cold night. Amidst breeding season, the minimum activity suggested that there is only one crocodile in the area. The sex is therefore unknown because in captivity the size of some females does exceed 2.5 m, while this individual is estimated to attain 2.8 m. Habitat suitability for a small crocodile population looks promising, provided that illegal hunting is under control. A few pools in dry season can accommodate just less than 10 crocodiles. Later relocation of crocodiles to other stretches in the sanctuary is an alternative if there is a severe drought. Although intraspecific competition can be high, interspecific competition is minimal due to small number of salvators and other large reptiles.

#### Phu Khieo Wildlife Sanctuary (PKWS)

Kreetiyutanon and Khumsuk (2002) photographed a footprint with a measurement 220 x 170 mm for a fore foot track and 210 x 190 mm for a rear foot track. Three basking sites were located near Huai Nam Phrom Creek as well. From the measurement, the animal may have a total length of up to 3.5 m. Two more footprints were reported in a different section of the creek. Therefore, at least 3 crocodiles live separately in PKWS. The plan to conduct more surveys in PKWS is set for this dry season. Currently, the current is strong and unpredictable.

### **DNA UPDATED RESULTS**

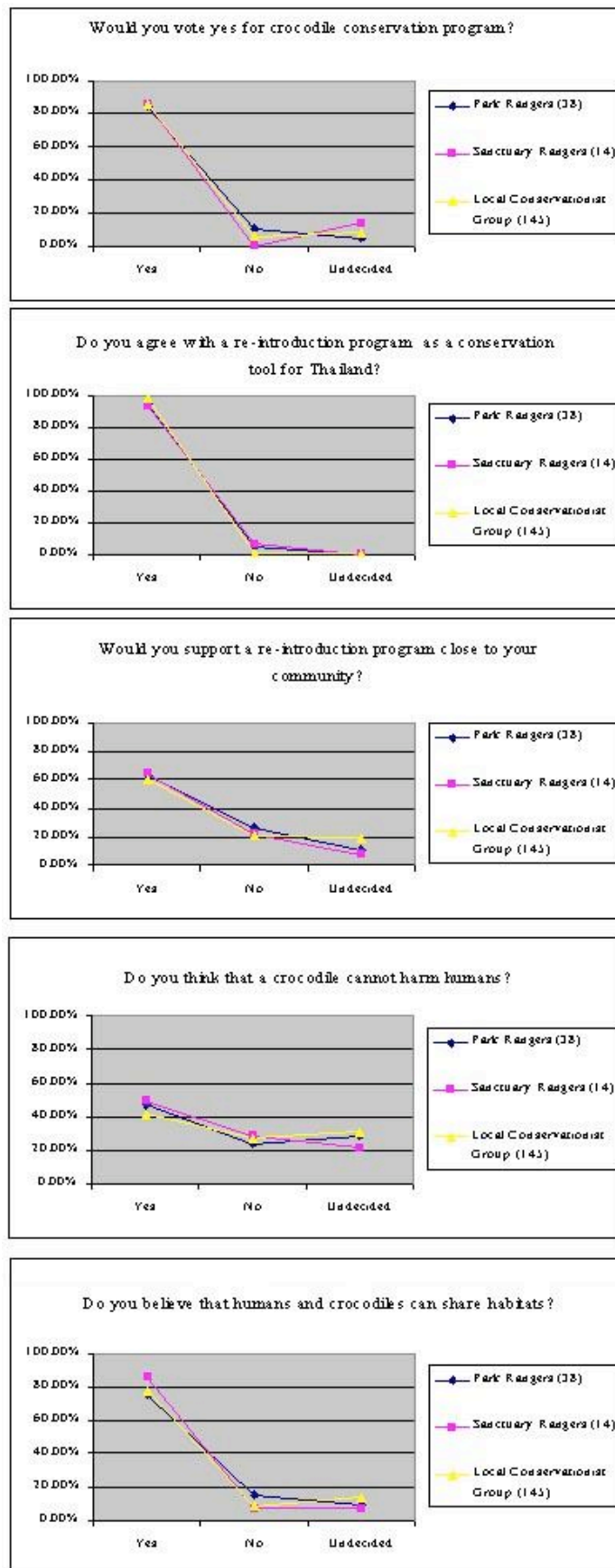
We were able to distinguish *C. siamensis* from *C. porosus*. We applied the American alligator microsatellite markers to differentiate both species. It is now in the process of cloning a specific microsatellite marker for the Thailand Siamese crocodile. The DNA samples are from captive animals. We expect to capture a wild crocodile in each study area to represent geographical variation in genetic material, in order to check genetic diversity and the range of heterozygosity of potential release stocks. A few groups of captive-bred crocodiles were selected from CMAT members' crocodile farms. Most were tested for purity of gene.

### **Interview surveys**

From interviews of 38 park rangers from KKNP and PSNP, 14 sanctuary rangers from KARNWS and PKWS, and 145 local conservationists near KKNP, PSNP, and KARNWS, the results show a significant increase in the number of supporter. Figure 4 could be summarized that people tend to support the project if they are well educated by a project coordinator. Although they are reluctant to welcome crocodiles into their vicinity, half of them think that crocodiles may bring no harm to humans. The need for community outreach and education to create a suitable social climate for accepting wild crocodiles is part of the project (Fig. 5). Social work with education program for schoolchildren and community was considered a major strategy. In KARNWS, local people form a group of conservationists. They campaign against construction of pavement road leading to the crocodile site, since they are afraid the poaching pressure would be out of control.

### **CONSERVATION STATUS AND POSSIBILITY FOR RE-INTRODUCTION**

Threats from poachers and aloewood (*Aquilaria* spp.) collectors with fishing and hunting activities have always been a major problem of wildlife conservation in developing country. Further natural threats such as flooding and interspecific competition are also major problems. Although most areas have suitable habitat, threat to crocodile may hinder the success.



**Figure 4.** Poll results from crocodile education program



**Figure 5.** Community outreach program for local conservationists, park and sanctuary rangers

Together with the Royal Forest Department, we plan to minimize threats to the species such as poaching and fishing, and restore or adjust environment to make it suitable for released animals. We emphasize on monitoring the core not the edge habitat of release areas. We also plan to release the genetic pool that is as similar as possible to the existing wild population. The release of juveniles is in a cause of several years within designated areas. In each area, crocodiles will be released together to make certain that they will not disperse to the distance that make social gathering, mating, and monitoring almost impossible.

Every precaution has been taken to make this re-introduction program the best conservation tool for Thailand Siamese crocodile. Everything that goes into this program has been checked and rechecked to insure long-term survival. We, therefore, sincerely hope that every step of the program will be successful. It is evident that this is going to be a long term and quite slow process, but we agree that the careful and cautious approach is likely to address some of the deep institutional and cultural issues around crocodile re-introduction in a successful way.

## **MANAGEMENT AND CONSERVATION RECOMMENDATIONS**

1. Continue promoting sustainable use of captive-bred crocodile products, which is part of “wildlife trade campaign” by WWF-Thailand to stop illegal trade of wild fauna and flora.
2. Royal Forest Department and Thai government must enforce protection to minimize poaching and fishing pressure. Today, National Park Division is budgeting the tourist infrastructure to promote many pristine tourist spots in most parks. This could bring an end to poaching behavior.
3. Expand an already established market-driven conservation program to the greater extent
4. Risk assessment must be conducted to evaluate the risk involved within project and from local communities, in order to increase public awareness.
5. A re-introduction workshop needs to be set up with representatives from the Royal Forest Department, Fisheries Department, Mahidol University, NGO, breeders, producers, and leather industry to discuss the following issues: wild population status, in-situ management, effort of market-driven conservation for Thailand program, and local sustainable development.

## **ACKNOWLEDGMENTS**

We wish to thank Dr. Plodprasop Suratsawadi, DG Royal Forest Department, for the research permit to conduct a study in protected areas. Dr. Napawan Nopparatnaraporn’s help with DNA

analysis is greatly appreciated. Special thanks go to Sriracha Farm Group for technical support and training for sanctuary rangers. We further want to thank all park and sanctuary rangers who assisted in series of surveys. FFI 100% Fund no. 02/21/06FLAG, YAP, NGTV, and CMAT grant no. 4401 and 4501 were sources of funding for the research. Finally, we would like to thank Dr. Robert Mather, WWF-Thailand for pioneering “The Wildlife Certification Scheme” to help prevent illegal trade of wildlife and promoting sustainable use of captive-bred animals that leads to market driven conservation.

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## **Incidence of Umbilical Scaring in Hatchling American Alligators**

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**ABSTRACT:** Umbilical scaring is the presence of excess scar tissue deposited between pectoral dermal layers at the site of yolk sac absorption in hatchling American Alligators (*Alligator mississippiensis*). The presence of this dermal condition plays a key evaluatory role in the overall quality and subsequent selling value for various commercial leather products. This stated, we have begun to quantify the extent and occurrence of this condition during the 2001 egg laying season. Eggs were incubated in two separate incubators (FCSC and CCF) at 31.5E C (the median temperature for a 1:1 sex ratio) to examine the relationship between artificial incubation of eggs and the subsequent occurrence of umbilical scaring. In addition, we developed a means to quantify umbilical scaring at two days and ten days post hatch to examine whether this technique can be utilized as a predictor management tool of future skin quality. Though umbilical scaring was noted to decrease from day two to day ten post hatch at both sites, no significant differences in the incidence of umbilical scaring were observed at either FCSC and CCF. These data suggest the need for additional research and management in the areas of incubation temperature regimes as well as the relationship between site and incidence of umbilical scaring.

**Key Words:** umbilical scaring, American Alligator, egg quality, leather goods, management

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## **Alligator Embryo and Hatchling Growth from Contaminated and Clean Lakes in Florida.**

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**ABSTRACT:** Research from our laboratory has shown increased alligator embryo mortality in eggs collected from sites contaminated with organochlorine pesticides (OCPs). It is not known, however, if hatchling growth and survival is equally affected. The objective of this study was to evaluate embryo and hatchling growth and survival from lakes with different degree of OCP exposure. During 2001, 40 clutches were collected from the following lakes: Apopka (total average egg OCPs = 12.4 mg/kg), Griffin (1.3 mg/kg), and Lochloosa (0.3 mg/kg). Eggs were incubated and monitored for embryo survival and hatch rates. A subset of hatchlings (10 from 5 clutches/site) was raised for 6 months, and survival and growth (body measurements and thyroid hormones) measured once a month. Although there were no differences in embryo growth between lakes, total embryo mortality was highest in eggs from Lake Griffin (57%, vs. 17% for the other lakes). Hatchling growth rates were highest for Apopka (0.7 g/day vs. 0.5 g/day for the other lakes), whereas hatchling survival was higher in animals

from Apopka and Lochloosa (80%) compared to Griffin (50%). Although these data does not rule out a possible role of OCPs in the development of alligator embryos and hatchlings, it at least suggests the involvement of additional factors. In this respect, our laboratory is currently examining differences in the nutritional quality of eggs among these sites (Funded by NIEHS-SFBRP).

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## **A Management Plan for Crocodiles in Belize**

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Although the status of *C. acutus* and *C. moreletii* in Belize are different, both species share the common concern of human-crocodile interactions as the primary driving force for conservation and management programs. In the absence of hunting and habitat loss *C. moreletii* appears to be secure, especially in northern Belize. The same is not true for *C. acutus* whose continued survival in Belize is tenuous. For both species, residential development in wetland habitats is the root cause of increasing contacts between humans and crocodiles. The common practice of feeding crocodiles in these areas exacerbates the problem. Hence, for both species a common solution is educational programs for residents and tourists. Beyond educational programs, the recommendations for management of both species differ and are related to their different status. Since *C. moreletii* are more secure there is a potential for a problem crocodile program similar to the nuisance alligator program in Florida where potentially dangerous crocodiles can be removed, perhaps even for commercial use. In any case, there will be more pressure to commercially exploit *C. moreletii* and a management plan will have to be developed to deal with this pressure. The primary threat to *C. acutus* is development of nesting and nursery habitat. For *C. acutus* a habitat conservation plan to insure the ecological sustainability of crocodiles and the economic sustainability of humans will have to be developed. The development of an ecotourism attraction based on wild populations of *C. acutus* will be an important component of a conservation plan. Taken together these steps can conserve crocodiles in Belize while providing benefits and security for humans.

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## **Causes of Low Egg Viability in Florida Alligators**

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Alligator egg viability (the proportion of eggs hatching from a clutch) has been chronically depressed on a majority of Florida lakes. Severe declines in egg viability ( $<0.05$ ) were observed during the late-1980s on Lake Apopka and during the mid-1990s on Lake Griffin. In recent years, egg viability on lakes Apopka and Griffin has improved, but egg viability on lakes Apopka and Griffin is still depressed relative to egg viability on lakes Orange and Woodruff, which have high (0.70-0.80) egg viability. We hypothesized that depressed egg viability could be caused by several agents, including pesticide residues, fatty acid imbalances, and nest material. Organochlorine pesticides, DDE (a metabolite of DDT) and toxaphene were found in high levels on Lake Apopka relative to eggs from other areas in 2000. Both of these compounds have been found to reduce reproductive success in birds and fishes. However, preliminary analyses have not found a significant association between egg viability and concentrations of DDE and toxaphene, either for individual lakes (Apopka, Griffin, Orange, Woodruff) or for all lakes combined. Preliminary examination of fatty acid composition of alligator egg yolks collected during 1998-2001 indicates no discernible differences between lakes with depressed egg viability (Apopka and Griffin) and lakes with elevated egg viability (Orange and Woodruff). No discernible pattern was observed between nest material and egg viability on any lake. Thus, no consistent patterns have been detected in the possible causes of depressed egg viability. Further investigations will be undertaken to examine whether endocrine disruption, hypereutrophication, algal toxins, vitamins deficiencies, and thiamin deficiencies are associated with poor egg viability.

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