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of the Species Survival Commission of the IUCN - The World Conservation Union

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FOREWORD

The two volumes of this PROCEEDINGS are a record of the presentations and discussions that occurred at the 11th Working Meeting of the Crocodile Specialist Group in Victoria Falls, Zimbabwe, 3-7th August 1992. The manuscripts are unreviewed and unedited. The CSG PROCEEDINGS, by definition, are records of what occurred at the meeting. They are not tomes filled with articles that were reviewed, edited, revised and polished subsequent to the meeting. Apart from preparing a table of contents, cut-and-pasting captions to figures, compiling the articles alphabetically by author, and numbering the pages consecutively, the papers are published just the way they were submitted. For this reason, they appear in a variety of formats and typefaces. Ian Games was the managing editor.

The opinions expressed herein are those of the individual authors and are not the opinions of IUCN - The World Conservation Union, or its Species Survival Commission.

IUCN - The World Conservation Union was founded in 1948, and has its headquarters in Gland, Switzerland; it is an independent international body whose membership comprises states (irrespective of their political and social systems), government departments, and private institutions, as well as international organizations. It represents those who are concerned about man's modification of the natural environment through the rapidity of urban and industrial development and the excessive exploitation of the earth's natural resources, upon which rest the foundations of his survival. IUCN's main purpose is to promote or support action which will ensure the perpetuation of wild nature and natural resources on a world-wide basis, not only for their intrinsic cultural or scientific values but also for the long-term economic and social welfare of mankind.

This objective can be achieved through active conservation programmes for the wise use of natural resources in areas where the flora and fauna are of particular importance and where the landscape is especially beautiful or striking, or of historical, cultural, or scientific significance. IUCN believes that its aims can be achieved most effectively by international effort in cooperation with other international agencies, such as UNESCO, FAO, and UNEP, and international organisations, such as World Wide Fund for Nature (WWF).

The mission of IUCN's Species Survival Commission (SSC) is to prevent the extinction of species, subspecies, and discrete populations of fauna and flora, thereby maintaining the genetic diversity of the living species of the planet. To carry out its mission, the SSC relies on a network of over 2,500 volunteer professionals working through more than 90 Specialist Groups and a large number of affiliate organizations, regional representatives, and consultants, scattered through nearly every country of the world.

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Volume 1

CFAZ CHAIRMAN'S OPENING COMMENTS FOR THE 11th WORKING MEETING AT THE IUCN/SSC CROCODILE SPECIALIST GROUP

It gives me great pleasure to welcome you all here today, and my first task must be thank those of you who have travelled around the world to be here. We have over 150 delegates from 27 countries outside Zimbabwe, which is good considering the tough economic times we live in.

My next task must be to thank our Minister of Natural Resources and Tourism for finding the time in his busy schedule to be with us to participate in the formal opening. You will be hearing from him in a moment.

We are also pleased to have with us the Director and other officials from the Department of National Parks, with whom we have a very close relationship, the Chairman of the Campfire Association, the members of which provide much of our crocodile egg resource, the Regional Director of the IUCN, the Mayor of Victoria Falls and, of course, our local Chief who will be guaranteeing the success of the meeting by giving us a traditional African blessing.

Those of you who were here 10 years ago will know that this is the second CSG meeting in the Victoria Falls that I have hosted as Chairman of the Zimbabwe Farmers and I sincerely hope that this meeting is as successful as the last and that our hospitality comes up to the same standard.

We have organised a very full itinerary both in the conference rooms and on the social side and I hope that you will all take full advantage of our organisation and facilities.

If all goes to plan it promises to be a very constructive, rewarding and enjoyable week.

If there is anything we can do for you, or if you need assistance, please do not hesitate to contact the Secretariat who will see what they can do.

On the crocodile side, we have made immense progress since the last CSG meeting was held in Zimbabwe. We certainly do not have all the answers, but we know a great deal more about Nile crocodile biology, conservation and management.

Over 85 scientific papers on crocodiles have originated in Zimbabwe, many of these since 1982 and over this short period our industry has grown from an output of 4000 skins a year to 30000, allowing us to invest much more heavily in research. Last year over 30% of our Associations budget went into research, much of it in supporting Government's programme.

At the September 1982 meeting our major concern was to have the Zimbabwe crocodile population moved to Appendix II in order that we might trade freely in our ranch produced skins.

Everyone else's concern was whether our population was still endangered or not. At the time our slogan was "Crocodile utilisation is conservation" and to further our cause we had stickers made for the occasion. We had them in Green too.

We are very pleased to be able to tell you today that our crocodiles are well and truly conserved and are thriving both on rancbes and in the wild. In fact, they have never been so happy.

They certainly get lots of attention. From the production side we have research projects on nutrition, incubation and veterinary subjects. The wild crocs have been chased all over Lake Kariba and elsewhere and their privacy invaded so that we know all about their most intimate habits including the way they progress when returned to the wild.

The Zimbabwe programme has progressed to the extent that 58000 eggs from the wild are collected each year and we pay over $60000 for those eggs that come out of communal lands under CAMPFIRE. The intention is that the appreciation of the monetary value of crocodiles will make people more tolerant of their more unpleasant habits.

We are proud of our conservation role in Zimbabwe and look upon ourselves very much as an agent of the Department of National Parks in this country. We have common aims and we are well aware of the need for us to do our part to help Zimbabwe maintain a clean record as far as CITES is concerned.

I could go on telling you how successful the Zimbabwe programme is, but I think I have just about spoken enough. You should all by now know who I am and please do not hesitate to come and see me directly if anything is not to your liking

However, before I finish I would like to comment on the situation in the United States which has tougher domestic legislation than CITES and which does not allow our African Skins to enter. This is a complete violation of human rights in that the whole US population is being denied high quality crocodile products being compelled to take tatty alligator rubbish instead. I think that this should be stopped!

Without further ado, I will ask the Minister, the Honorable Dr Herbert Murerwa to present to us his opening remarks.

PRESENTATION FROM THE MINISTER OF ENVIRONMENT AND TOURISM TO OPEN THE 11th WORKING MEETING OF THE IUCN/SSC CROCODILE SPECIALIST GROUP

Welcome to Zimbabwe. It gives me great pleasure to open this meeting of the Crocodile Specialist Group with a few comments which I hope prove to be appropriate and contribute to the spirit of your meeting.

From the perspective of the early 1970's, when it seemed that hunting would never be controlled, crocodile conservation must have looked very depressing and it is no wonder that all the species were placed on the CITES Appendices when the Convention was concluded.

Since then, of course, it has been recognised that several of the most restrictive listings, on Appendix I, were not appropriate and in addition the status of many species has improved. As a result, crocodiles have been on the agenda at CITES for many years and over the last 20 years, we have come to expect the crocodiles to be at the cutting edge of innovative conservation, especially in the CITES context.

Before expanding on this, it is worth pointing out that the establishment of CITES clearly drew the battle lines between those whose answer to the abuse of a natural resource is prohibition, and those who believe that the answer to abuse is better management to give sustainable use. In Zimbabwe we subscribe to the latter view, especially since we strongly believe that sustainable use is a strong conservation tool in many circumstances.

It would seem that this principle is more readily accepted and demonstrated with crocodiles than with any other species and we are clearly not the only people who are trying to conserve crocodiles through their use. I am happy that so many people with similar experiences to those of Zimbabwe are here today - I can assure you that it is not often that I am asked to address an international audience which almost universally believes in the same conservation philosophy as Zimbabwe!

I would now like to move back to the issue of crocodiles as conservation pioneers.

Although CITES is often seen as a catch-all conservation treaty it only addresses trade as a factor affecting the conservation of species. Where habitat loss or other factors are causing the decline, as so often is the case, CITES cannot really help. Indeed, it is our experience that under these conditions CITES is often a definate hinderence.

Where a species is under pressure from habitat loss the intuitive reaction is to increase protection from exploitation by banning international trade.

However, where the issue is habitat loss the removal of value from the species also removes management options. Some lateral thinking and a great deal of experience lead us to believe that habitat loss can only be addressed by making it economically unattractive to convert wild lands to agriculture and settlement. In this, international trade can play an important part and wildlife utilization and trade should never be stopped without very careful assessment of the conservation costs and benefits.

In line with this principle, we are proud that Zimbabwe was the first country to move its crocodile population to Appendix II under the ranching criteria. The last time the CSG met here, almost exactly 10 years ago, Zimbabwe was struggling to have its CITES listing for the Nile crocodile changed for its conservation benefit. Today we can see the results of this succesful downlisting. Crocodiles, which eat a number of our people each year, are at least tolerated by the average Zimbabwean and in some circles of course they are highly prized - not just by the farmers, but also by poor rural people who now benefit economically from crocodiles.

It is of some satisfaction for me to be able to tell you that our farmers have just paid poor rural communities over $ 60000 for crocodile eggs collected from areas in which the people have been given appropriate authority for their wildlife under our CAMPFIRE programme.

We have watched with interest as other countries have gone through the same process and as CITES has adapted to new circumstances and advances in crocodile management. Indeed, at every CITES meeting it always seems to be crocodiles for which new management strategies are being developed and for which CITES most readily adapts.

I suppose it is because they are not cuddly animals.

The Special Criteria or quota system was a great advance as far as we are concerned which helped many of our neighbours in Africa a great deal. We support the idea of Appendix II quotas, and of the strengthening of Appendix II in general. If Appendix II worked properly it could accommodate many of the species and populations which are on Appendix I. While some crocodile species are clearly endangered, we would always question the use of Appendix I and it is interesting to see CITES wrestling with the problem of the Phillipines crocodile and the Chinese Alligator which, though clearly endangered, will benefit from controlled trade from farms.

Finally, I have to say that we have a very high opinion of the CSG and the way it has supported pragmatic conservation and I hope that you intend to continue this process at this meeting.

I believe that during this week you will be having a number of workshops including one which is looking at the CITES resolutions which affect crocodiles.

CITES is peppered with crocodile resolutions and at the very least we would all benefit greatly from the consolidation of these. I think it would also be worth your while to consider abandoning some of the outdated CITES models, such as ranching, replacing these with a general system of quotas which allow mixed stategies.

Once again, welcome to Zimbabwe and good luck with your meeting.

Fitting Curves to Crocodilian Age-size Data: Some Hesitant Recommendations

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Introduction

While we are gathered together every two years, somebody usually gets up to tell us about crocodilian growth rates, and as he or she talks, most of us stay around to listen. Beyond mere politeness, there are at least three reasons for our forbearance. First, we believe that the relationship between crocodilian age and size is biologically interesting and directly relevant to most management strategies. Second, we understand that after you've caught a croc which is to be released, you must do <u>something</u> to justify the trouble, expense, and fun of the hunt. Measuring an animal's size is "doing something," and if one can also establish an age for the varmint, so much the better. Third, as scientists most of us really like to measure things, to systematize our measurements, and to tell other scientists about what we have measured. In our work we concentrated on the "systematizing" part of the process, and to do so we have (1) evaluated the fit of three models to samples from a population of simulated crocs whose underlying growth pattern is known and (2) tried to determine how well several models perform inductively when we use them to generalize beyond samples from an actual crocodile population.

This paper is divided into six sections. In the first we explain how we created our population of simulated crocodilians and how we took samples from it. In the second section we describe the models which we fit to the samples. In the third section we evaluate the fit of the various models. Next, in section four, we describe another set of models and explain how we applied them to samples from a population of <u>Crocodylus acutus</u>. In the fifth section, we evaluate model performance. And in our conclusion we offer tentative recommendations on how one might summarize crocodilian growth patterns.

Section I: Simulated Populations and Samples for Analysis

We constructed a simulated crocodile population whose members grow according to a known function. We allowed random variability around that growth function (mean amplitude of the variability is proportional to a given animal's predicted size). From that population we took twenty-five probability samples according to each of three different sampling schemes.

Points 1-5 below describe the construction of the population. Points 6 and 7 explain how the samples were caught.

1. Each simulated crocodile in our population is constructed to have a known age (measured in days) and a known total length (measured in centimeters).

2. The simulated population of crocodilians was created and "grown" according to a formula that gives predicted total length at time t (PTL_t) as a function of age (t) and 4 growth parameters:

$$PTL_t = [S_a^{1-m} - (S_a^{1-m} - S_0^{1-m})e^{(-2[1+m]t/T)}]^{1/(1-m)},$$

where S_a is asymptotic length, m is the curve shape parameter, S_0 is length at time zero (hatchling length), e is the base of natural logarithms, t is time, and T is the growth-rate parameter as expressed by Brisbin et al. (1986). For this simulated population we chose parameter values approximately equal to those estimated for a south Florida population of Crocodylus acutus. [1]

3. Originally this simulated population had one animal at every even-day age from 2 days to 8000 days. Then each simulated animal was assigned a "survival probability." This probability decreases with age in such a way that:

a. From t=0 to t=360, survival probability, P, is given by

$$P = (0.998076)^t;$$

i.e., about half of the animals might be expected to die off by one year of age.

b. From t= 361 to t = 8000, survival probability is given by

$$P = (0.5)*(0.999711)^{t-360};$$

i.e., animals that reach one year of age might be expected to "decay out" by about 10%/year.

4. Animals were "killed off" according to their P (or survival probability, as described above) by comparison against

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[1] Many readers will recognize the above equation as the full, four-parameter Richards model. S_a is set at 400cm; m is set at 0.273; S_0 is set at 30cm; t (age) is measured in days; T is set at 6000 days. Given these parameter values, the equation simplifies to approximately

$$PTL_t = [77.929-(66.075)*EXP(-0.0004243*t)]^{\wedge}1.3755$$

a set of uniform random numbers. This attrition reduced the simulated population from 4000 to 884 animals.

5. "Random" variability was introduced into "total length" in the following way. Where TL is the length variable to be constructed, and PTL is total length as predicted by the deterministic formula above, and Z is a pseudo-random variable (normally distributed, with average 0 and standard deviation of 1), then:

$$TL = PTL + PTL * (0.1) * (Z).$$

6. We wanted to examine three different sampling schemes: (i) equal capture probability for all animals, (ii) a slight bias in favor of catching younger animals, and (iii) a strong bias in favor of catching younger animals. Therefore, for each of the 884 members in the simulated crocodilian population, we established capture probabilities three different ways: [2]

a. Capture probabilities were equal (for all animals, CPU = 0.4); this will be called the UNIFORM sampling scheme.

b. Capture probabilities were somewhat higher for young animals than for older ones: CPM = 0.5 - 0.000025*AGE. That is, the probability of catching an individual animal is 0.5 when the animal is a fresh hatchling and declines linearly with age to 0.3 by the time the animal is 8000 days (about 22 years) old; this will be called the MEDIUM sampling scheme.

c. Capture probabilities were much higher for young animals than for older ones: CPS = 0.8 - (0.000075)*AGE. That is, the probability of catching an individual animal is 0.8 when the animal is a fresh hatchling and declines linearly with age to 0.2 by the time the animal is 8000 days (about 22 years) old; this will be called the SMALL sampling scheme.

7. Finally we used a pseudo-random number generator to produce a capture variable which we compared against CPU, CPM, and CPS. For each capture-probability algorithm, we ran through the simulated population twenty-five times to produce (for each type of capture-probability sampling scheme) twenty-five independent data sets of animals "captured."

At this point we have seventy-five samples available for analysis. The next section, MODELS, will explain what we did with these samples.

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[2] The following three capture-probability "lines" were selected (i) to represent the three different sampling schemes and (ii) to produce approximately 100 animals in the simulated samples.

Section II: Models Applied to Samples of Simulated Crocodiles

We investigated three related models that give crocodile length as an asymptotic, monotonically increasing function of age.

A. RICHARDS model. This model is specified by four parameters (variously expressed by various authors): STARTING SIZE, ASYMPTOTIC SIZE, CURVE SHAPE, and "AVERAGE" GROWTH RATE. Our other two models are special cases of this mother of all sigmoid curves. In the body of this paper we shall often call this THE FULL MODEL, [3] and the algebraic form we used for it is:

$$S_t = [S_a^{1-m} - (S_a^{1-m} - S_0^{1-m})e^{(-2[1+m]t/T)}]^{1/(1-m)},$$

where S_t is size at time t, S_a is asymptotic size, m is the curve shape parameter, S_0 is size at time zero, e is the base of natural logarithms, t is time, and T is the growth-rate parameter as expressed by Brisbin et al. (1986).

B. VON BERTALANFFY models. These models are frequently used in the literature on reptile growth, perhaps because they are based on actual, semi-understandable physiological assumptions. [4]

1. VON BERTALANFFY MODEL FOR LINEAR GROWTH. [5] This model, a decaying exponential function, is a special case of the Richards curve family: the shape parameter is set to 0. In the body of this paper we shall call this THE VON BERTALANFFY MODEL.

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[3] Readers will recall that this full Richards model is actually the "correct" one, the pattern according to which our population of simulated crocodiles was actually grown. As we shall see, however, examination of the samples does not always allow the researcher to tell which model is correct, even from the limited assortment which we investigate.

[4] Basically, the von Bertalanffy model assumes that growth is a function of the difference between anabolic processes (which are assumed proportional to metabolic rate which is in turn assumed to be the 0.75 power of body mass) and catabolic processes (which are assumed to be proportional to body mass). See Andrews (1982).

[5] Some authors call this the monomolecular model (Brisbin, "Ninth working meeting . . ."; Brisbin and Newman, 1991; Leberg et al., 1989).

2. VON BERTALANFFY MODEL FOR GROWTH IN MASS.[6] This model, a sigmoid function, is a special case of the Richards curve family: the shape parameter is set to 2/3. Curiously, Brisbin ("Ninth working meeting . . .") used this curve in one model of alligator length.[7] Clearly, when dealing with linear dimensions this model lacks the virtue of easy physiological interpretability, but it does sometimes provide a good empirical fit. In any case we chose to use it in our length models as an arbitrarily chosen, fixed "shape," sigmoid curve. In the body of this paper we shall call this THE FIXED SIGMOID MODEL.

Section III: Results of Analyses on Simulated Crocs

Here we deal with three overall questions: (1) From our limited set of models, how easy is it to pick the correct one? (2) How much difference does it make if you pick the wrong model? (3) How much difference does the sampling scheme make?

A. Picking the correct model. We know that the population of simulated crocodiles was grown according to the FULL MODEL[8]; that is the correct one. But if we were ignorant about the actual population model, how confidently could we pick it out by examining the samples? The criterion usually employed is analysis of residual variation around the model. Of course in any direct comparison of residual variance, the FULL MODEL can never do any worse than a tie for first place, no matter what the "true" population growth regime might be. Therefore it is conventional to use the F-distribution in evaluating model fit: How often can we reject the null hypothesis that some reduced model fits just as well as the FULL one? The following table tells the rather sad tale:

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[6] Our two Von Bertalanffy models, for linear dimensions and for mass, are algebraically interconvertable if one assumes that mass is a function of the cube of the linear dimension under analysis.

[7] In this paper the curve is simply termed "the von Bertalanffy model" as opposed to "the monomolecular model," which we prefer to call "the von Bertalanffy model for linear growth."

[8] That is the full, four-parameter Richards model.

Type of model:	Type of sampling scheme: UNIFORM	MEDIUM	SMALL	ALL
VON BERT. MODEL	11/25	9/25	9/25	29/75
FIXED SIGMOID MODEL	2/25	4/25	6/25	12/75
BOTH MODELS	0/25	0/25	0/25	0/75

Table 1: Proportion of samples in which we had statistically significant evidence (F, at the 0.05 level) for rejecting the ("incorrect") reduced models in favor of the ("correct") full model.

Note that we can distinguish the full model from the von Bertalanffy model only about a third of the time. The full model does even worse against the fixed sigmoid model. And we could not select the FULL model against both competitors in any of our seventy-five samples. The moral is simple: At least under some conditions, it's awfully hard to find the underlying population model by examining residual variation to fit in samples!

B. If one is unlikely to find strong evidence for the ("correct") FULL model over its two competitors, then how severe are the errors one is likely to make in selecting one of the ("wrong") reduced models? Any complete answer to this question depends on the context of one's investigation. For this simulation study, we shall address this question in two ways.

1. First, we can evaluate model performance by seeing which models do best how often in estimating three population parameters of possible interest:

a. Hatchling length; HL.
b. Asymptotic length; AL. [9]
c. Length at age 10 years; L(10). [10]

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[9] Readers should remember that the asymptotic length predicted by a model is not "the biggest any crocodile is ever going to get." Rather it is an expected (sort of an average) maximum size, around which we might see considerable variability.

[10] We figured that expected length at an intermediate life stage might be more interesting to researchers than either hatchling length (which typically is pretty well known) or asymptotic size (which might intrigue more journalists than

The following four tables give the number of times a given model performs best (of the three models) in estimating given parameters under given sampling schemes:

Type of model:	Parameter being estimated HL	L(10)	AL
FULL MODEL	21	2	8
VON BERT. MODEL	2	21	3
FIXED SIGMOID MODEL	2	2	14

Table 2: Which model is best at estimating which parameters under the UNIFORM sampling scheme.

Type of model:	Parameter being estimated HL	L(10)	AL
FULL MODEL	18	6	6
VON BERT. MODEL	3	16	5
FIXED SIGMOID MODEL	6	5	14

Table 3: Which model is best at estimating which parameters under the MEDIUM sampling scheme.

Type of model:	Parameter being estimated HL	L(10)	AL
FULL MODEL	22	7	3
VON BERT. MODEL	0	17	9
FIXED SIGMOID MODEL	3	1	6

Table 4: Which model is best at estimating which parameters under the SMALL sampling scheme.

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biologists). The exact age we decided to evaluate was chosen rather arbitrarily-- because we thought it might be a sort of coming-to-maturity age for a crocodilian and because 10 is such a pretty, round number.

Type of model:	Parameter being estimated HL	L(10)	AL
FULL MODEL	61	15	24
VON BERT. MODEL	5	54	17
FIXED SIGMOID MODEL	24	17	34

Table 5: Which model is best at estimating which parameters under ALL sampling schemes taken together.

Examination of these tables does not immediately convince one that the "correct" FULL model is all that much better than either of its two reduced competitors. Indeed, for some specific tasks the other ("incorrect") models appear to perform better. [11]

2. As we investigate the problems that could result from difficulties in model selection, we might also wonder about the statistical bias of each model in estimating the three parameters defined above. The following table addresses that question:

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[11] The reasons for this are complex. The high end of all curves responds to the strong influence of a few points whose position varies widely across the samples. On the other hand, the relative abundance of small animals in all samples "locks" the low end of all curves into position. Within these constraints the FULL model, "seeking" a better <u>overall</u> fit, is likely to miss certain specific age-size points by more than its competitors. On the other hand, by fixing its shape, we force the von Bertalanffy curve down in its center, towards the "correct" A(10). The relative performance of these competing models would <u>not</u> be the same given other "true" underlying models of growth in the population.

	UNIFORM sampling			MEDIUM sampling			SMALL sampling		
	FULL	VON B	SIGM	FULL	VON B	SIGM	FULL	VON B	SIGM
HL	+	-	+	NS	-	+	NS	-	+
L10	+	NS	+	+	NS	+	+	NS	+
AL	-	+	-	NS	+	-	NS	+	NS

Table 6: Model bias in estimating three parameters under three sampling schemes. "+" indicated statistically significant over-estimates; "-" indicates statistically significant under-estimates; "NS" indicated no statistically significant difference between population parameters and estimates. [12]

Again, no clear pattern emerges, and one sees no terribly convincing empirical argument for preferring the correct, FULL model over its reduced competitors. Perhaps that's fortunate since it's so hard to demonstrate that the FULL model is the right one.

C. In addition to our concern about model selection, we can also examine to some degree the importance of sampling scheme. When we examine estimates for our three length parameters (HL, L[10], and AL), we find that in 17 out of 18 cases, for whatever model, predicted lengths are "better" for the UNIFORM sampling scheme than for either the MEDIUM or SMALL sampling schemes or for both taken together. Furthermore, as the following table indicates, several of the differences are significant (though the sheer number of hypothesis tests should make us slightly uncomfortable). Thus we have at least limited statistical evidence that sampling schemes can be important.

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[12] Caution should be used in interpreting this table, for statistically significant biases can result from both (1) large average errors in estimating a parameter (which is bad) and (2) small variance in estimates (which is good).

sampling schemes	FULL MODEL			VON BERT MODEL			FIXED SIGMOID MODEL		
	HL	L10	AL	HL	L10	AL	HL	L10	AL
UNIFORM vs. MEDIUM vs.	.115	.998*	.006	.007	.848	.002	.759	.961	.257
UNIFORM vs. MEDIUM & SMALL	.055	.955	.002	.003	.678	.002	.544	.787	.106

Table 7: P-values on the null hypothesis that there is no difference between parameter values as estimated under the three different sampling schemes. Three-way comparisons are by Kruskal-Wallis one-way "ANOVA"; two-way comparisons are by Mann-Whitney U. For all comparisons except the one marked by * the relationship was in the direction expected under the alternative hypotheses of "UNIFORM allows estimates better than MEDIUM allows estimates better than SMALL," and "UNIFORM allows estimates better than MEDIUM and SMALL taken together." Evaluation under the Bonferroni procedure for multiple comparisons suggests that only values of $p < 0.0028$ should be considered significant.[13]

We have learned in these sections that there are no particularly clear winners in the competition of fitting models to our simulated data. As we apply a different set of "models" to real-world data on American crocodiles, we shall at least be able to identify a set of real losers.

[13] Non-parametric statistics were used because of doubts about the shape of the theoretical distribution of parameter estimates. For brief information on multiple comparisons and the Bonferroni procedure, please see Wilkinson. 1988, pp. 490-491.

Section IV: Actual Croc Data, Models and Application

1. The data. We used actual growth records taken from a population of Crocodylus acutus in southern Florida. The data were collected by Paul Moler (Florida Game and Fresh Water Fish Commission). In this paper we are concerned not with the specific growth of American crocodiles but rather with the performance of various growth models in fitting the data. Therefore, in order not to poach on Paul's intellectual property, we have been careful (1) never to fit any growth curves to his entire data set and (2) never to make public any specific parameter values for curves fit to subsets of Paul's data. The subset of data we used included about 850 capture-events for 340 known-age animals.

2. Curve fitting and testing plan.

a. We used a random number generator to chop the data set into two approximately equal parts, a CALIBRATION DATA SET and a TEST DATA SET.

b. We fit the following 12 "models" to the calibration data set:

REGRESSION

LINE ALL: length as a function of age, all captures;

LINE LAST: length as a function of age, last captures only for each animal;

QUAD ALL: length as a function of age and age squared, all captures;

QUAD LAST: length as a function of age and age squared, last captures only;

CUBE ALL: length as a function of age, age squared, and age cubed, all captures;

CUBE LAST: length as a cubic function of age, last captures only;

FOUR ALL: length as a function of age, age squared, age cubed, and age to the fourth power;

FOUR LAST: length as a quartic function of age, last captures only.

VON BERTALANFFY

VONB INT ALL: Von Bertalanffy model fit (by a nonlinear program using the Quasi-Newton method of variance minimization; SYSTAT) to all inter-capture intervals for all animals;

VONB INT LONG: Von Bertalanffy model fit (as above) to only the longest inter-capture interval (first capture to last capture) for each animal;

VONB FD ALL: Von Bertalanffy model fit by a finite difference method (using linear regression to estimate asymptotic length and the growth rate parameter; see Andrews, 1982, p. 287) to all inter-capture intervals for all animals;

VONB FD LONG: Von Bertalanffy method fit by a finite difference method (as above) to only the longest inter-capture interval for each animal.

c. The specific curves derived as above (fit to the CALIBRATION DATA SET) were applied to the entirely different TEST DATA SET, and residual sums of squares were compared to see which models worked best. Because we could not define the shape of the probability density function for this residual variance, we maintained a record of the rank of model fit (1 for "best," 12 for "worst") for non-parametric analysis.

d. We repeated steps a-c above for a total of 35 tests.

Section V: Analysis and Evaluation

There are some classes of "models" which the researcher should not even consider.

(i) Higher-order polynomials. Of course the best fits to the CALIBRATION data sets were inevitably obtained by the fourth-power polynomials, which could snake their way around to fit whatever points were at hand. As one should also suspect, these "models" were among the worst in explaining variance within the TEST data sets. Third-power polynomials were almost as bad:

RANK BASED ON:	CUBE ALL	CUBE LAST	FOUR ALL	FOUR LAST
median	6	5	7	9.5
mean	6	5	7	10

Table 8: Higher Polynomials, Rank out of 12

Among the fourth-order polynomials, there were some real horror stories, including some equations that left more residual variation in the TEST data than the fit of a simple mean.[14] Furthermore, for both cubic and fourth-order polynomials, the statistical significance of coefficients associated with higher-order terms (in their fit to CALIBRATION data) was of no apparent help in guessing goodness of fit to TEST data.[15] Thus, in our study, all the old warnings against polynomial regression are affirmed: They describe very well, but extrapolation is probably disastrous, and generalizations beyond the data in hand are dangerous.

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[14] Yes, this is a negative coefficient of determination. You can think of it as being a sort of negative R-square.

[15] The reasons for this are not mysterious. Large animals are scarce in the samples (as indeed they are in the population). For this reason the regression is particularly sensitive to violations of the assumption of homoscedasticity.

(ii) Linear regression. Crocodiles don't grow at the same rate throughout their lives, so it's silly to model their growth by a straight line. Their fit to TEST data was predictably bad:

RANK BASED ON:	LINEAR ALL	LINEAR LAST
median	9.5	9.5
mean	8	9

Table 9: Linear Regression, Rank Out of 12

(iii) Von Bertalanffy fit by finite difference methods. Andrews (1982) suggests that using linear regression to estimate Von Bertalanffy parameters should be avoided if a non-linear curve-fitting program is available. That is certainly true for our work! The fit of such curves to our TEST data sets is almost uniformly terrible:

RANK BASED ON:	VONB FD ALL	VONB FD LAST
median	9.5	12
mean	11	12

Table 10: Von Bert., Finite Difference, Rank Out of 12

b. Almost-decent options.

Quadratic regressions fit the CALIBRATION data sets fairly tightly, and they usually perform almost as well on the TEST data sets:

RANK BASED ON:	QUAD ALL	QUAD LAST
median	3	3
mean	2	3

Table 11: Quadratic Equation, Rank Out of 12

Thus we might conclude that quadratic equations do a pretty good job of describing crocodile growth. Of course there is one severe problem because the quadratic (= parabolic) equations must not be extrapolated to very old animals-- unless one assumes that some very serious crocodile shrinking is going on!

c. Options to be considered.

The integrated form of the von Bertalanffy equation fits the TEST data sets well:

RANK BASED ON:	VONB INT ALL	VONB INT LAST
median	3	1
mean	4	1

Table 12: Von Bert. Integrated Form, Rank Out of 12

It is interesting to note that the fit using only one inter-capture interval (the longest) per animal provided significantly better performance than the fit to all inter-capture intervals. [16]

Section VI: Conclusion

It should be clear that we have no fancy new theoretical insights to tell you. Nevertheless, we do have a few modest recommendations that we'd like to offer.

1. Things not to do.

a. Using linear regression to estimate von Bertalanffy parameters in finite difference analysis appears not to be a good idea.

b. Polynomial regression (especially with equations higher than second order) can describe data sets quite well, but we recommend against it. Extrapolation of such equations is always a bad idea, and if regression assumptions are not perfectly met (they seldom are), any generalization beyond in-hand data is very dangerous.

2. Things to be careful about.

a. Transforming data for conventional regression analysis can create models which are difficult to interpret. Furthermore, since transformations alter variance, one must not directly compare residual variance around fitted models.

b. Given most samples that biologists are likely to obtain, it is difficult to determine with certainty what the underlying population model really is. For example, under several sampling schemes, F-tests are not very powerful for

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[16] P is about 0.01 by SIGN test on ranks. This is rather nice since the one-interval-per-animal fit helps assure independence of observations. Such independence is appropriate if one wishes to perform inference involving confidence intervals or hypothesis tests. Overall, however, our work leaves us leery of performing such procedures on crocodile growth curves, even under the best of circumstances.

rejecting null hypotheses that reduced-parameter models fit as well as the full Richards model.

c. Crocodilian populations often have lots more young animals than old ones.[17] Furthermore, practicable sampling schemes (especially those that secure known-age animals) sometimes exacerbate the problem of disproportional representation by age. For these reasons, individual observations of older, larger animals often have extreme statistical leverage on the shape of fitted growth curves. Thus one needs to be careful when fitting mathematical curves to age-size data. For example, one or two observations (perhaps of aberrant individuals) can largely define the asymptotic length estimated for a population.[18] Thus we recommend that people remain cautious about describing crocodilian growth patterns until their sample includes a substantial number of large animals.

d. Given (1) the typical structure of wild crocodilian populations, (2) the nature of sampling strategies conventionally applied to their study, and (3) the behavior of our sample statistics under simulation, we would recommend caution in the use of inferential procedures involving confidence intervals or formal hypothesis tests. All too often our sample statistics did not lie within purported "95% confidence intervals" of the known population parameters.

3. Things one might consider doing.

a. If one is interested in the overall growth pattern of a crocodilian population, then it's probably worth the extra trouble to ensure that older, larger animals are represented <u>at least proportional to their abundance</u> in samples to be analyzed.

b. We believe that either the von Bertalanffy model or the full Richards model may often be used for summarizing the growth of crocodilians. The former is more appropriate if one wishes to compare results with other published data; the latter is probably better if one is concerned about the possibility of technical "specification error." Of course

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[17] In a sense, even if one could examine every member of a living crocodilian population, the older, larger individuals might provide an inadequate "sample" of the growth trajectories available to the species.

[18] For example, in our 35 sub-samples of the <u>C. acutus</u> growth data, our best estimation method produced estimates of asymptotic length ranging from 263.4cm to 572.5cm. These two extreme values were the exceptions to a general pattern with a somewhat more reasonable standard deviation (83cm), but one should note that they were generated <u>from random samples of the same population of data points</u>.

neither should be applied until the researcher has examined a scatterplot of the data. [19]

c. We think that perhaps it may be wise for researchers to worry less about fitting general curves to scatterplots and to concentrate (at least initially) on close examination of the point-cloud itself (which scatterplot, we are convinced, should certainly be presented in any formal publication). To some degree all "growth curves" are abstract human generalizations. Even an individual crocodilian does not always grow according to a fixed, internal schedule (that's the lowly sort of thing that young mammals-- which basically must grow or die-- are forced to do); rather it responds to the varying environmental conditions that surround it, growing faster or slower as food and warmth permit. And when you get a whole population of crocs, the whole picture becomes even more complex.

Thus in a size-age scatterplot, cohort clusters of outlying data points (or even single outliers) may, under careful analysis, reveal more relevant information about the biology of the beast than four-digit parameters fit to abstract mathematical curves. (Indeed the most important function of these "growth curves" may be that they assist us in the identification of outliers for systematic analysis.)

Anyhow, when all is said and done, we reckon the very best use of growth curves is to encourage managers and biologists to ask questions like, "Is that extra-fast-growing male going to contribute more than his share of genes to the next generation?" or "What the heck is happening to the hatch of 1987 anyhow?"

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[19] Relatively "assumption-free" curve-fitting techniques such as SYSTAT's LOWESS routine (try various levels of the "tension" parameter) are quite appropriate in exploratory phases of data analysis.

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Population Dynamics, Ecology and Conservation of the Black Caiman, Melanosuchus Niger in Ecuadorian Amazonia.

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The Black Caiman, Melanosuchus Niger was distributed widely throughout the Amazon Basin until the middle of the present century. Although few reports are available in the literature concerning the status of this species until the beginning of the twentieth century, Wallace (1853), Bates (1863), Goeldi (1898) and Hangman (1902) gave anectdotal accounts of abundant populations along the "alto Solimoes" (Upper Amazon River) and found large numbers of the species in the Mexiana, Marajo and Caviana Islands of the Amazon River delta. The occurence of Melanosuchus niger populations in Ecuadorian Amazonia has been reported by La Condamine (1778), De Ulloa (1789), De Velasco (1985), De la Espada (1881) and Schmidt (1928).

Black Caiman populations have been severely depleted because of extensive hunting during the past 70 years. Aguirre (1956) mentions that between 1950 and 1954 a quantity of 560,000 skins was exported from Manaus and Belem. He stated that the minimum size of the Black Caiman to be harvested should be 230 cm total length which corresponds to the minimum breeding size of <u>Melanosuchus</u> females (Aguirre, 1956). Fittkau (1973) estimated that during the 1960's more than 5 million skins were traded and in addition 1 to 2 additional individuals were sacrificed for each skin reported in the trade. Carvalho (1967), Medem (1972, 1983), Smith (1980), Rebelo and Magnusson (1983) provide data about the effect of hunting on <u>Melanosuchus niger</u> populations in Brasil.

Aquirre (1956), Medem (1963), Carrillo de Espinoza (1970) Fittkau (1970, 1973), Magnusson (1984) report some important ecological data. Harron (1985), Harron and Emmons (1991) present data on the population and nesting ecology of the Black Caiman in Cocha Cashu (Peru).

Few ecological data have been compiled on the Black Caiman in Ecuador. Medem (1963, 1983) presents data mainly based on personal communications from settlers and hunters. Asanza (1985) provides data on the distribution, ecology and conservation of the Alligatoridae in Ecuadorian Amazonia.

Results.

<u>Melanosuchus niger</u> was heavily exploited by hunters in Ecuadorian Amazonia during a period of 40 years (1930 - 1970) (about 500,000 trade skins were taken) and in many localities the species has evidently been depleted (Asanza, 1985). Most Black Caimans were hunted during the 1950s and '60s and the skins exported to Leticia (Colombia) and Manaus (Brazil).

The Black Caiman is protected by a 1970 federal law in Ecuador which bans wildlife exploitation. In addition, more specific decrees and laws, the Decreto No. 487 (1980) and Ley No. 74 of August 1981 prohibit commercial hunting of all reptiles and the export of any indigenous species.

Asanza (1985, 1988), and Asanza et al (1988) found that Black Caiman inhabit lakes and rivers up to an altitude of 300 meters, but its range is restricted by habitat preferences, interspecific interactions with Caiman crocodilus, and past hunting. Currently, human activities such as continued hunting, deforestation, pollution, fishing and live trading are then causes for declining populations of Melanosuchus niger throughout much of its range.

Nonetheless, there are some localities which remain important for maintenance of the species in the wild. Significant populations can still be found in the Aguarico river system (Cuyabeno lakes and river, Guepi, Lagartococha lake system and river, Imuya Pacuya and Zancudococha lakes, and Cocaya river); the Napo river system (Jivino and Indillana rivers, Taracoa, Limoncocha, Anango, Challuacocha and Panacocha lakes, Tipitini and Yasuni rivers, Garzacocha and Jatuncocha lakes); lower Nashino and Cononaco rivers; the middle and lower Curaray river; lower Pindoyacu river; the Pastaza river system (Bufeo, Capahuari and lower Ishpingo rivers); lower Yaupi and Upper Morona rivers. These systems were surveyed at least once since 1978 and some of them more than twice during the 1980s.

Because of lack of funds to carry out surveys in most of the localities just four of them were censused annually. Site selection was based on the trophic quality of the waters and because they belong to the Protected Areas System of Ecuador and therefore considered to minimize external disturbance that could confound survey results.

The Cuyabeno lake and river system, Zancudococha, and Lagartococha lakes and river belong to the "Reserva de Produccion Faunistica" Cuyabeno Reserve. Limoncocha belongs to the "Reserva Biologica" Limoncocha Biological Reserve. In all the localities Caiman crocodilus is sympatric with Melanosuchus niger.

The populations belonging to the Cuyabeno Reserve have shown very similar abundance throughout the survey period. The Cuyabeno lakes, and Cuyabeno lakes and river sysemshave mean densities (5.68 animals/ km and 3.15/ km respectively) in a period of 9 consecutive annual censuses. (Figure 1) Zancudococha lake presents sympatric populations of 23.53/ km over a 5 year period of consecutive censuses. Lagartococha (Imuya) shows a mean density of 23.59/ km over 2 years of survey (figure...).

The Limoncocha lake belonging to the Limoncocha Biological Reserve shows a steady decline of its population in 8 years of annual surveys (figure 3.).

In Zancudococha and Lagartococha the population ratio of Black Caiman vs Spectacled Caiman is approximately 3:1. Limoncocha shows similar data during the first two years (1983 - 1984) of surveys. In subsequent years (1985 - 1990) the ratio has changed in favour <u>Caiman</u> <u>crocodilus</u> but without increasing the abundance of the population. Beginning in 1985 there was a steep decline in population numbers followed by continued population decline until 1990 the most recent year for which data is available.

In Cuyabeno the ratio of Black Caiman vs Spectacled Caiman is only about 1:5, as supported by recent survey data (Asanza, 1985).

Discussion

The data related to the Cuyabeno Reserve suggest that populations found in the various localities show stability but lack apparent increase. The Cuyabeno lakes and Cuyabeno lakes and rivers show no changes or trends in the 1 Black Caiman per 5 <u>Caiman</u> <u>crocodilus</u> ratio. The other localities such as Zancudococha and Lagartococha (Imuya) similarly maintain the ratio of 3 Black Caiman per 1 Spectacled Caiman.

The densities of 23.52/ km and 23.59/ km in Zancudococha and Lagartococha (Imuya) are very similar, and differ strikingly with those of Cuyabeno lakes and Cuyabeno lakes and river system which present densities of 5.68/ km and 3.15/ km where the species ration is much more skewed toward Spectacled Caiman..

Despite the fact that during a period of 40 years in this century the Black Caiman populations were heavily hunted throughout much if not all its range in Ecuador, the Cuyabeno lakes populaton feature strong competition with Caiman crocodilus. The Spectacled Caiman appers to play the role of a fast colonizer of "empty" lakes and rivers formerly populated by Black Caiman.

By being more adaptable to changing ecological conditions such as intense hunting and habitat degradation (e.g. deforestation, decline in trophic quality, pollution), Caiman crocodilus tends to outcompete the former dominant species (Black Caiman), and thus explains the hindered recoverey of Melanosuchus in the Cuyabeno Region.

FIGURE Nº 1

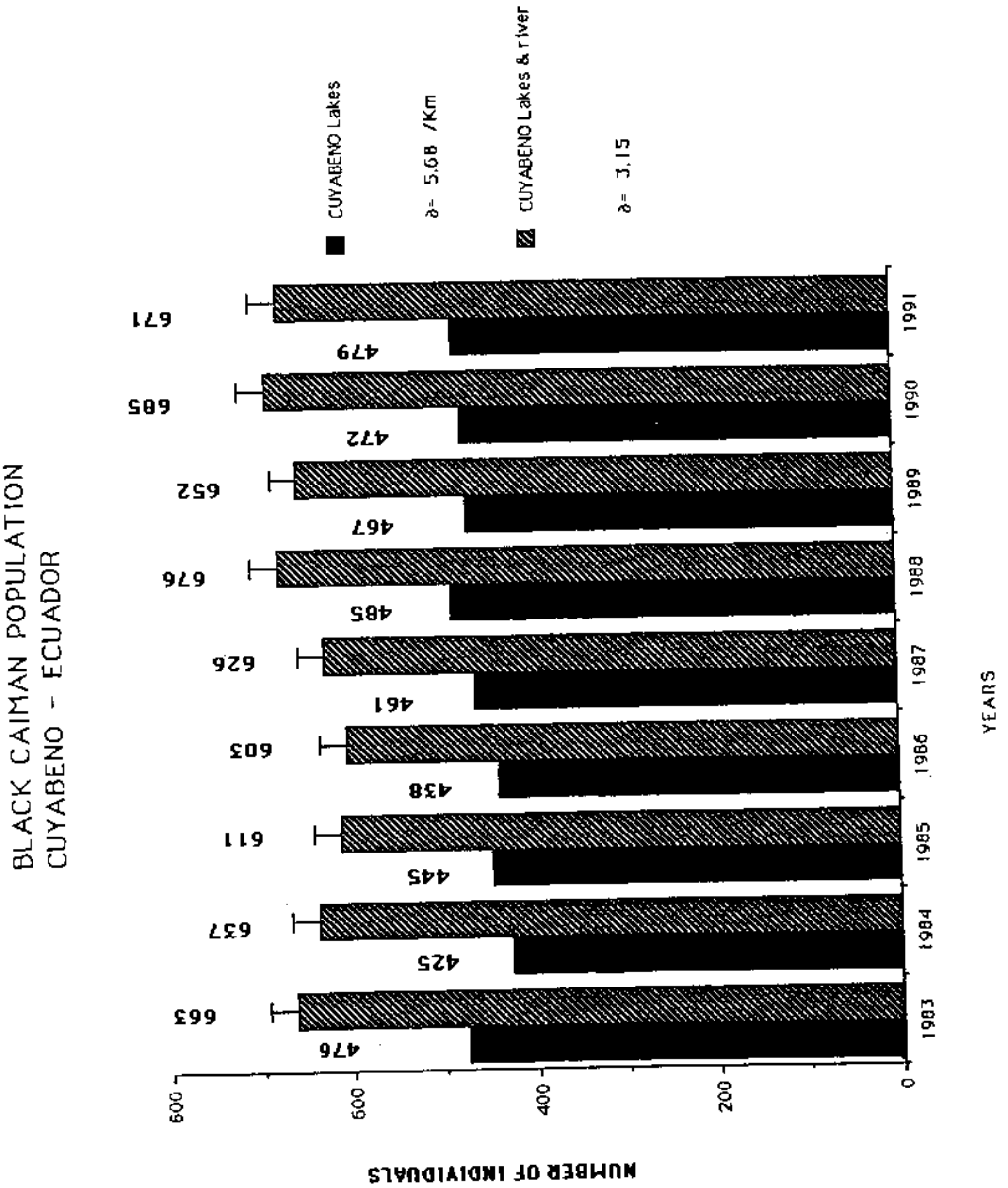
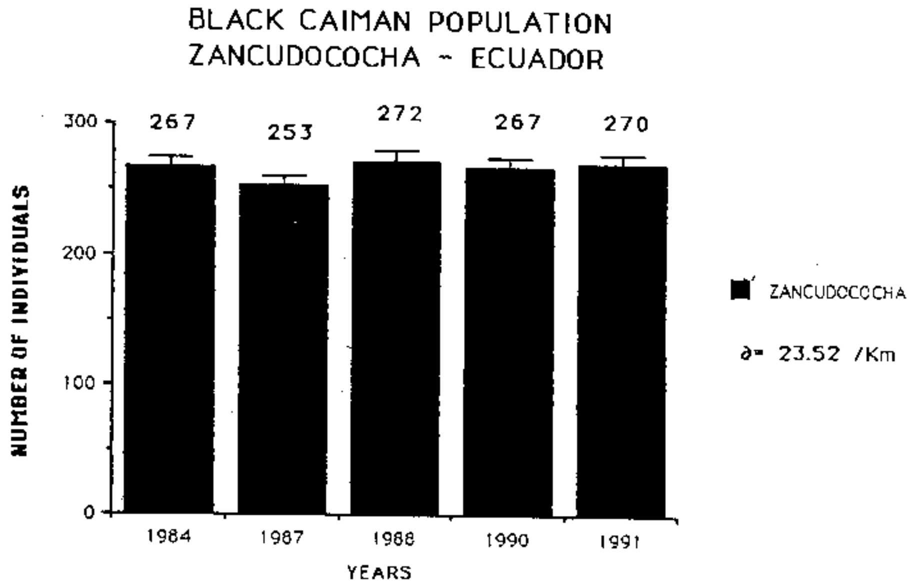

BLACK CAIMAN POPULATION
CUYABENO - ECUADOR
CUYABENO Lakes
ð= 5.68 /Km
CUYABENO Lakes & river
ð= 3.15
NUMBER OF INDIVIDUALS
YEARS
1983
476
663
1984
425
637
1985
445
611
1986
438
603
1987
461
626
1988
485
676
1989
467
652
1990
472
685
1991
479
671
0
200
400
600

FIGURE Nº 2


BLACK CAIMAN POPULATION
ZANCUDOCOCHA - ECUADOR
NUMBER OF INDIVIDUALS
YEARS
267
253
272
267
270
1984
1987
1988
1990
1991
ZANCUDOCOCHA
∂= 23.52 /Km

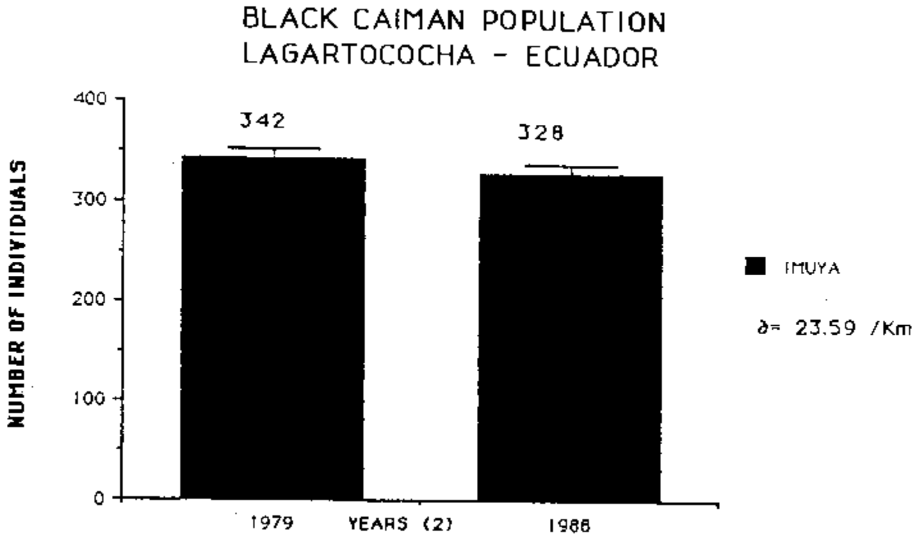
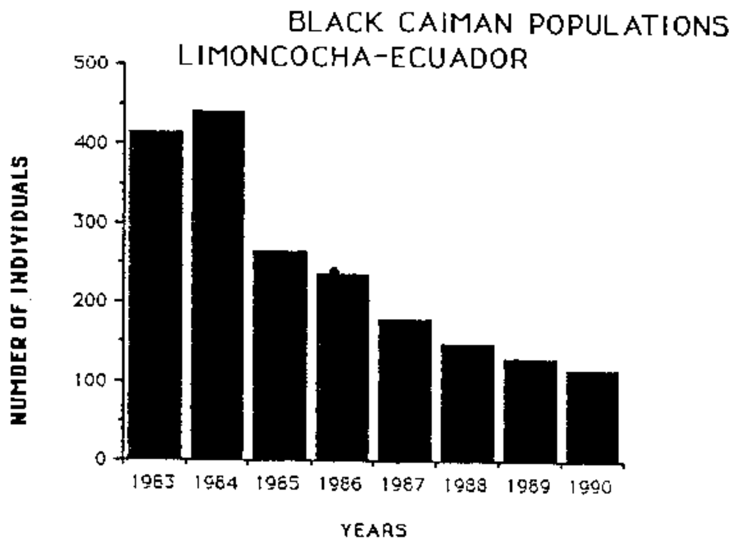
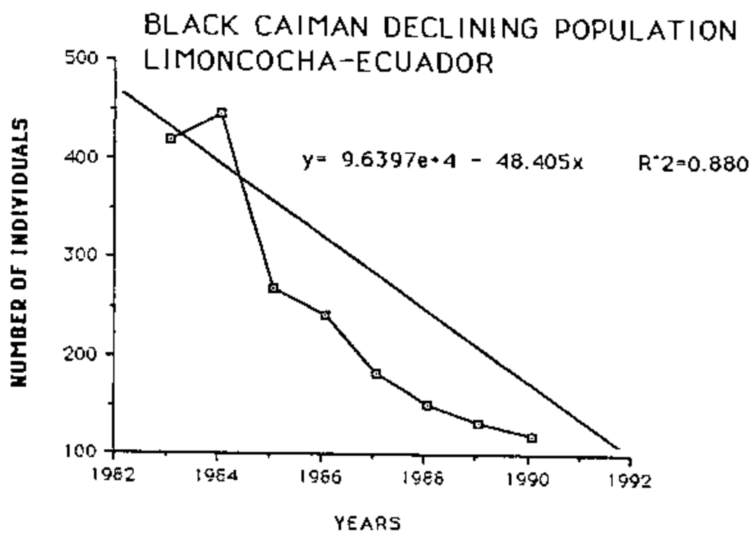

BLACK CAIMAN POPULATION
LAGARTOCOCHA - ECUADOR
NUMBER OF INDIVIDUALS
342
328
1979
YEARS (2)
1988
IMUYA
∂= 23.59 /Km

FIGURE Nº 3


BLACK CAIMAN POPULATIONS
LIMONCOCHA-ECUADOR
NUMBER OF INDIVIDUALS
500
400
300
200
100
0
1983 1984 1985 1986 1987 1988 1989 1990
YEARS


BLACK CAIMAN DECLINING POPULATION
LIMONCOCHA-ECUADOR
NUMBER OF INDIVIDUALS
y= 9.6397e+4 - 48.405x
R^2=0.880
500
400
300
200
100
1982 1984 1986 1988 1990 1992
YEARS

"Effect of diets complemented with Sodium L-Thyroxine, white corn flour and a complement of vitamins and essential amino acids in Caiman Crocodilus growth."

Avendaño, Gregorio; Báez, Leonor; Michelangeli, Leonardo.

1.- INTRODUCTION

In recent years, many studies have been carried out for optimizing the - growth of Caiman crocodilus in captivity. Such parameters as water temperature, amount of food, feeding time, food type and the combination thereof, are - very important in the growth of babas.

It is Known that the thyroid hormone is essential to growth during the first stages of life, not only in man but also monkeys, ruminants, rodents and birds. The thyroid hormone effect on humam growth is fundamentally manifested in children in the growth stage.

Precocious metamorphosis (1) was observed in experiments carried out with - "temporaria" frog, "esculenta" frog, "Bufo vulgaris" and "Tritón alpestris", in which tadpoles were fed with horse thyroid glands.

It is presumed that the thyroid hormone growth promoter effect is based on its ability to promote protein synthesis.

It has been reported (2) that in the carbohydrate metabolism, the thyroid - hormone stimulates almost all aspects: it accelerates the glucose intake in - cells, increases glycolysis, increases gluconeogenesis, increases the gastrointestinal tract absorption rate and increases insulin secretion with secondary effects on the carbohydrate metabolism.

The object of this work is to evaluate the effects of diets complemented with sodium L-Thyroxine, white corn flour and complement of vitamins and - essential amino acids in Caiman crocodilus growth.

2.- MATERIALS AND METHODS

Babas (Caiman crocodilus) of both sexes were used. At 24 hours of emerging from the eggs, the babas were placed in 6x2 m tanks (density = 16.6 babas per 2m). Previous experiments indicated that the water temperature of the tanks - during the summer months had a maximum 9.2 °C temperature fluctuation - (Minimum temperature: 25 °C and maximum temperature: 34.2 °C therefore the tanks were kept at a controled 30.5 °C temperature (optimum for the baba - metabolism) and with clean water circulation 24 hours a day.

The animals were kept on a basal diet for four months prior to initiation - of the diverse experimental diets. The basal diet (10% of the weight) - consisted of: 75% fish meal, 24% bone and blood meal, 1% Pecutrin, 84 mgs.- Virginiamicine/Kg of mix and 300 mgs oxytetracycline/Kg. of mix

From the second month of the experiment, the basal diet (10% of the weight) was modified to: 75% fish, 24% red meat, 1% Pecutrin, 84 mgs Virginiamicine/ Kg. of mix and 300 mgs Oxytetracycline/Kg. of mix.

At four months of the experiment, the basal diet (10% of the weight) was - modified to: 50% red meat, 50% Babarina, 1% Pecutrin, 84 mgs Virginiamicine/Kg of mix and 300 mgs. Oxytetracycline/Kg. of mix.

2.1. Experimental Design

100 Babas were selected at random from a group of 850 babas. The remaining 750 were used as a control group and continued with the basal diet. - The 100 babas were divided into four groups of 25 babas each.

Group 1 : Basal diet (10% of the weight) + 0.025 mgs/day of sodium L-Thyroxine.

Group 2 : Basal diet (10% of the weight) + 0.025 mgs/day of sodium L-Thyroxine + 100 grs/day of white corn flour.

Group 3 : Basal diet (10% of the weight) + 0.375 grs/day of vitamins and - essential amino acids.

Group 4 : Basal diet (10% of the weight) + 0.025 mgs/day of sodium L-Thyroxine + 0.375 grs/day of vitamins and essential amino acids.

As of 5 months of the experiment, the amount of sodium L-Thyroxine (0.05 - mgs/day),white corn flour (200 grs/day) and vitamins and essential amino acids (0.750 grs/day) was doubled.

Sodium L-Thyroxine (Testam) Laboratorio FARMA was used.

- White corn flour (P.A.N.) REMAVENCA
- vitamins and essential amino acids compound (Promotor 43) Laboratorio - CALIER
- Babarina - Protinal
- Virginiamicine - Laboratorio Lilly
- Oxytetracycline: 200 mg/cc. concentration - Laboratorio Mc Kesson
- Pecutrin - Minerals - Laboratorio Bayer

Two of the 6 x 2 m. tanks were divided longitudinally with a grid and the - four experimental groups were placed inside.

Treatment duration for all experimental groups was 8 months. A bimonthly weight and length control was kept.

2.2. Diet Administration

The ingredients were mixed and placed in approximate 2 cm. pieces on a - wooden table in the dry zone of the tank. The diet was administered once a day (4pm.).

2.3. Weight

The babas were weighed every 2 months per group on a 20 Kg. capacity - scale (Jacobs Manvill).

2.4. Size

The babas were measured every 2 months individually from tail to snout.

2.5. Histopathological Study

During the first two months of treatment, mortality in all babas - (fundamentally in the control group) was very high, thus 10 control group specimens were sacrificed by cervical dislocation and hematological and parasitological examinations were performed (Marine Biologist, Gina Armas de Conroy, M. Sc. Aguatic Pathobiologist). These examinations were carried out by - observing fresh preparations of the different organs and annexes, such as - lungs, liver, spleen, intestine, stomach, trachea, oesophagus and blood.

Blood samples were extracted by cardiac puncture. Sodium heparine was used as an anticoagulant. Blood smears were colored with GIEMSA.

Once all treatments were finalized (8 months), the babas were weighed, measured (length and width) and the sex was determined according to the works of (Chabreck, 1967; and Brazaitis, 1969). The same amount of male and femal specimens was obtained.

3.- RESULTS

3.1. The effect of diets complemented with sodium L-Thyroxine, white corn flour and a complemented of vitamins and essential amino acids on:

Results are summarized in the following tables:

Table I : Weight, Size and Mortality Percentage in babas complemented with sodium L-Thyroxine, white corn flour and a complex of vitamins and essential amino acids.

MONTH	0				2					4						6					8					
Group	Weight (grs)	Size (cms)	Animal #	Natural Death	Weight (grs)	Size (cms)	Animal #	Natural Death	%	Weight (grs)	Size (cms)	Animal #	Natural Death	%	Group	Weight (grs)	Size (cms)	Animal #	Natural Death	%	Weight (grs)	Size (cms)	Animal #	Natural Death	%	Total Mortality
1	54,01	27,50	25		91,30	30,23	23	2	8	246,66	39,90	15	2	8,7	1	386,66	46,93	15	0	0	565,38	53,50	13	2	13,3	24
2	55,60	27,16	25		93,47	30,43	23	2	8	228,57	38,92	14	1	4,3	2	400,00	46,00	10	4	27,8	477,77	50,30	09	1	10	32
3	54,04	27,28	25		95,65	30,02	23	1	4	244,44	39,69	18	1	4,3	3	411,76	47,41	17	1	5,6	552,94	54,17	17	0	0	12
4	56,00	26,96	25		91,30	30,41	23	2	8	268,42	40,15	19	1	4,3	4	488,88	48,27	18	1	5,3	616,66	55,13	18	0	0	16
Control	53,93	29,27	750		99,76	31,11	431	319	42,5	249,87	40,68	401	30	5,9	Control	379,19	47,18	387	14	3,4	545,48	53,28	376	11	2,8	49,87

Group 1 : Basal diet + sodium L-Thyroxine

Group 2 : Basal diet + sodium L-Thyroxine + white corn flour.

Group 3 : Basal diet + vitamins and essential amino acids.

Group 4 : Basal diet + sodium L-Thyroxine + vitamins and essential amino acids.

Group 5 : Basal diet.

<u>Table I</u> : Average weight and size increase in babas complemented with sodium L-Thyroxine, white corn flour and a complex of vitamins and essential amino acids.

Month	0 - 2		2 - 4		4 - 6		6 - 8	
Group	Weight (grs) Average/Month	Size (cms) Average/Month	Weight (grs) Average/Month	Size (cms) Average/Month	Weight (grs) Average/Month	Size (cms) Average/Month	Weight (grs) Average/Month	Size (cms) Average/Month
1	18,65	1,37	77,68	4,83	70,00	3,51	89,36	3,28
2	18,94	1,64	67,55	4,24	85,71	3,54	38,88	2,15
3	20,81	1,37	74,39	4,83	83,66	3,86	70,59	3,38
4	17,65	1,73	88,56	4,87	110,23	4,06	63,89	3,43
5	22,92	0,92	75,05	4,78	64,66	3,25	83,14	3,05

Group 1 : Basal diet + sodium L-Thyroxine.

Group 2 : Basal diet + sodium L-Thyroxine + white corn flour.

Group 3 : Basal diet + vitamins and essential amino acids.

Group 4 : Basal diet + sodium L-Thyroxine + vitamins and essential amino acids.

Group 5 : Basal diet'

3.3. Histopathological Study

3.3.1. Haemathological Results.

Table III : Blood Values

VALUE	SAMPLE No.							
	1	2	3	4	5	6	7	8
HD (g/100 ml)	-	-	-	-	-	-	-	-
Ht (%)	24	18	20	23	23	12	20	19
Erythocyte Count (X 10/mm3)	0.83	-	0.50	0.67	0.56	0.70	0.44	0.73
V.C.M. (m3)	480	-	400	343	411	171	455	260
C.M.H.C. (%)	-	-	-	-	-	-	-	-
H.C.M. (nng)	-	-	-	-	-	-	-	-

Table III shows blood values obtained in the 10 samples of the control animals sacrificed for this purpose.

The plasm presented a clear colorless aspect in samples No. 1, No. 2, No. 3, - No. 4, No. 6 and No.8

The plasm presented a clear, pale straw color in sample No. 5.

The plasm presented a "milky", light colored aspect in samples No. 7.

Table IV : Haemathological Results : Leukocytic Formula and Morphological - Aspects

VALUE	SAMPLE No. 1	2	3	4	5	6	7	8
Lymphocytes (%)	50	*	31	45	*	66	60	58
Monocytes (%)	35	*	61	36	*	28	40	40
Netrophiles (%)	10	*	5	7	*	2	0	2
Basophiles (%)	5	*	2	11	*	4	0	0
Eosinophiles(%)	0	*	0	0	*	0	0	0
Macrophages (%)	0	*	1	1	*	0	0	0
	100	*	100	100	*	100	100	100

* The blood smear reading could not be effected

Table IV shows cell count values obtained in control babas.

In the blood tests, some nuclei in declepsidral form were detected in the peripheral blood erythrocites of sample No. 3 and No. 7. In other inferior - cultivated aguatic vertebrates (eg. teleostean fish), the presence of - erythrocytes with these nuclear characters have been found in animals with a follic acid deficient diet.

Clear signs of anisocytosis were observed in the peripheral blood of - sample No. 3. In addition to this, the average corposcular volume was very small in the case of sample No. 6 and No. 7 and somewhat smaller in the case of sample No. 4, representing 37.5% of the haemathologically tested - babas. The microcytosis presence at the peripheral blood level has been related to a Vitamin E deficiet diet in cultivated teleostean fish.

The relative number, morphology and distribution of thrombocytes were - apparently normal in the blood smears tested.

A marked cytoplasmatic granularity was observed at the hepathoycte level, as well as numerous melanophages in the sinusoids.

3.3.2 Parasitological Results :

Table V :

	SAMPLE No.									
	1	2	3	4	5	6	7	8	9	10
Blood	-	-	-	-	-	-	-	-	-	-
Trachea	-	-	-	-	-	-	-	-	-	-
Esophagus	-	-	-	-	-	-	-	-	-	-
Lungs	-	-	-	-	-	-	-	-	-	-
Liver	-	-	-	-	-	-	-	-	-	-
Spleen	-	-	-	-	-	-	-	-	-	-
Stomach	-	-	-	-	-	-	-	-	-	-
Intestine	+	+	+	+	+	+	+	+	+	+
Rectum	-	-	-	-	-	-	-	-	-	-

+ : Abundant thrichomonads were found inside the entire intestine

Table V shows the parasitological study results performed on control - babas.

As observed in the Table, parasites were only detected in the intestine.

In all C. Crocodilus specimens, the liver was a clear grey color with a - tendency to cream, and slightly soft on tact. When observing fresh - preparations of this organ, a marked lipide infiltration was found.

Hairiness atrophia and fusion areas were detected in the intestine, as well as mixed leukocytic cellularity in the intestine membrane itself.

4.- CONCLUSIONS

1) The most favorable basal diet for experimental babas was : 75% - fish, 24% red meat, 1% Pecutrin, 84 mgs of Virginiamicine/Kg. of mix and 300 mgs Oxytetracycline/Kg. of mix. Similar works (5,6) report - that fish feeding produces a higher yield than red meat.

2) Mortality in group 2 (basal diet + sodium L-Thyroxine + white corn - flour) increased significantly after six months of experimentation. It is Known that white corn flour contains a large complex carbohydrate - proportion. The high mortality percentage may be correlated with the absence, in these animals, of certain enzymes involved in the degrading of such carbohydrates, which would cause their accumulation. Roland - Coulson (1991) reported that babas were unable to use raw plant matter owing to the absence of the sucrase enzyme required to hydrolyze plant sucrose into glucose. (7)

3) The experimental groups complemented with vitamins and essential amino acids (groups 3 and 4) obtained lower total mortality values.

4) Diets complemented with sodium L-Thyroxine, white corn flour, vitamins and essential amino acids, did not significantly alter size and weight growth of babas (Caiman crocodilus) bred in captivity.

5) From the parasitological results obtained, it may be concluded that, - although it is true that trichomonad presence is almost normal in this group of animals, such a high amount of these, as observed, is not at all beneficial for the animals, since the intestinal absorption will - be lower owing to inflammatory problems. In order to correct this problem, the following was recommended:

a.-Add metronidaxole in an amount of 10 mgs/Kg. of food for 3 successive days.

b.-Disinfect the tanks with Vanodine.

The described histopathological case is interpreted as one of metabolical-nutritional type alterations, without evidence of steatitis type changes. The conclusion was that fish, bone and meat meal are not sufficient food for small babas bred in captivity. The mortality caused by this nutritious deficit was compensated in the experimental groups complemented with sodium - L-Thyroxine, white corn flour and vitamins and essential amino acids.

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THE INVOLVEMENT OF RURAL COMMUNITIES IN THE CROCODILE RANCHING PROGRAMME IN MADAGASCAR

O BEHRA, RAMANDIMBISON

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GENERAL

The decline of crocodile populations in the world, combined with their constant, if not increasing, economic value, has led many countries to develop crocodile farming programmes. Farming technology as well as population management programmes have evolved considerably during the last fifteen years in many very different countries of the world. If it was hunting pressure that was the principal cause leading to the disappearance of crocodiles, then it is the notable socio-economic differences between the countries that has led to the establishment of relatively different management programmes, depending upon the country in question.

Also, in countries such as the United States and Australia, the management problems faced are hardly linked to the economic problems of rural populations living on the rivers alongside crocodiles, but rather, the authorities responsible for crocodile conservation have mainly to face the problem of public education where crocodiles are still seen as a dangerous and undesirable animal (Buttler, 1987). In Africa this negative perception also exists but the conflicts between men and crocodiles are often much more important given the economic dependence of the people on the habitats frequented by crocodiles: artisanal fishing, tropical culture such as rice culture, the use of waterways for transport and obtaining drinking water, etc It is why, therefore, the economic aspect seems far more important in these countries. Indeed, it is even more obvious that in these developing nations, abstract ecological concepts are less easily perceived by those in control than short term economic projects. For many, "Environmental and ecological concerns and the deteriorating renewable resource situation must tberefore be depicted in "concrete" economic terms" (Muthoo, 1990).

As the crocodile farming industry has now really started earning considerable sums in terms of foreign exchange, more than 8.16 million Zimbabwe dollars per year in Zimbabwe (Hutton & Lippai, 1992) numerous governments have become extremely interested in and concerned with crocodile conservation. All the more given that the system is established to collect crocodile eggs from the wild without detriment to the wild population because, with the advance of crocodile farming technology, the natural mortality of these eggs can be offset via their continued survival, after collection, on crocodile farms.

Be that as it may, at the practical level, the benefit of these conservation management programmes is mixed because if the benefits from the crocodiles are in turn used for crocodile protection, then the rural communities living alongside the crocodiles, do not benefit at all and, as a result, have no motivation towards the protection of crocodiles. Given that for these communities, the crocodile could, quite justifiably, be considered a nuisance, they then proceed on a crocodile extermination course.

Also, it has become more and more evident in, for example, Zimbabwe and other developing countries that rural populations have to be implicated in management programmes. However, to actually effectuate any tangible economic benefit for these peoples has proved to be far from simple (Hutton & Child, 1989). In fact, schemes to involve rural communities in egg collection operations, such as those already proposed in other countries, such as Botswana (Medem, 1981), have proved to be not at all satisfactory especially given the delicacy required whilst collecting the eggs, which is difficult to explain to the rural communities who are, by far and large, poorly educated.

A similar problem occurred in Papua New Guinea with an United Nations programme which also tried to involve the rural communities directly into the creation of farms and the farming of young crocodiles. One recalls that these small farms did not work and that even though the project began with the best of intentions, the villagers had to wait three or four years before they received any revenue for their work (Sinba, 1989). Also, the intention to change the method of collection to that of hatchlings in place of eggs proved to be non-profitable because of the problems of hatchling conservation and fragility together with the time limit of collection (Bolton, 1990).

The only sytem which seemed to offer any hope of success was that attempted in the north of Zimbabwe in 1985 (Hutton & Child, 1989), which involved the rural communities in the location as well as the protection of crocodile nests. In Madagascar, although there were only two farms, of little importance, before 1989, no management programme has ever been established in this country. It was in 1989, following the request of the Government, that FAO financed a preparatory project on the development of crocodile farming in Madagascar. The project leader successfully argued for the need to orientate the plan towards a ranching approach, which advocates perfectly the need to involve rural populations at least during the collection.

THE MADAGASCAR STORY

Situated in the Indian Ocean, east of the continent of Africa (more precisely Mozambique), Madagascar is the fourth largest island in the world and is divided in two longitudinally by an important mountain chain. This chain is aligned more to the east with a large difference between the Eastern and Western slopes (Bastion, 1967)

Situated in the tropics, the island is subject to a rainy season and a dry season, with a large variation in duration and intensity of each from area to area. The geography of the country has an impact on the formation of flooded rivers during the rainy season and, in contrast, incredibly dry periods during the dry season. If these conditions are not ideal for small crocodiles, there is no doubt that in the beginning, the low density of humans along with a very favourable biogeography for crocodiles, provided the Nile Crocodile (*Crocodylus niloticus*) with a very favourable territory in Madagascar.

For some locals in Madagascar crocodiles were sacred and protected (Behra & Hutton, 1988). At the same time, since the beginning of the century crocodiles were hunted by many people (Petit G, 1925), although the hunters did not hunt regularly but rather following attacks on humans - a practice which was not sufficient to stop the proliferation of crocodile populations (Raffray, 1950). In the 1950's, the colonial French administration attempted to exterminate crocodiles in the country by offering bonuses for killing crocodiles and collecting the eggs (J O Mad & Depend N° 1539). However, this plan failed since from the first few weeks many thousands of eggs were collected and the administration could no longer pay the people. For example, Decary R (1950) tells us that an inhabitant of Marovoay collected, for his bonus, 7000 eggs in three weeks.

As in most African countries, it was hunting that was the main cause for the drop in population numbers and if the high export trade figures in the 1940's are surprising (Behra & Hutton, 1988), there is no doubt that during the 1960's the drop in exports was linked to a simultaneous drop in the populations.

The perception of crocodiles in the country is such that despite the ratification of the Washington convention by Madagascar on 05 August 1975, which brought about the ban of all exports of crocodile skin products, it was not until 15 June 1988 that the crocodile was lifted from the problem animal category to be classed as game.

Since 1985 Madagascar has once again been authorised through CITES to export crocodile skins, the populations having, from all accounts, increased since the international trade ban in 1975. Meanwhile, hunting has become quite uncontrollable and can only negate the management system already considered unsatisfactory for an animal such as the crocodile. Population surveys conducted between 1987 and 1988 (Behra & Hutton, 1988) showed the populations to be low compared with that of protected African rivers, or rivers exploited uniquely for their eggs. However, their numbers were relatively similar to those in rivers with considerable human settlement. It was then in 1989 that Madagascar asked for the assistance of the FAO to establish a project for the development of crocodile farming.

FAO PROJECT FOR THE DEVELOPMENT OF CROCODILE FARMING

At the end of 1989, the FAO financed an assistance project for the development of crocodile farming in Madagascar, following the request of that country's government. The project leader was Olivier Behra with Ramandimhison acting as one of the two technicians required as part of the project format. The main goal of the project was to establish the feasibility of establishing a program for the development of crocodile farming. The project included the training of potential crocodile farmers as well as officials from the Department of Water and Forests. At the same time suitable areas for crocodile egg collection were investigated as well as the initiation of a programme for the development of farming management techniques.

Given the international constraints and the intention to work towards a programme concerning the conservation of crocodiles, it was decided to concentrate on developing a ranching-biased programme which involved rural communities. A training programme for potential farmers on the subject of farming techniques (stressing the importance of having quality goods at the end of the day to market) was organised as well as set up surveys to locate areas suitable for nest collection.

The surveys were carried out continuing the work of Behra and then Behra and Hutton in very precise areas following a detailed analysis of the biogeography of the western region, considered to be the most interesting. The surveys revealed three zones of particular interest for the development of an egg collection system. Out of the dozen or so interested farmers, four finally emharked on farming projects and began building the infrastructure required.

Egg collection occurred in many different zones (also hatchling collection) but this report concentrates on the one specific area called Besalampy where special attention focussed on a study of local response to their possible involvement in egg collection.

In the three zones specified, the response from the locals was quite good with regard to their interest in the subsequent sale of crocodile eggs but Besalampy had the added advantage of being already designated a collection area by the Department of Eaux and Forets, crocodile farming having been established there since the start of the project, and thus presented the most value technically to this report. The farm manager, in one year, had succeeded in building a brick-housed farm with an incubator temperature controlled to half a degree and ponds heated with similar accuracy.

BASALAMPY AREA

Basalampy is situated in the extreme west of Madagascar in a relatively isolated area such that the road into the town is impassable for six months of the year. Being close to the sea (16°44' S, 44°29' E), the town is by the Maningoza River which comes from the south east and is then joined by the Sambao River before emptying into the ocean. These two rivers are surrounded by small lakes which have, without a doubt, made the region such good crocodile habitat. If the road is impassable for 6 months of the year it is in particular due to the major floods occurring during the wet season, although during the dry season these rivers become very shallow. The associated lakes therefore provide a good refuge for crocodiles during these extreme periods.

The small villages that occur around the rivers are for the most part small hamlets and the area is sparsely populated except for itinerant travellers. The climatic difficulties and the isolation of the area make the region non-desirable for settlement, the agriculture practised there barely supplying the needs of the people for an entire year.

ORGANISATION OF EGG COLLECTION IN THE AREA OF BESALAMPY

The first collection organised in the region was a result of preparatory work carried out by Ramandimbison. Many people replied positively to this preliminary work assuring of their ability to locate nests and that they would be interested in the subsequent sale of the eggs. The collection itself was headed by Behra, aided by Ramandimbison and a technician from the farm in question (under construction) who was responsible for paying the locals involved.

Although the people responded favourably to the preliminary enquiries made by Ramandimbison, there was some disbelief concerning any follow-up that would ensue and, combined with their negative attitude towards crocodiles, they destroyed a considerable number of nests prior to the arrival of the collection team. The eggs were eaten or destroyed to prevent any increase in crocodile numbers - it was noted here, and elsewhere, that crocodile eggs are not traditionally eaten but living conditions had so deteriorated that certain groups no longer had any choice and ate whatever they could find.

Be that as it may, in less than eight days it was possible to collect more than 1000 eggs from locations that were not known by the team before the operation. Ramandimbison remained in the area the following week and was able to collect practically the same number of eggs. It was often the case that while the team went to look for the first couple of nests with a villager other people also went to look for other nests. For each nest found, the person who found it received 1000 Malgache francs (about 70c US at that time) per egg, a price calculated to make a clutch worth as much as that of an adult skin bought locally.

The eggs collected were placed in polystyrene boxes filled with vermiculite and carried by men to a vehicle and then along the tracks back to the town - a journey often lasting many hours. Usually arriving at the village every evening, the eggs were stored until a certain number of boxes had accumulated when they were collected by the farmer in a light aircraft (Cessna) and taken to the farm, where they were immediately incubated.

In the second season, a collector from the farm organised the egg collection and took only 1500 eggs, at the request of the farmer.

THE RESPONSE OF RURAL COMMUNITIES TO THEIR INVOLVEMENT IN CROCODILE EGG COLLECTION AFTER THE SECOND COLLECTION SEASON

The results presented here are the outcome of several days spent in the field by Ramandimbison. The locals who were questioned numbered only 12 in the Southern part and 24 in the North of the pilot site. Also, the questionnaire, comprising forty questions, wad put to the group upon their return and so the lack in certain opinions could lead one to consider following up this work with another psychological enquiry after the third collection season.

Be that as it may, the first replies are original and therefore the most interesting.

The questions to which answers were most sought after were prinicpally the following:

a) are the people interested in crocodile egg collection?

b) are the people organised with regard to egg collection?

c) has the attitude of the people to crocodiles changed?

d) are the crocodiles still hunted? or the eggs destroyed?

e) is there indifferent protection from the locals for crocodiles?

f) what are the aspirations of the people for the future?

The results were different from the different sites of enquiry. However, it showed that the most positive results invariably came from the area where collection was the most important to the people and where the economic incentive was equally important.

a) On the subject of the interest of the people towards crocodile egg collection the response was undeniably positive. Indeed, the region was very poor and the economic returns poor due to the frequent dry spells and so the revenue generated from crocodile egg collection is often relatively high and allows for luxuries such as clothes, bedding, kitchen equipment and even carts or zebu in certain cases.

Although this is the general case, it sometimes happens that the man of the family (in the Southern region) is happy to spend his collection benefits himself outside of the village for his own pleasure.

It is interesting to note that although the man played the main part in the collection, women also participated and the benefits usually ended up within the family unit.

b) No structural programme for the collection was set up by the people and it was interesting to see if the local populations were actually able to set one up themselves.

This was not the case at all but the success was linked to the importance of the collection as well as the site in question.

The operation per se, however, was the same in each locality.

Each time that one of the villagers located a crocodile nest he went to the administrative head of the village to inform him. He, in turn took note of the name of this person and the approximate location of the nest and then registered the name, date and time of find on paper and went with that person to find the nest. The piece of paper was placed inside the nest. This removed any confusion regarding the "ownership" of the nest as it was thus ascribed to the **first** person who found it.

This system was organised according to a traditional hierarchal system. The administrative personnel in charge (the head of the village - given the title of "president of Fokontany" by the local administrator in charge) had his own personal interest in the scheme as he was given a certain percentage of the number of eggs found. This percentage (equivalent to 3 eggs per nest) was paid to him when the person locating the nest was in turn paid by the farmer/collector. The head of the village becomes a major part of the collection system and its local promotion thereof regarding the protection of the nest sites.

In the north of the country, the system was set up entirely by the locals and worked perfectly, even being accompanied by a relay system between the people of the villages or the surroundings to keep an eye on the site and prevent any outsiders from coming in to eat the eggs or xebu passing over the nests.

In the south the same system was attempted except that the results were uot as encouragiug. Some people did not declare the nests that they found so that they would not have to pay their fee to the head of Fokontany and one nest was even stolen and made to look as if it had been depredated.

However, this could be interpreted as a lack of surveillance due to a parallel lack in the number of nests available to suitably justify continual site surveillance.

Briefly, in the North a spoutaneous organisation of the people by the people was witnessed which proved to work very well.

c) Except with those people for whom the crocodile was considered sacred in Madagascar, the general attitude of people towards crocodiles still remains a negative one, such as one can gather from certain naturalists like Perrier de la Bathie (1914) at the beginning of the century. Indeed in the summary of an interesting article on crocodiles, "... the Madagascan crocodile is not graceful, something which spoils the rivers of the island. Certainly the bulkiest entity of this land, with underhand manners, ferocious and with many victims being taken per year, it urgently demands that they be destroyed by any means possible". Perrier de la Bathie could add to this that on the other hand, the crocodile is an interesting animal and its eventual disappearance could be mentioned with a certain nostalgia, but for the Malgache in general and in particular those living in crocodile infested areas, there is, for the most part, nothing to add to those first statements of this naturalist.

Perrier de la Bathie already said in his article in 1914 that the Malgache did not understand that crocodile populations could be diminished by killing the adults.

The only result of killing big crocodiles is that the physical size of the population is decreased but not the number of crocodiles. The population actually increases because it creates more space for subadults. In the case of the area where the pilot study was conducted, it is interesting to note that the people there thought the same thing. However, they also believe that if the collection is carried out efficiently it will contribute to the decrease in numbers of crocodiles, or at least halt their augmentation.

This was particularly so in the North of the pilot study, where the locals, who normally looked for any possible way to get rid of crocodiles changed their attitude and, even if they are still a long way from actually loving these animals, they leave them to live in peace.

In the South, this is not exactly the case with those involved in egg collection. It is important to consider that in the surrounding area during the last year four people were injured by crocodiles and many zebu were killed.

d) It seems that there is practically no more hunting going on in the area but it is difficult to link this to collection because skin prices have dropped considerably and the locals are no longer motivated to hunt crocodiles.

If the actual price, offered locally, of 500 Fmg/cm helly width (about 30 cts/cm) were to rise above 1200 Fmg, it is possible that some hunters would begin hunting again. During the last egg collection season, it was still the case that those nests not collected were destroyed to stop the increase in crocodile numbers.

e) The main subject of the study was to see if there would be indifferent protection of the crocodiles at the end of the crocodile ranching programme. Even though those people in the South were evidently interested in egg collection they did not seem too concerned with the need to preserve the breeding stock.

In the North, at the pilot site, in contrast, it is undeniable that protection measures are there. They exist in the form of continual site monitoring to stop people from destroying the nests and also to prevent zebu from destroying the nest areas. In this area, protection of breeding stocks is a success story. This can be witnessed outside of the collection programme where local populations asked, spontaneously, if they could have an administrative authority to prevent zebu movement over the reproduction site as well as foreigners coming in to kill _their_ crocodiles.

f) The expectations of rural populations regarding the ranching programme are relatively easy to unerstand and are, above all, to collect as many eggs as possible, to organise the collection a bit better so that those involved can be informed in advance of its structure and to increase the price to more than 1000 or 2000 Fmg (US $1.3) per egg.

CONCLUSION

Naturally, these results have to be looked at bearing in mind that this was a pilot study, and that the present economic situation of the crocodile industry might not make it replicable to other regions or countries. The most fundamental result is that an animal reagarded as negatively as the crocodile is can be, due to its economic value, be considered by these peoples as a renewable resource belonging to the community.

It is even more fundamental to see that this system was set into action itself because it was decided during the setting up of the project to never talk about crocodile conservation.

This had the advantage of not putting the locals against the project and to really see if they can take the decision to preserve these problem animals for the economic purposes they represent.

Having private investors implicated in the collection, hatching, and rearing programme made the project more lasting. Indeed, the second collection was set up by the farmers themselves on the same principal of renumeration for the locals.

One cannot expect that a 15 month project can really lead to the setting up of a definite management programme for crocodile populations in a country as big as Madagascar that started with nothing. Problems remain to be solved, to develop and improve the programme to a higher level of importance in the country as well as reinforce management organisations.

Be that as it may, these results show that one can seriously consider the involvement of local communities in exploitative projects that are reasonable and lasting for wildlife and can be a more interesting means of protecting species and their habitat in a developing country.

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LONG-TERM POPULATION STUDIES OF AMERICAN ALLIGATORS INHABITING A RESERVOIR: INITIAL RESPONSES TO WATER LEVEL DRAWDOWN

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ABSTRACT: A population of American alligators (*Alligator mississippiensis*) inhabiting a 1130 ha nuclear reactor cooling reservoir has been studied for more than 20 years, producing a data base that now can be used to evaluate the responses of these animals to subsequent changes in their habitat. Beginning in June and continuing through September 1991, the water level in this reservoir was lowered 6m to allow for repair work to the dam. The study reported here extended from July 1991 through the summer of 1992, during which time the reservoir remained at the lowered level. The drawdown reduced the water surface area by 50%, exposing and killing the majority of the lake's submerged/emergent aquatic vegetation. Both during and immediately after drawdown activities, the number of alligators counted in the reservoir by night eyeshining techniques increased possibly as a result of increased visibility of smaller animals due to the lack of emergent vegetative cover. High numbers of alligators were also observed during aerial census flights during the spring following drawdown. Fourteen adult alligators outfitted with radio transmitters in September 1991 revealed differences in spatial distributions and movement patterns between the sexes during the fall and following winter in the drawdown reservoir. Males showed more extensive fall movements while most females tended to remain close to the locations where they were originally captured. There was no evidence that the drawdown adversely affected the winter survival of adult alligators in Par Pond. Six of the telemetered alligators spent the winter in moderately deep water along a <300m stretch of exposed reservoir shoreline. An additional female was found wintering with young in an extensive circular subterranean den system that remained dry throughout the winter due to the lowering of the water level. Six alligators (four males/two females) were recovered elsewhere in the area after having been marked or telemetered in Par Pond. Two of these alligators were later killed in smaller nearby impoundments, most likely by larger alligators residing in the habitats to which these emigrants had moved. Three nests initiated before drawdown activities all successfully hatched young. Despite the greater distances of these nests from the receded shoreline, all three females continued to tend these nests and subsequently, moved

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as much as 100 m with their newly-hatched young into the lowered reservoir. Due to the lack of cover however, it is unlikely that many of these young survived. Unfavourable conditions for nesting, and habitat conditions that have undoubtedly resulted in low survival of juveniles, have probably been the most important impacts of the reservoir drawdown upon its resident alligator population.

INTRODUCTION

Man-made impoundments are becoming an increasingly abundant form of wetland habitat as natural lotic systems are altered for purposes of human industrial, recreational and/or irrigational needs. Crocodilian populations inhabiting such wetlands must either adapt to living in these new reservoir habitats, move elsewhere or perish. Although some populations are surviving in such impoundments (Alcala and Dy-Liacco 1989), little information is available concerning these animals' population biology and productivity in these habitats. Particularly lacking is any information concerning the responses of such animals to the periodic lowering of water levels which is commonly required in multipurpose reservoirs.

Among the best-studied crocodilians utilizing a man-made reservoir are the American alligators (*Alligator mississippiensis*) inhabiting the 1130 ha Par Pond reactor cooling reservoir on the U.S. Department of Energy's Savannah River Site (SRS) near Aiken, South Carolina, in the southeastern United States (Murphy 1977, 1981; Brisbin 1982; Brandt 1989, 1991). Throughout the over 20 years that the Par Pond alligator population has been studied, this reservoir was never subjected to drawdown activities, and the resultant stability of its water levels allowed the development of extensive beds of submerged/emergent aquatic vegetation, particularly in those portions of the lake within the ≤ 6m depth contour (Parker *et al.* 1973; Smith *et al.* 1986). Between early July and mid-September 1991, however, the water level of Par Pond was lowered by approximately 6m to allow for repair work to the reservoir's retaining dam. This drawdown reduced the surface area of the reservoir by approximately 50% and exposed nearly all of the submergent/emergent vegetation along the lake's margins. The reservoir has remained at this lowered level throughout this study (July 1991 through July 1992), leaving a bare shoreline, surrounded by approximately 526 ha of exposed mudflats which, during the spring of 1992, began to undergo terrestrial plant success in many areas.

Previous studies of the Par Pond alligators have revealed that the number of resident animals has more than doubled from an estimated 110 to 266 individuals from 1972-1978 to 1986-1988 (Murphy 1977, 1981; Brandt 1989, 1991). These same studies have shown that while the sex ratio has not changed during this period, the population's age structure shifted strikingly from a high proportion (64%) of large adults in the 1970s to a high proportion (81%) of juveniles in the 1980s. As indicated by Brandt (1989, 1991), these changes have been accompanied by an increase in the reproductive output from an average of 2.3 to 4.0 nests per year during the same period, all being indicative of a healthy and growing population which at that time, had not yet reached its carrying capacity. There is now concern, however, that changes created by the reservoir drawdown of 1991 might reduce the reservoir's suitability for alligators, particularly juveniles as a result of exposure and destruction of submergent/emergent vegetation along the lake's margins.

The study reported here was designed to document the initial responses of Par Pond alligators to the drawdown of Par Pond. By using census procedures and other techniques similar to those employed in earlier studies of this population and by taking advantage of the numerous individuals in the population that had been previously marked, an effort was made to present the responses observed in the context of previous information available for this population (Murphy 1977, 1981; Brandt 1989, 1991). Research efforts were focussed on three areas: (1) population numbers and spatial distribution, using standardized census techniques, (2) behaviour and movement patterns of individuals within the population, using radio telemetry techniques, and (3) reproductive biology. With the exception of aerial census surveys which continued through July 1992, all aspects of the study reported here were conducted between July 1991 and March 1992.

The SRS is located along the northwesternmost limits of the alligators' inland range in the southeastern United States, and this study provided an opportunity to document various aspects of the alligators' post-drawdown wintering ecology, and to present a comparison with the results of earlier pre-drawdown studies of the wintering ecology of alligators in this same reservoir system (Brisbin *et al.* 1982).

MATERIALS AND METHODS

Study area:

The Par Pond reservoir is located on the U.S. Department of Energy's Savannah River Site (SRS). This 750 km^2 site was closed to public access in the early 1950s and since that time has been used for various nuclear industrial activities. The SRS is located along the northern shore of the Savannah River and occupies portions of Aiken, Allendale and Barnwell Counties of South Carolina. The area is located in the Upper Atlantic Coastal Plain. Brisbin *et al.* (1982) report that winter temperatures in this area averaged 4.9, 4.6 and 4.9°C for December, January and February, respectively, for the period 1971-1981. Extreme lows for these same months during this period were -8.9, -15.6 and -10.0°C, respectively. Further descriptions of the climate, topography, flora and fauna of the SRS have been provided by Jenkins and Provost (1964), Murphy (1981) and Hillestad and Bennett (1982).

The Par Pond reservoir was constructed in 1958 by impounding an area that included the confluence of several natural stream watercourses. This created a reservoir with three major extensions which have become known as the Hot Arm, North Arm and West Arm (Figure 1). The Par Pond reservoir system also includes two smaller reservoirs; Pond B (81 ha) and Pond C (67 ha), which have, along with Par Pond itself, received the cooling water effluents of one or two operating nuclear reactors. The thermal gradients and early history of reactor operations at the site have been described by Parker *et al.* (1973), Gibbons and Sharitz (1974) and Brandt (1989), and the responses of Par Pond alligators to these thermal inputs have been described by Murphy (1977, 1981) and Murphy and Brisbin (1974). All thermal input to the Par Pond system ceased in August 1987, and both of the associated reactors have been inoperative since that time.

Night Eyeshine Counts and Aerial Census Surveys:

Night eyeshine counts and aerial census surveys were designed to incorporate, as much as possible, the same techniques used by Murphy (1977, 1981) and Brandt (1989, 1991) in determining pre-drawdown population numbers of alligators in Par Pond. Briefly, eyeshine counts were conducted from an airboat on nights with reduced wind and wave action in order to maximize alligator visibility, with the entire periphery of the reservoir (initially 53 km but then later reduced as the drawdown progressed) being surveyed during each census. Night eyeshine counts were conducted on 3, 8 and 29 July, 26 August, 24 September and 23 October, 1991. Aerial census surveys were conducted from a fixed-wing aircraft flown at a speed of 130 knots at an altitude of about 90 m. Again, the entire periphery of the reservoir was surveyed on each aerial census, with flights being conducted on 11 July, 12 September, and 17 and 25 October in 1991, and on 9, 17 and 25 March, 22 April, 12 and 19 May, 9 and 30 June, and 3 July in 1992. Discussions of sources of bias and assumptions that must be made or met in the design of night eyeshine counts and aerial census surveys are provided by Woodward and Marion (1978) and Caughley (1974), respectively.

None of the surveys conducted during the present study produced estimates of actual population size either during or after the drawdown of the reservoir. However, both night eyeshine counts and daytime aerial surveys can estimate the minimum numbers of alligators present, and if certain assumptions concerning the probability of sighting of individuals are made or can be discounted, information from such counts can be used as indices of population size.

Capture and Radiotelemetry:

Adult alligators were captured for outfitting with radiotransmitters using a modified version of baited trip snares (Murphy and Fendley, 1975; Murphy *et al.* 1983) that were set along the receding edge of Par Pond during and shortly after the cessation of drawdown activities. Snares were set for a total of five nights and involved a total of 44 trap nights. These sets resulted in the capture of 15 adult alligators (trap success = 34.1%). Nine males were captured in snares in the North Arm between 28-29 September 1991 (Figure 2). Each was measured, equipped with a radio transmitter and released at the site of capture. The snares were then moved in order to achieve more complete coverage of the reservoir's shoreline. This resulted in the capture of four additional females on 7-8 October 1991 (Figure 3). These females were also equipped with radio transmitters and released, as was a fifth female that had been captured from a boat with a snare pole in the Hot Arm on 19 September 1991. Two additional adult males captured in snares in the West Arm were marked by notching tail scutes (Brandt 1989) and released without transmitters. The nine males equipped with transmitters ranged from 2.41 - 3.56 m in total length while the five females ranged from 1.91 - 2.50 m.

Radiotransmitters weighing less than 250g were attached with 270 lb test stainless-steel leader line to the dorsal nuchal scutes. Attempts were made to determine the locations of all alligators on 4, 9, 18 and 31 October, 8 and 19 November, 13, 23 and 30 December in 1991, and on 16 January, 7 and 19 February and 12 and 26 March in 1992, producing a total of 158 locations of individual animals. Transmitter-equipped alligators that left the reservoir were located at more frequent intervals to better determine the extent of their excursions and fates. Radio locations were determined with a hand-held antenna from a small boat or airboat or from the shore. Although visual observations were occasionally made of transmitter-equipped animals, most of the locations were determined for submerged alligators by recording the position directly above the point of vertical exit of the strongest radio signal from the water column. In a few cases, particularly in the case of animals which left the reservoir, it was necessary to estimate locations by visual triangulation. However it was usually possible to plot individual locations with an accuracy of approximately $\pm$10m.

In addition to the adults equipped with radio transmitters, four smaller alligators were captured by hand or with snare poles using techniques described by Chabreck (1963) and Brandt (1989, 1991). These animals were captured between 18-20 July 1991, and were fitted with coloured plastic collars to permit later visual identification. Resightings of these additional marked animals were used to further document alligator movement within and emigration from the drawdown reservoir. Recaptures of alligators marked in previous studies (Murphy 1977, 1981; Brandt 1989, 1991) were identified by tail scute notches (Brandt 1989).

Reproductive Studies:

Nests were located during the summer of 1991 by visiting areas of known past nesting and searching the reservoir shoreline by boat and foot. Once located, nests were visited at approximately bimonthly or, when possible, weekly intervals to determine hatching success and the subsequent fate of the young.

RESULTS AND DISCUSSION

Population Numbers:

Eyeshine counts conducted after the initiation of the drawdown (Figure 4), were higher than those reported for the same months in 1988 by Brandt (1989; Figure 4). This may have resulted from the continued increase in the population, as documented by that study and/or may have been due to an increase in the animals' visibility along the lake's shoreline which was now devoid of vegetative cover. The same factors could also have contributed to an increase in the number of alligators seen on aerial survey flights during and shortly after drawdown (July-November 1991), as compared to the number counted during these same months in previous years (Figure 5; Brandt 1989). A sharp decline in numbers of alligators seen on night eyeshine surveys between late July and mid-September 1991, occurred during a period when eyeshine counts recorded in previous years were either constant or slightly increasing (Figure 4). This decline could not have been an artifact related to the loss of shoreline vegetation and instead, may have reflected the beginning of emigration of alligators from the reservoir as will be discussed later.

Analyses of night eyeshine count data indicated that the distribution of alligators in the reservoir two weeks after the initiation of drawdown was significantly different than expected based on the area of water available in each arm (X^2 = 11.07, $p<0,05$, df=3; Table 1). There were fewer animals observed in the Main Lake than expected and more in the Hot Arm. By October 1991, the distribution had shifted, with more animals in the West Arm than expected and fewer in the Main Lake (X^2 = 25.95, $p<0.05$, df=3). As will be shown later, these results were further supported by the movements of several radio telemetered alligators that had been captured elsewhere in the reservoir but by late October, had moved into the West Arm where a winter concentration area was subsequently discovered (Figures 2 and 3). The October 1991 increase in the percentage of eyeshine counts in the West Arm contrasts with the findings of Murphy (1977) who found the percentage of alligators in the West Arm to decrease from September through October of 1972-1973. In the latter case, however, this response was shown to be related to the increasing use of Par Pond's Hot Arm, through the fall and winter months, in response to the introduction there of heated reactor effluents. The distribution of alligators throughout Par Pond in 1991 also contrasted sharply with the findings of Brandt (1989) whose data showed a concentration of animals in the Main Lake in 1987 and relatively low use of the reservoir's arms. In 1991 however, the arms were preferred and use of the Main Lake was disproportionally low (Table 1).

Reproduction:

Three nests were located at Par Pond during 1991. All were in close proximity to if not exactly at nest sites from previous years. By the end of August all of these nests were at least 100m from the lowered shoreline of the reservoir. In each case, the females remained in attendance and all nests hatched even though in one case the female had to move the hatchlings 150m to the water. A total of 44 hatchlings was marked from two nests. No hatchlings were marked from the third nest, but at least eight were later observed along the shoreline.

In one case the hatchlings were found in a shallow pool adjacent to what may have been a den. These animals may have survived the winter because of the shelter provided by such a den. In the other two cases, the hatchlings were found along the shoreline in areas with no vegetation and very little cover. It is unlikely that many of these animals survived. As yet unpublished studies of the avian community of Par Pond have shown marked increases in the numbers of wading birds at the reservoir since the drawdown (Keith Bildstein, pers. comm.), and these birds along with larger alligators and large-mouthed bass (*Micropterus salmoides*), that are also abundant in Par Pond (Gibbons and Sharitz 1974), would represent significant sources of predation upon hatchling alligators inhabiting such exposed shorelines.

Movements and Distribution:

The initial capture locations and subsequent movements of the nine male and five female adult alligators equipped with radio transmitters are shown in Figures 2 and 3, respectively. The distributions of the sexes differed markedly throughout the reservoir in September/October when initial captures were made. All alligators captured by trip snares in the reservoir's North Arm were males, while four out of the five females captured were taken in the West Arm. Later in October, the males that had been captured in the North Arm showed considerable movement, with two moving as far as the West Arm and two leaving the reservoir itself. However, only one of the females showed any movement between regions of the reservoir. This female was captured near the west end of the retaining dam in the West Arm and later moved the entire length of the reservoir to the upper reaches of the North Arm where it later spent the winter. By October, the three females that had been captured in the West Arm began to concentrate, along with a radio-telemetered male from the North Arm, in a limited portion of the West Arm where they would later spend the winter.

With the onset of colder weather in December-January, all long-distance movements of the radio-telemetered alligators ceased, and their distribution within the reservoir was typified by that shown in early February (Figures 2 and 3). At this time, nearly half (6/13) of the alligators equipped with radio transmitters were located in open water along a <300m stretch of south-facing shoreline bordering a narrow portion of the West Arm. The six telemetered alligators using this winter concentration area were equally divided between the sexes, with the three males having all been originally captured in the North Arm. Two other telemetered males wintered at the northwestern-most extreme of the Hot Arm where earlier studies (Murphy 1977, 1981; Murphy and Brisbin 1974) showed concentrations of larger males to have occurred prior to 1987, when nuclear reactor effluents maintained elevated water temperatures at this location.

Radio-tracking studies were terminated in late March/early April. At this time, despite the arrival of warmer weather, the females still had not moved from their winter locations, and all but one remained in the same general area of the reservoir where they had been captured (Figure 3). Their behaviour in this regard was quite similar to that reported by Goodwin and Marion (1979) whose radio telemetry studies showed that the wintering locations of alligators inhabiting a Florida lake were generally a more limited subset of their ranges during warmer months.

With the arrival of warmer weather in March, some of the telemetered males began to show increased movements throughout the reservoir. Two of these males one of which wintered in the North Arm near where it had been captured and the other from the West Arm winter concentration area, respectively showed mid-winter and March forays into the Hot Arm. In each case, the animal returned thereafter to its former wintering site. This behaviour was similar to that described before the reservoir drawdown by Murphy (1977) who also observed forays by radio-telemetered males between their wintering sites and other parts of the reservoir in late winter/early spring, with the animals similarly returning to their wintering sites afterwards. In the present study however, the forays were exactly the reverse of those described earlier since in the latter case (Murphy 1977) the wintering sites had been located in the Hot Arm and spring forays were made to-and-from the West Arm instead of vice-versa. However, this reversal of seasonal movement patterns might well have been due to the cessation of the input of thermal effluent to the Hot Arm rather than being a consequence of the reservoir drawdown *per se*.

<u>Emigration and Mortality</u>:

Since initiation of the reservoir drawdown, six alligators (four males and two females) have been documented as having moved away from Par Pond proper, after having been previously marked in that reservoir (Table 2; Figure 6). In three of these cases (alligators D, E and F, Table 2) it could not be conclusively shown that the movements actually resulted from the reservoir's drawdown since these individuals were marked several years before the water level was lowered. In only one case did the departing individual return to Par Pond (alligator C, Table 2; Figure 6). Two of the emigrating alligators were found dead in nearby reservoirs (Pond B and Pond C) to which they had moved (Table 2; Figure 6). Both of these smaller impoundments are known to have several resident adult alligators (Murphy 1981), some of which were undoubtedly larger than the emigrants from Par Pond. In both cases, the dead animals showed signs of having been savagely attacked by another larger alligator. Limbs, and in one case the entire alligator's head, were torn from these animals; bodies (Table 2), and although both carcasses were torn in many places, there was no evidence that either animal had been consumed by the attacker. While it cannot be shown that these alligators did not die from natural causes, it would seem very unlikely that resident alligators would have so violently attacked the already dead carcasses of these two animals without the intention of feeding upon them to some extent. Intraspecific aggression resulting in death of one of the combatants is well-known in a number of species of crocodilians including the American alligator especially in the case of territorial males (Lang 1989; Pooley and Ross 1989). Female-female territorial aggression has also been recorded by Pooley and Ross (1989), particularly during the breeding/nesting season that included the period when the adult female emigrant alligator was found dead in Pond B (Table 2). No deaths of resident alligators were recorded in any of the wetlands surrounding Par Pond during the course of this study. These considerations suggest that one of the likely effects of the Par Pond drawdown has been to cause an increase in the mortality of adult alligators of both sexes that emigrated from the shrinking reservoir and were subsequently killed in aggressive encounters with resident alligators in nearby habitats to which they had moved.

Only one alligator death was recorded in Par Pond during the course of this study. A juvenile alligator measuring 0.96m in total length was found in a torpid state on 18 February 1991 on the mudflats. This animal was located 115m to the east of the entrance of a winter den, as will be described later (Figures 6 and 7), and was found on the edge of a small pool (5m diameter) in the mudflat, that had the appearance of having been excavated by the actions of a larger alligator. This juvenile was considerably larger than any of the young that had been observed in the den but was very thin and missing the distal portions of both forelimbs which appeared to have been amputated in a struggle with a conspecific or some other predator. This juvenile was returned to the laboratory for further observation where it proved active and alert. It was marked and released at the site of capture two days later and was not seen again until it was found dead at the same location on 27 March 1991. The discovery of an alligator of this small size in the open, during the winter months, is an unusual occurrence at Par Pond and suggests the possibility of stress-induced winter movement related to the presently lowered water level in the animal's habitat.

The cause of the observed emigrations was likely conspecific aggression which undoubtedly increased as the falling waters reduced the sizes of territories available to resident animals of Par Pond. Twice as many males as females were documented as leaving Par Pond and it is indeed the males which would be expected to show the greatest increase in conspecific territorial aggression as the reservoir was drawn down. An extended aggressive encounter between two large alligators was observed in shallow water along the eastern shore of the Main Lake in mid-September 1991 (F.W. Whicker, pers.comm.). This encounter was the first of its kind ever recorded for the Par Pond alligator population and involved biting, rolling and tail-slapping, but neither combatant was apparently seriously injured.

Wintering Ecology:

The American alligator has been reported to make frequent use of den structures during the winter months to provide protection from low temperature extremes. The use of such dens, that are usually located either in shallow water or at the water's edge with submerged entrances, has been reported from throughout the species' range, including Florida (Goodwin and Marion 1979), Texas (Kellogg 1929), Louisiana (McIlhenny 1935) and North Carolina (Hagan *et al.* 1983).

However the use of such winter dens has never been documented in any of the previous studies of Par Pond alligators (Murphy 1977, 1981; Brisbin et al. 1982; Brandt 1989, 1991). Detailed descriptions of the behavior of alligators during cold winter weather in this reservoir system by Brisbin et al. (1982) rather have shown adult alligators to submerge in either shallow water in the reservoir's coves or along steeply-sloping bottom contours near deeper parts of the lake, where they likely exhibit the "icing behavior" described by Hagan et al. (1983) during periods of particularly low temperatures.

On 28 January, 1992 however, an adult alligator was observed inside an extensive winter den that was located at what, before the drawdown, had been the water's edge of a small cove along the eastern shore of Par Pond's Main Lake (Figure 6). Since only the head and forequarters of this alligator could be seen extending from one of the distant branching tunnels of the den (Figure 7), its length could only be estimated as being approximately 1.5-2.5m. This alligator was presumed to be a female that was known to inhabit and nest in this particular cove. Further support for the identification of the denned alligator as being this female was provided during subsequent exploration of the den on 10 February, 1992 at which time a group of at least four small juveniles was discovered in a side chamber of the den, approximately 1.0-1.5m from where the adult alligator (which was not seen at this time) had been previously located (Figure 7). The size of the juveniles suggested that they probably had hatched in the fall of 1990 at a time when the entrance and much of the entryway of this den had almost certainly been underwater.

The presence of water in winter dens has been thought to provide alligators with important thermal buffering during periods of cold temperature (Spotila et al. 1972; Hagan et al. 1983). The possibility that the drawdown of Par Pond might result in cold temperature stress to the juveniles and/or the adult alligator in this now dry winter nursery den was therefore examined by monitoring it with three temperature probes: (1) 1.0m inside the den entrance, (2) 5.0m further inside the den near the point where the juveniles had been located, and (3) 3.0m outside the den entrance at an elevation of 1.0m above the dry lake bed (Figure 7). These three probes recorded temperatures (±0.01°C) every 30 min from 18 February through 22 April 1992. During this period, temperatures outside the den showed much higher variability (CV =63.4%) than did temperatures inside the den entrance (CV=29.0%), which in turn were significantly more variable than temperatures further inside the den near the brood chamber (CV=10.6%; $F=5.37$; $df=2736, 2830$; $p \leq 0.01$). Even on days when outside air temperatures fell below -5°C and varied throughout the day by nearly 25°C, inside den temperatures varied by less than 2.0°C and were at times more than 15°C warmer than the outside air temperatures (eg. 13-14 March 1992; Figure 7). The dates for which den temperature profiles are provided in Figure 7 were among the coldest recorded during the period that the probes were in place at the den. Even so, temperatures within the den where both the adult and juveniles were seen remained well above the accepted lower limit of body temperature for this species (5°C; Brisbin et al. 1982). Although the den temperatures were considerably below the species' preferred body temperature of 32-35°C (Colbert et al. 1946), the ability of a den such as described in this study to function as a blackbody cavity would indicate that alligators within it, regardless of their body sizes, should all be well within the limits of their "climate space" (sensu Spotila et al. 1972), and that access to water under such conditions should not be necessary for thermoregulatory purposes. At some point during the winter, however, access to water still might be necessary to prevent dehydration/dessication - especially in the case of juveniles.

Exploration of the winter den by crawling through its tunnels, revealed it to consist of a circular main tunnel enclosing an area approximately 6-8 m in diameter (Figure 7). Three side tunnels branched from the main tunnel, one of which was too small in diameter to be explored. The den system included two main chambers: (1) a smaller chamber of a little less than 1.0 m in diameter, where the juveniles were seen, and (2) a larger chamber measuring 1.5-2.0m in diameter and about 1.0m in height. The larger chamber also contained a small amount of pine litter, but it could not be determined whether this material had any relationship to the use of this den by alligators and no alligators were seen in the den during its exploration on 16 July 1992. The den's tunnel system represented a total length of about 24m, with a typical cross-section of the main tunnel measuring 30-40 cm in height by 70-120 cm in width. The tunnel was roughly oval in shape with a flattened bottom. Chen et al. (1990) described a similar shape for the cross-section of a tunnel from the den of a Chinese alligator (Alligator sinensis). Although these authors describe the construction and use of elaborate den/tunnel systems by the Chinese species, until the present study, there had been no evidence that the American species ever constructed subterranean dens with a comparable degree of complexity.

Chen et al. (1990) indicate that the size and complexity of the Chinese alligator's burrow vary with age and sex, with those of females being more complex. Both the cross-sectional size and length of the Par Pond burrow were within the range of sizes given by these authors for the burrows of adult Chinese alligators whose tunnels are 33-36cm high by 39-60cm wide and which are between 10-25m in length. Like the dens described by Chen et al. (1990) for the Chinese alligator, the Par Pond den also had two entrances that were located in a south-facing thickly vegetated vertical embankment near (what had been) the water's edge. These authors also describe small diversionary side chambers for young, located at the point of bifurcation of den tunnels, which is exactly the configuration of the chamber containing young in this study (Figure 7). Chen et al. (1990) also describe the presence of a "sleeping platform," water pool and air holes opening to the surface in the den systems of Chinese alligators. While there was a small hole in the roof of the easternmost side tunnel of the Par Pond den (Figure 7), there was no evidence that this structure had been purposely constructed by the alligator. The absence of water from the Par Pond den prevented a determination of which if any portion of the tunnel system or chambers might have contained water when the den was originally constructed. The entire Par Pond den system was generally less than 10-20cm below the surface of the ground - considerably less than the 1.0-1.8m depth reported by Chen et al. (1990) for the den of the Chinese alligator.

With the exception of the adult found in the den described above, all other alligators observed at Par Pond remained in the reservoir's open water during the winter months. Although few visual observations were recorded during the winter, all of the telemetered alligators spent the colder months in locations that made it extremely unlikely that any den use was taking place. All of the animals were found in areas that until only recently had been covered by a depth of 6-8m of open water, and the single observation of den use described above as well as other previous studies all indicate that when winter dens are used by alligators of either species, they are always constructed either at the water's edge or in relatively shallow water ($\leq$ 2m), thus allowing the occupant easy access to the surface to breathe (Kellogg 1929; McIlhenny 1935; Chabreck 1966; Goodwin and Marion 1979; Hagan et al. 1983; Chen et al. 1990). Winter locations of telemetered alligators monitored in this study were usually in the water adjacent to the now bare shoreline of the lowered reservoir and any evidence of den construction on or near the water's edge would have been obvious.

The winter habitat chosen by these adult alligators was quite similar to that used by a large adult (total length = 2.77m) male alligator which was studied by Brisbin et al. (1982) in the Pond B reservoir in 1977. As described by these authors, this individual endured winter air and water temperatures as low as 0.3 and 4.0°C, respectively, while positioned approximately 2m offshore along a bare unvegetated portion of that reservoir's shoreline. This alligator was oriented perpendicular to the reservoir's shoreline and rested on steeply sloping unvegetated bottom sediments in water that ranged from 0.80-2.00m in depth from the alligator's head to its tail, respectively.

The general characteristics of the reservoir shoreline and bottom contour of the West Arm location where six of the 13 telemetered alligators spent the winter months in close proximity to one another during the present study (Figures 2 and 3), were strikingly similar to those of the habitat chosen by the alligator studied by Brisbin et al. (1982), as described above. Brisbin et al. (1982) described how behavioral adjustments in the position of the alligator they studied apparently allowed that animal to utilize the deeper waters of the reservoir as a heat source for thermoregulation during cold weather, and although such behavior was never observed for any of the alligators monitored in the present study, the microhabitat conditions chosen by all of these animals would have allowed such winter thermoregulatory behavior to still take place despite the drawndown state of the reservoir. Although the winter of 1991-1992 was generally milder than most in this region, the survival of all 13 telemetered alligators from November 1991 through the spring of 1992 suggests that the drawdown of the reservoir was unlikely to have affected the winter survival of adults in this population.

Conclusions/Management Implications:

Both night eyeshine counts and aerial census surveys suggest that a considerable number of adult alligators have remained in the Par Pond reservoir despite its present lowered water levels (Figures 4 and 5). These alligators have most likely subsisted on an increasingly vulnerable food base including birds, turtles, fish and other prey species that no longer have the benefit of protective vegetative cover along the lake's margins. How long this prey base will continue to persist under these conditions however, is currently not known, and social stress/cannibalism will almost certainly increase if prey resources decline, as would be inevitable if the reservoir is not refilled within the following year.

Despite the number of alligators still present in the reservoir, this study has shown that a number of adults of both sexes have already emigrated from the Par Pond population and that this has resulted in the deaths of at least some of these individuals (Table 2). This will result in a net decrease in the overall breeding population of alligators on the SRS as a whole. The deaths of some smaller males (eg. alligator B, Table 2) in this manner might not have a significant impact on future population productivity on the site. However the loss of large adult females (eg. alligator D, Table 2) through such emigration and territorial conflict would almost certainly have a negative impact on the population's reproductive output. The female killed in Pond B for example, represented one of the largest size classes recorded for females from Par Pond (Murphy 1977; 1981; Brandt 1989), and Joanen (1969) has reported a positive correlation between body size and reproductive output (clutch size) in this species. Nevertheless, if the reservoir is refilled in the near future and proper nesting habitat is reestablished, a population of large breeding adults should still be present.

The emigration of large adult alligators following the drawdown of Par Pond also has important implications for the safety of personnel working in the vicinity of this reservoir. By leaving Par Pond and moving elsewhere in the area, emigrant alligators increase the likelihood that they will come to reside in locations where contacts with site personnel will be more frequent. Just such a situation occurred in the case of the largest male that emigrated from Par Pond in this study (alligator F, Table 2). After residing in Par Pond for a number of years, this individual left the reservoir and began to frequent the vicinity of a construction site below the retaining dam, where its aggressive actions toward workers at that location required its subsequent capture and "harassment" (through radio transmitter attachment by researchers). This action resulted in the animal's moving further downstream out of the construction area, to a point where its contact with site personnel has now been eliminated and yet the animal's movement can continue to be monitored/assessed from a safety point of view.

The drawdown of the Par Pond reservoir evidently had little effect on the ability of its remaining resident adult alligators to survive the winter months. The winter survival of smaller alligators, particularly very young juveniles, in this population is less certain. The observations reported here indicate that at least some groups of young spent the winter with their mothers in subterranean dens although these dens no longer contained water as a result of the drawdown. Even in the case of the elaborate den reported here however, it is not known whether the group of young observed underground in February survived for the remainder of the winter months. In any case, female alligators in the Par Pond population appear to be quite adaptable in caring for their nests and young, even under the drastically altered environmental conditions produced by the drawdown.

Despite the extraordinary efforts of females that tended nests at Par Pond in the summer of 1991, it is unlikely that many hatchling alligators from that year survived for long in the lowered reservoir with its almost complete lack of vegetative shoreline cover. Although some hatchlings may have been moved by their mothers to other wetlands nearby, there are now probably few if any small alligators still living in the reservoir itself. Furthermore, as the water level continues to be held at its lowered level, habitat conditions in those areas previously used for nesting by the reservoir's alligators, will remain unsuitable for this purpose in the future, as the result of the loss of extensive stands of shoreline vegetation. This suggests that the reservoir's alligator population will likely experience a second consecutive year of almost complete breeding failure, with still additional years of failure to follow if the reservoir is not refilled. This threat to both present and future reproductive output is probably the most important single source of impact of the Par Pond drawdown upon its resident alligator population, and if continued through time, it could have the effect of "setting back" this population's numbers and age structure to those which characterized it in earlier years, as described by Murphy (1977, 1981). To whatever degree this may prove to be the case, the information provided by the long history of previous studies of these animals should be a valuable asset in interpreting the importance of future changes in this reservoir and its resident alligator population.

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Table 1. Distribution of alligators in the Par Pond reservoir in 1987 and during/after the lowering of the reservoir's water level by 6m from June - September 1991.

Region[a]	Surface Area (ha)[b]		Number of Alligators[c,d]			
	Pre-drawdown	Post-drawdown	July 1987	October 1987	July 1991	October 1991
Main Lake	351.7 (31.4)	245.1 (44.4)	34 (53.1)	18 (52.9)	10 (11.1)	7 (11.7)
North Arm	356.2 (31.8)	145.2 (26.3)	10 (15.6)	4 (11.8)	36 (40.0)*	21 (35.0)
Hot Arm	136.6 (12.2)	65.7 (11.9)	5 (7.8)	5 (14.7)	20 (22.2)	12 (20.0)
West Arm	275.5 (24.6)	96.6 (17.5)	15 (23.4)	7 (20.6)	24 (26.7)*	20 (33.3)
	1120	552.6 (49.3)[e]	64	34	90	60

[a]As shown in Figure 1.

[b]Figures in parentheses represent percentage of the total reservoir surface area, under either pre- or post-drawdown conditions.

[c]Figures in parentheses are percentages of the total number of alligators counted.

[d]Asterisks indicate that July values for use preference (percentage of alligators observed/percentage of water area available) differ significantly ($p \leq 0.05$) from corresponding values for October of the same year, as determined by Chi^2 tests.

[e]Percentage of the pre-drawdown surface area of the total reservoir.

Table 2. Characteristics and fates of alligators marked or outfitted with radio transmitters in the Par Pond reservoir and subsequently found to have moved to other nearby bodies of water on the U.S. DOE Savannah River Site between July 1991 and March 1992, following the lowering of the reservoir's water level by 6 m from June - September 1991.

Alligator[a] (sex)	Total Length (m)	Last Capture in Par Pond.[b]	Sighting/Recovery[b]	Comments
A. (female)	1.51[c]	18 July 1991; North Arm of Par Pond (A1).	13-19 Aug. 1991; below Pond B outfall (A2).	Marked with a colored plastic collar and tag; resighted several times.
B. (male)	2.16[c]	28 Sept. 1991; North Arm of Par Pond (B1).	18 Oct. 1991; Pond C reservoir (B2).	Outfitted with a radio transmitter; found dead with signs of attack by a larger alligator - 3 legs torn from body.
C. (male)	2.73[c]	27 Sept. 1991; North Arm of Par Pond (C1).	9-10 Oct. 1991; small stream and beaver pond ±0.8 km east of eastern shore of Par Pond's North Arm (C2).	Outfitted with a radio transmitter; had returned to Hot Arm of Par Pond by 18 Oct. 1991 and did not leave the reservoir again.
D. (female)	2.42[d,e]	27 June 1986; West Arm of Par Pond (D1).	26 May 1992; northern portion of the Pond B reservoir (D2).	Found dead with signs of attack by a larger alligator - head and both hind legs torn from body.
E. (male)	1.96[d]	20 May 1989; West Arm of Par Pond (E1).	25 Sept. 1991; L-Lake reservoir, 10 km to the southwest of Par Pond.[f]	Captured while studying alligators at the L-Lake reservoir; identified by tail scute markings.

Table 2 (cont'd)

Alligator[a] (sex)	Total Length (m)	Last Capture in Par Pond.[b]	Sighting/Recovery[b]	Comments
F. (male)	3.43[d]	8 April 1988; Hot Arm of Par Pond (F1).	10 July 1992; just below the Par Pond retaining dam (F2).	Captured when the animal became a hazard to personnel working on the Par Pond dam.

[a]Identification codes correspond to locations indicated on Figure 6.

[b]Symbols in parentheses refer to locations indicated on Figure 6.

[c]Measured at the time of last capture in Par Pond.

[d]Measured at the time of recovery.

[e]Could not be measured directly (head missing); total length was estimated from measured tail length, using the ratio of tail/total lengths of comparably-sized females in this population.

[f]Locations not indicated on Figure 6.

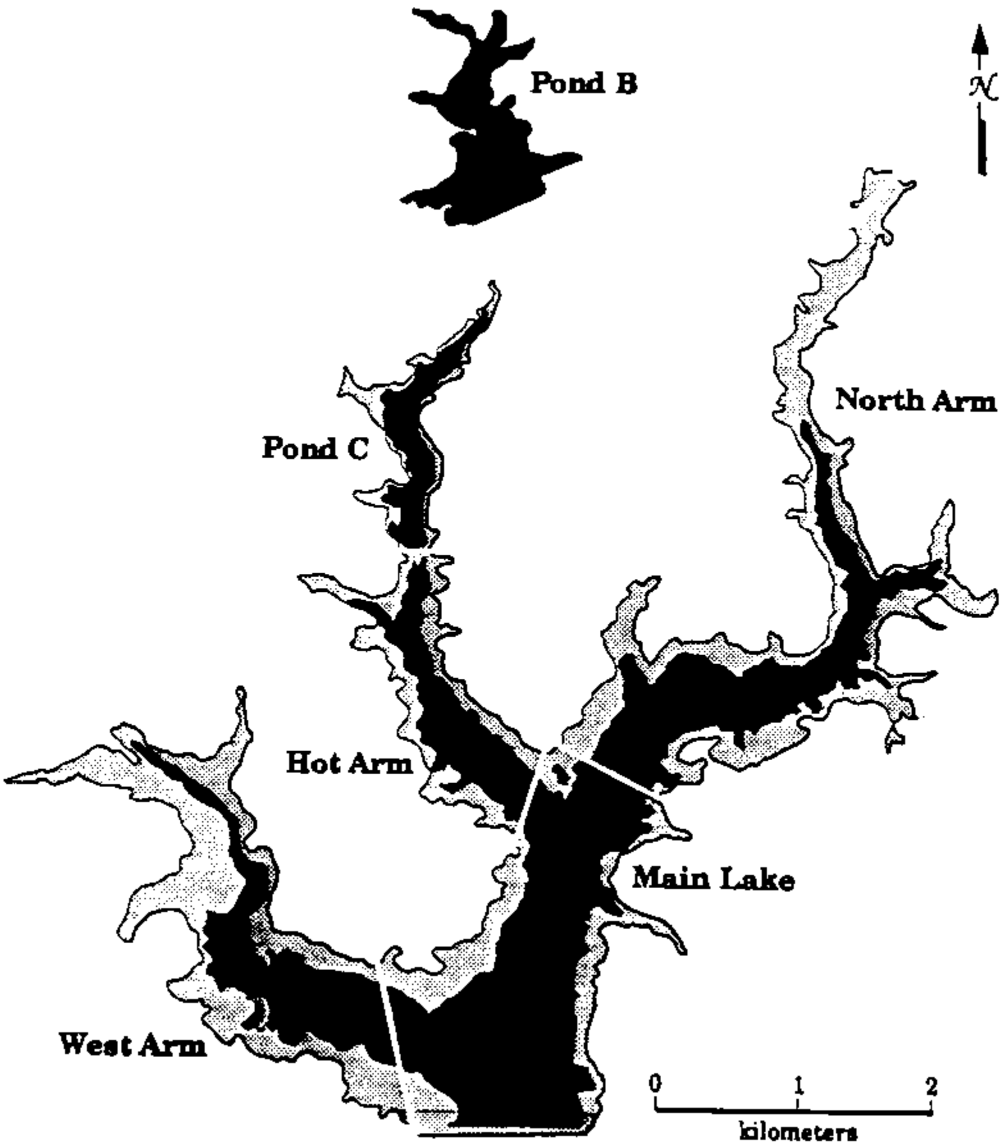

Figure 1. Map of the Par Pond reservoir and the associated Pond B and Pond C reservoirs on the U.S. Department of Energy's Savannah River Site. White lines divide Par Pond into the named regions for purposes of analysis of alligator distribution. Blackened areas indicate open water and shaded grey areas indicate mudflats exposed following the lowering of the Par Pond water level by 6m from June - September 1991.

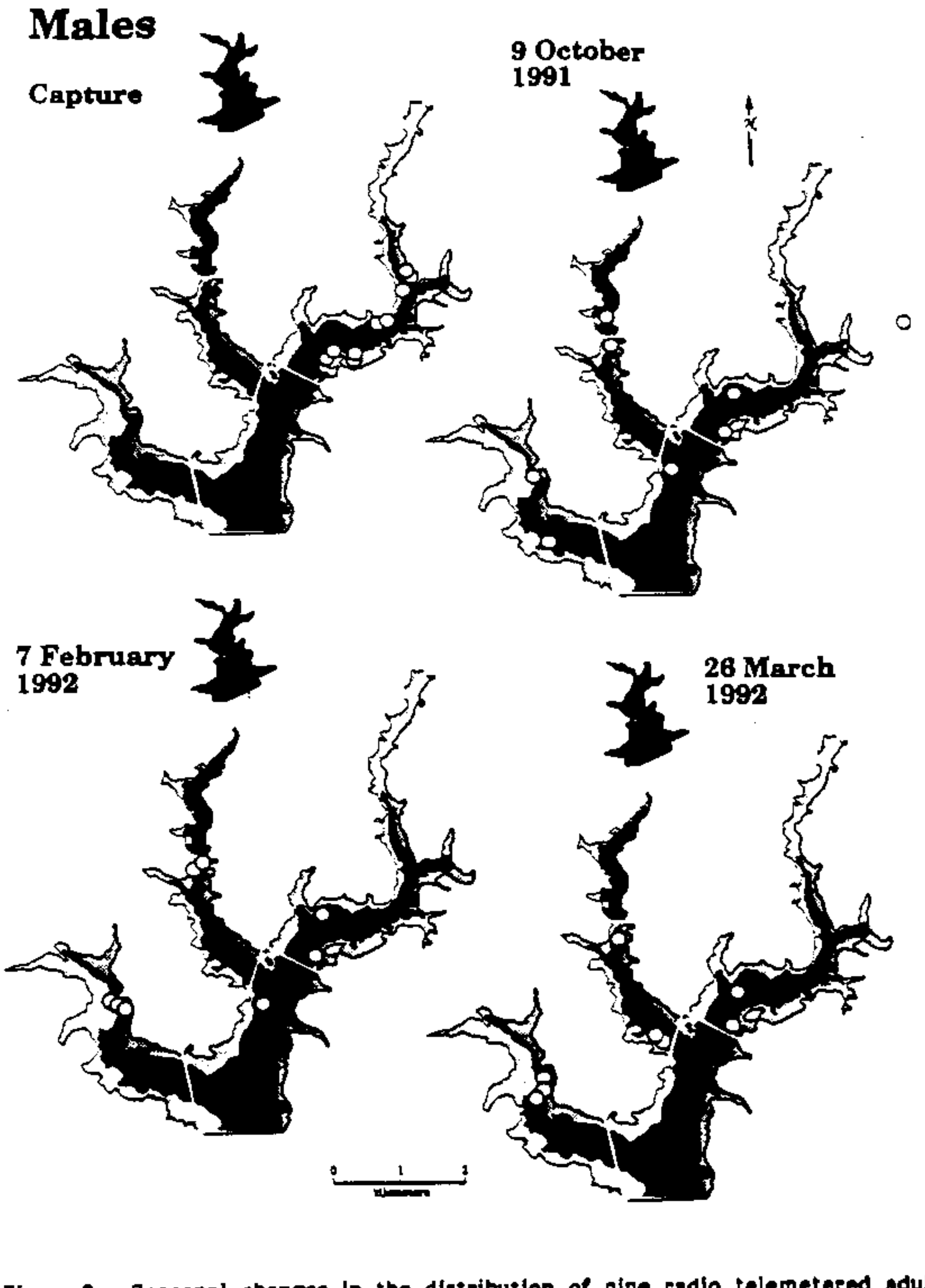

Figure 2. Seasonal changes in the distribution of nine radio telemetered adult male alligators captured in the Par Pond reservoir between 27-29 September 1991. Open circles represent the location of a single individual, and other symbols and regions of the reservoir system are as indicated in Figure 1. Not every individual could be located on each day, and the male that moved to Pond C was found dead on 18 October 1991 (see text).

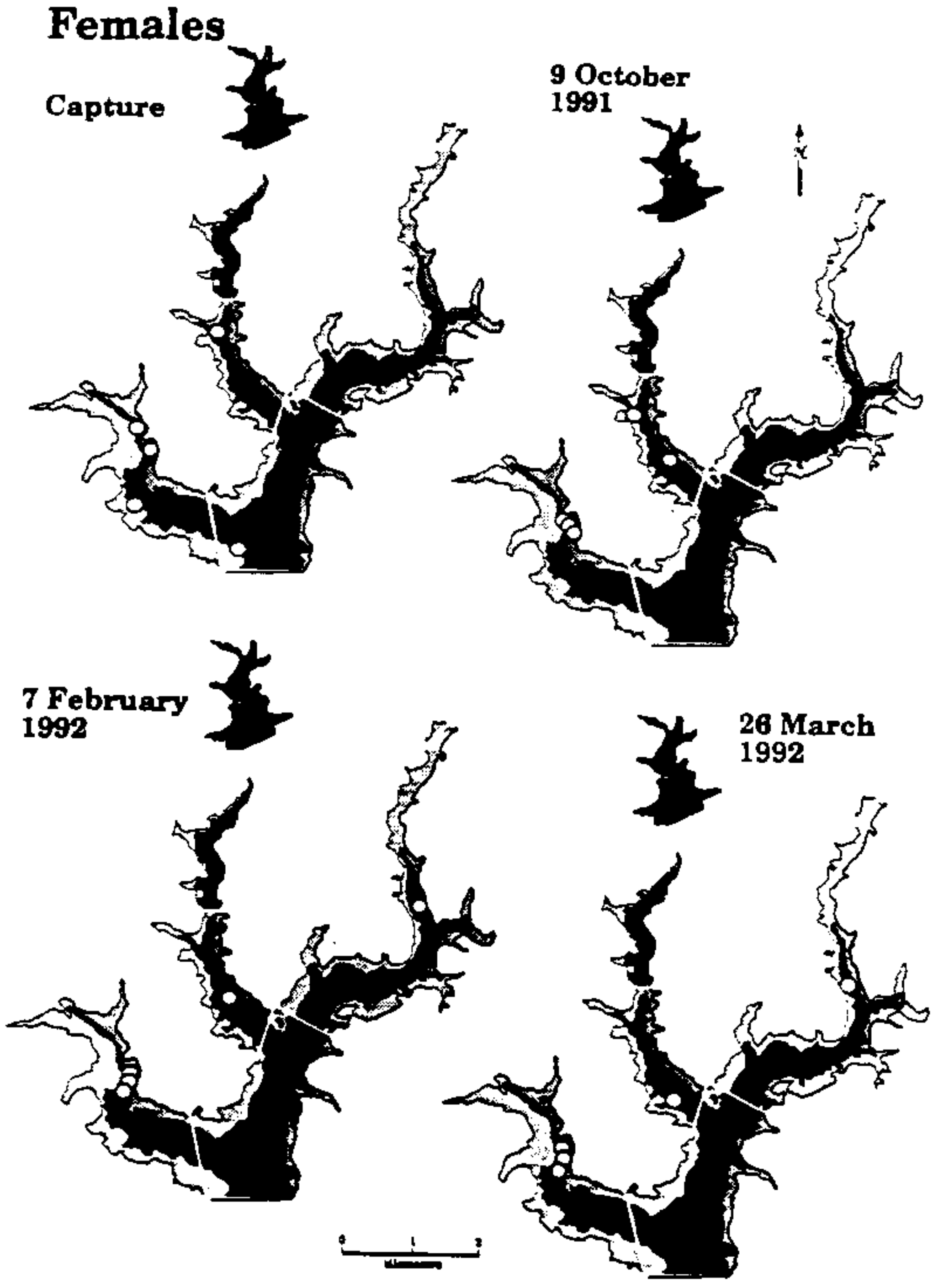

Figure 3. Seasonal changes in the distribution of five radio telemetered adult female alligators captured in the Par Pond reservoir between 19 September and 8 October 1991. Open circles represent the location of a single individual, and other symbols and regions of the reservoir system are as indicated in Figure 1.

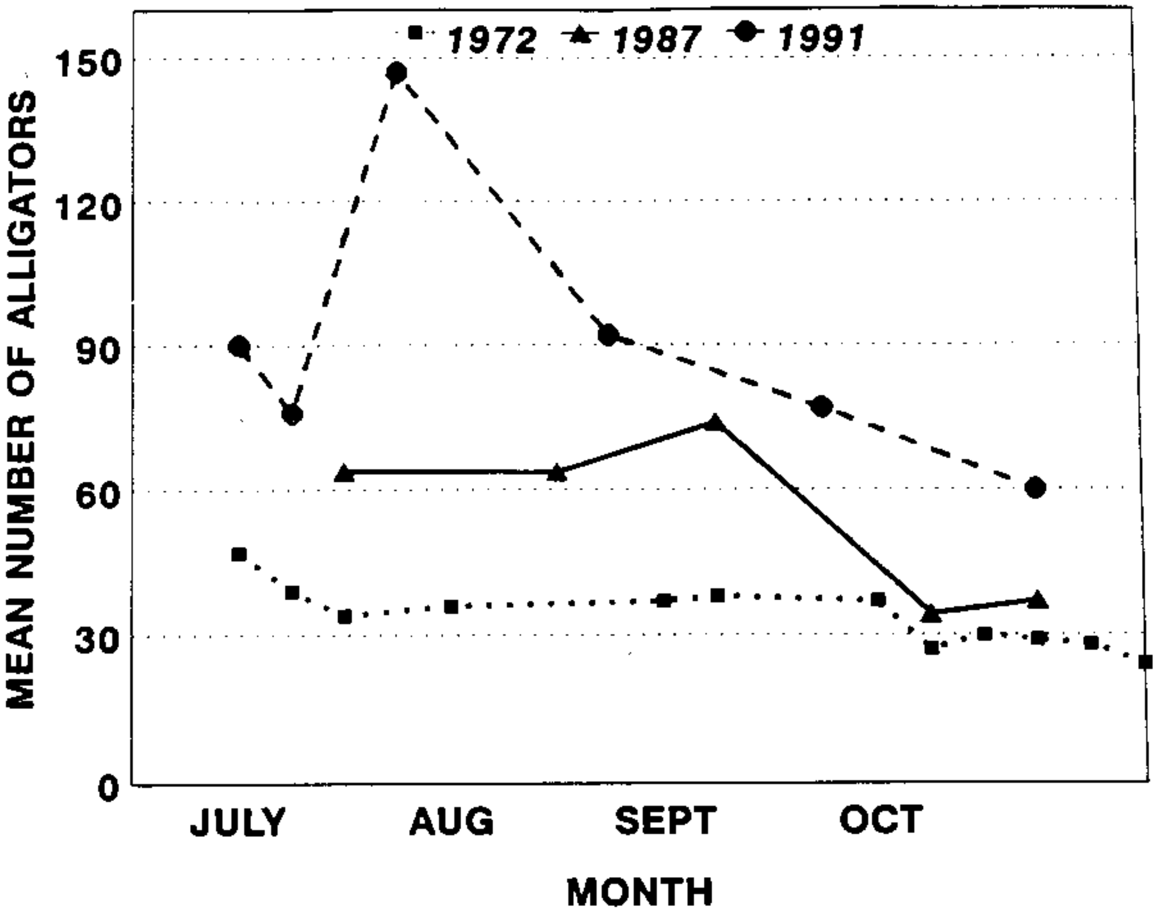

Figure 4. Number of alligators seen on the Par Pond reservoir during night eyeshine counts before, during and immediately after reservoir drawdown that occurred between June and September 1991, with the water level then continuing to be held at its lowered state. Data for 1972 and 1987 are from Murphy (1977) and Brandt (1989), respectively. Each point plotted for 1972 and 1991 represents the results of a single eyeshine count, while each point plotted for 1987 represents the mean of 3-4 counts that were conducted within a weekly period (Brandt, 1989.)

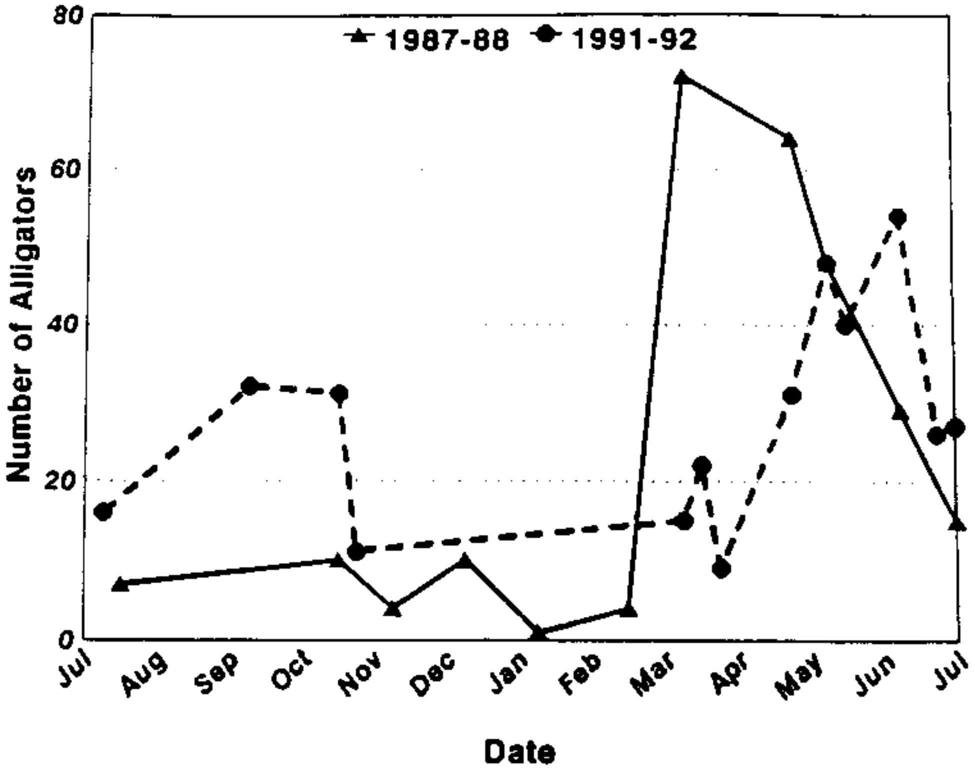

Figure 5. Number of alligators counted on aerial survey flights over the Par Pond reservoir before, during and after reservoir drawdown that occurred between June and September 1991, with the water level then continuing to be held at its lowered state. Each point represents the results of a single survey flight; data from 1987-1988 are from Brandt (1989).

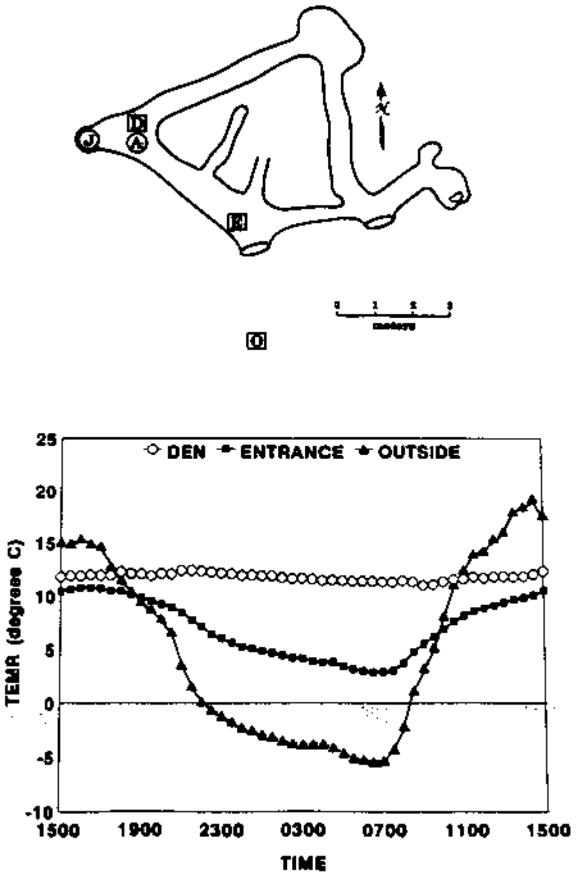

Figure 7. Top: Diagrammatic representation of an overhead view of a subterranean winter alligator den at the Par Pond reservoir (Figure 6). Circled letters A and J indicate the points at which an adult and juvenile alligators were observed on 28 January and 10 February 1992, respectively. Locations indicated by the square-enclosed letters O, E and D represent the locations where constant-recording temperature probes were placed outside the den, within the den entrance and inside the den itself, respectively. Bottom: Changes in the temperatures recorded during a 24-hour period on 13-14 March 1992, at the winter alligator den pictured above. Temperature records for the den, entrance and outside were recorded at locations indicated in the diagram above by the square-enclosed letters D, E and O, respectively.

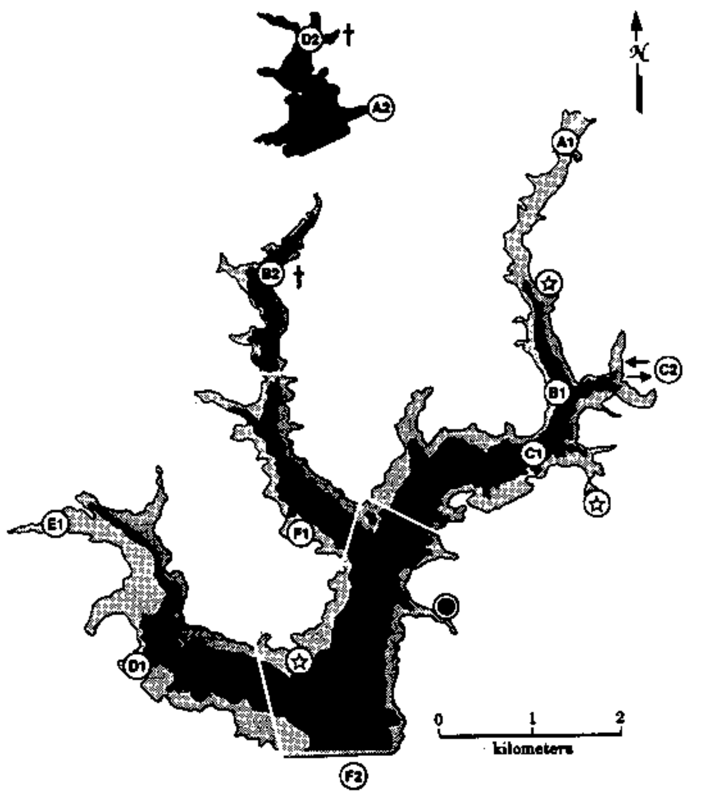

Figure 6. Locations of three alligator nests (circled stars), a winter den (circled solid circle) and capture and recovery/sighting locations of individual alligators that were known to have emigrated from the Par Pond reservoir. Symbols A1, B1, C1, D1, E1 and F1 indicate the last known points of capture or sighting within Par Pond for alligators A through F in Table 2, respectively. Symbols A2, B2, C2, D2 and F2 indicate the last known points of sighting or recovery of the same individuals, after having emigrated from the reservoir. The emigration of individual E is not shown, being 10 km to the southwest of Par Pond. Double arrows indicate that individual C returned to Par Pond after emigration, and crosses indicate locations where individuals B and D were found dead.

GROWTH RATE OF CAIMAN (*Caiman crocodilus yacare*) IN THE PANTANAL WETLAND, BRAZIL

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Growth rate of Caiman (*Caiman crocodilus yacare*) was studied at Nhumirim ranch, southern Pantanal, Brazil. Animals were captured or recaptured from January 1987 to September 1990. The integrated form of Von Bertalanffy's model was used to derive growth parameters. Effects of rainfall, sex, year of capture and site on growth rates of small (< 25 SVL) and large (> 25 SVL) were tested. Growth rates of small individuals showed a high variability around the Von Bertalanffy's curve and were affected by year of capture and site. Large animals exhibited a more definite pattern of linear decrease in growth rates and were less affected by environmental factors.

A Population Model for The Nile Crocodile with an Analysis of Sustainable Harvesting Strategies

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INTRODUCTION

In the late 1980's a model was required by CITES to help make more wide ranging recommenuauons for conservation and management of the nile crocodile . The same need had been identified by Zimbabwe's Department of National Parks and Wildlife Management where an initial study (Craig et al., 1989), grew into a report to CITES (Craig et al., 1992). This paper is a repetition of the most important conclusions reached as a result of that work.

The main need was for predictions about likely levels of sustained yields of various harvesting strategies and their impacts on crocodile populations. It was recognised that existing information might be inadequate to give accurate predictions, but these were nevertheless urgently required, based on such information as was available, with some statement of the reliability of the original information and about the effect of that on the confidence in the predictions. This approach, it was hoped, would provide provisional options for crocodile management and at the same time highlight those aspects where additional information was urgently needed. In the event, existing information was found to be so inadequate in some respects that novel information was also incorporated.

It was felt that the lack of accurate information did not permit the construction of a model incorporating the degree of complexity of some previous crocodilian models (e.g. Nichols et al. (1976)). This resulted in an approach where, for the most part, calculation replaced computer simulation, and where the results and their underlying causes were intuitively simple to interpret.

METHODS

The model was based on the discrete Lotka-Volterra equation:

$$\sum l_x m_x e^{-rx} = 1 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

No attempt to simulate stochastically determined outcomes was made, as this was considered unimportant under the envisaged circumstances of the population. Density dependent effects were not allowed for because:

a) there is inadequate information to allow these to be simulated realistically and

b) the conclusions can usefully be limited to a stage of population developement where density dependent effects are unimportant.

Values of the life table parameters (l_x and m_x in Equation 1) and the assumed confidence ranges were derived from the literature on the Nile crocodile (Graham,1968, Hutton,1988) and other crocodilians (Nichols et al., 1976, Smith and Webb, 1985, Webb et al., 1989). These are summarised in Table 1.

Some improvement to existing information on the growth curve for the Nile crocodile was considered essential and this was derived afresh using previously unpublished data on size-related growth increments from scute sections taken from Cahora Bassa crocodiles. Growth in crocodiles was assumed to take the form:

$$length(metres) = (3,2 + 0,004t).(1 - 0,9e^{-gt}) \quad \ldots\ldots(2)$$

This (Craig et al., 1992) is most sensitive to the value of g, which was the subject of the renewed estimate.

Table 1. Values used to estimate life-table parameters

PARAMETER	VALUE	RANGE	% IMPORTANCE
1 Growth curve constant g	0,093	0,073 - 0,126	33,7
2 Age at maturity (from 1)	16	12 - 20	(as above)
3 Age at senescence	55	45 - 65	0,1
4 Survival age 0 - 1	0,1	0,025 - 0,175	41,5
5 Survival 1 - maturity	0,9	0,86 - 0,94	22,1
6 Survival post-maturity	0,99	0,98 - 1.0	0,8
7 Egg loss	0,17	0,11 - 0,23	0,2
8 Nesting effort	0,7	0,6 - 0,8	1,0
9 Sex ratio	0,53	0,5 - 0,56	0,2
10 Egg inviability	0,11	0,09 - 0,13	0,1
11 Clutch size intercept	-128	-136 - -120	0,3

Equation 1 was solved for e^r to obtain an estimate of potential rate of increase for the Nile crocodile. This was repeated for upper and lower range values for all parameters in which uncertainty was assumed. Regression coefficients of estimated e^r against the confidence interval of each uncertain parameter were used to give overall approximate confidence limits to this estimate, and to estimate the relative contributions to this uncertainty of the uncertainty of individual parameters (Craig et al., 1992).

Sustainable harvests were calculated by asking what level of change in l_x or m_x would convert an increasing population to a stationary one, i.e. would make $e^r = 1$. Equation 1 is then solved for the new parameter value, for example, for egg harvests, where q is the proportion of eggs collected, m_x in equation 1 becomes $(1 - q)m_x$ at equilibrium, rearranging the equation then gives:

$$q = 1 - \frac{1}{\sum l_x \, m_x} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

(Craig et al., 1992).

RESULTS AND DISCUSSION

Given the parameter values of Table 1, the potential rate of increase for Nile crocodiles was estimated to be $e^r = 1{,}08$, i.e. an 8% annual rate of increase. Uncertainty in the parameters used, however, result in approximate conficence limits of $e^r = 1{,}03$ to $e^r = 1{,}13$.

The vast majority of uncertainty (Column 4 of Table 1) in the value of e^r appears to derive from poor estimates of three parameters, namely survivorship to age 1, survivorship from 1 to maturity and age at maturity. Clearly, if there is to be an improvement in our ability to make predictions, future research must concentrate on obtaining better estimates of these.

Sustained yields of a variety of harvesting strategies show that egg collection and rearing to a size of 1,2 metres is superior to any other strategy, e.g. Table 2 compares the yield of egg collection with cropping animals from the wild directly for skin.

Table 2. Comparison of egg collection with cropping animals >1,2 metres

STRATEGY	SUSTAINABLE % TAKEN	SKIN YIELD (index of area)
Egg collection	92%	4959
Cropping from wild	8%	218

There may be less differential economically between the strategies of Table 2, because of the cost of hatching and rearing crocodiles, but in conservation terms, it is the absolute comparison which is valid.

The robustness of egg collection as a strategy is also obvious from the percentage of eggs it is permissable to collect. Such a high proportion collected would be unlikely to be achieved even if there were no restrictions on egg collection. This robustness becomes even more apparent when options involving replacement of juveniles are investigated. Here the return of 0,5% (of the number of collected eggs) as crocodiles reared to the length of 1,2m results in restoration of sustainability even when all eggs are collected (Craig et al., 1992).

The simple model of crocodile population dynamics described here enables some useful conclusions to be drawn about safe harvesting strategies. That these also seem intuitively acceptable is additionally encouraging.

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HORMONAL DETERMINATION OF GENDER AND BEHAVIOUR IN REPTILES

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The success of captive breeding and husbandry of crocodilians for conservation and for commercial purposes depends upon successful reproduction. In addition, important parameters of health, growth, and successful adaptation to captive conditions are known to be influenced by conditions during incubation. These effects, which have important consequences for the commercial producer, are the result of interactions between behavior of animals and the hormones they secrete. In recent years significant advances have been made in understanding the complex relationship between the behavior, hormonal activity, and reproduction in reptiles. Many of these results have direct application to crocodile farming and others provide intriguing insights into some unsolved problems of crocodilian husbandry and reproduction. In this paper we report on recent results with reptiles as they might apply to crocodilians and we describe a technique for manipulating the sex of hatchlings independent of incubation temperature that has far reaching potential for conservation and commercial production.

We focus on three factors that influence reproduction. These are:
(i) the importance of behaviors of conspecifics,
(ii) how experience as an embryo can influence the adult phenotype, including reproductive competence, and
(iii) how these and other recent discoveries in reptile reproduction can be used to manipulate sex ratios in captive and perhaps wild populations.
Disregard of these factors may account for the poor success of some captive breeding programs.

Behavior of conspecifics.

An important source of cues regulating reproduction is the animal's social environment. Courtship displays evolved to assist in the identification of individuals of the same species, the appropriate sex, and their competence to reproduce. The complementary interactions among individuals during breeding can, like physical and biotic stimuli, regulate the onset, maintenance, and offset of reproduction (figure 1). They do so by synchronizing and coordinating the intricate physiological processes that underlie both male and female reproduction. Research on species of other vertebrate classes established that social cues include not only visual signals, but signals mediated by every known sensory modality. There have been five such demonstrations in reptiles, three with lizards each representing a distinct clade, and two with a snake. Taken together, this evidence clearly indicates that behavior is a potent regulator of reproductive performance in captive reptiles.

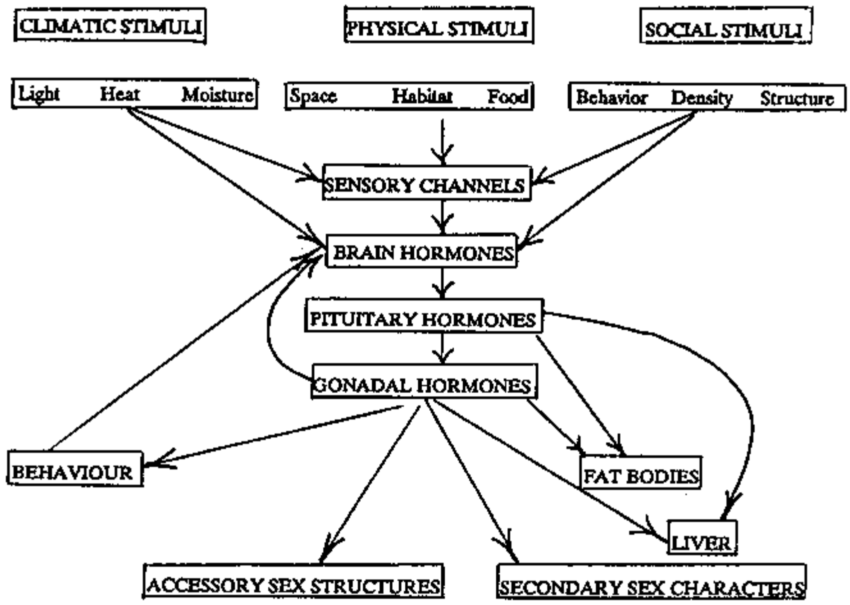


Figure 1. Stimuli affecting reproduction and interacting effects on hormones, organ systems and behaviour.

1. The green anole (*Anolis carolinensis*). In these studies, winter dormant female green anoles were exposed to a stimulatory photo-thermal regimen while being housed under different social conditions (Crews, 1974a; Crews et al., 1974). Females housed as isolates or in all-female groups underwent ovarian growth in response to this unseasonal environmental regimen. Although many of these females eventually ovulated and laid eggs, the eggs were always lightly shelled or completely lacking an eggshell. This is an indication of subnormal pituitary gonadotropin secretion. If females were housed with sexually active males, the rate of ovarian growth was significantly increased (Figure 2).

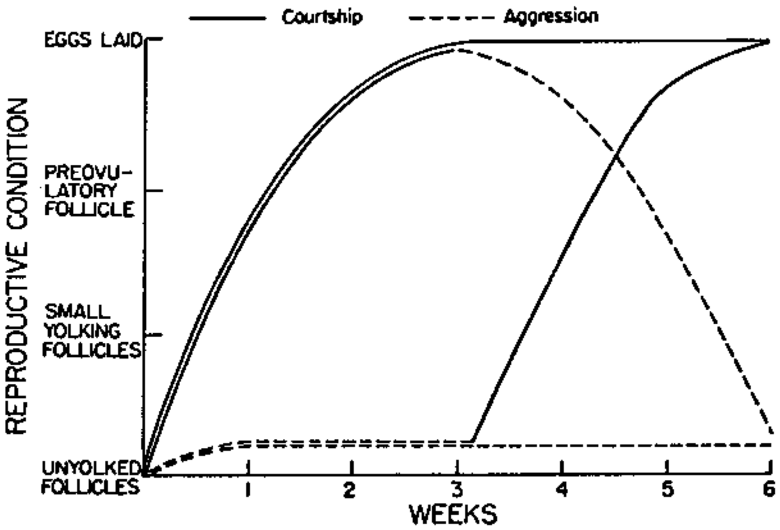


Figure 2. Effect of male behaviour on ovarian growth in female green anoles. Exposure to courting facilitates ovarian activity whereas the aggressive posture inhibits ovarian growth. In this experiment, females were exposed to the courtship or aggression stimulus for the entire six weeks or for three weeks and then stimulus switched for the next three weeks.

The mere presence of a male is not sufficient. Female green anoles housed with a castrated male, who is not sexually active, show a pattern of ovarian growth that is not different from that of females that are housed in all-female groups or as isolates (Crews, 1974b). On the other hand, if females are exposed to castrated males that have received androgen replacement therapy (which reinstates sexual activity), the pattern of ovarian response is similar to that of females housed with intact, sexually active males.

This behavioral facilitation of reproduction is due specifically to the courtship display of the male (Crews et al., 1974). Indeed, the more frequently the male displays, which in this species consists of bobbing movements associated with extensions of the dewlap, the more rapid the rate of ovarian growth (Crews, 1974a). Taken together, these studies suggest that failure in a captive breeding program requires assessment of the behavior and level of activity of males in the breeding population.

It is important to keep in mind that specific behaviors can also inhibit reproduction. Female green anoles exposed to male-male aggression, rather than to male courtship, never initiate ovarian growth, even if they are exposed to a stimulatory environmental regimen (Crews, 1974a)(Figure 2). Indeed, this aggressive behavior, which is not directed towards the female but rather to other males, is so potent a stimulus that reproductive females will cease all further reproductive activity and any yolking follicle(s) that are present will undergo atresia. Obviously, a captive breeding program should be designed to minimize agonistic interactions among males.

It also is important to understand that this behavioral modulation of reproduction operates in a reciprocal manner. That is, not only does male behavior influence female ovarian growth, but so does female behavior influence male reproductive activity. This can be seen in male green anoles (Crews and Garrick, 1980). Using the same conditions as in the above experiments, males housed in all-male groups or in isolation show a diminished pattern of testicular activity compared to males housed with intact females.

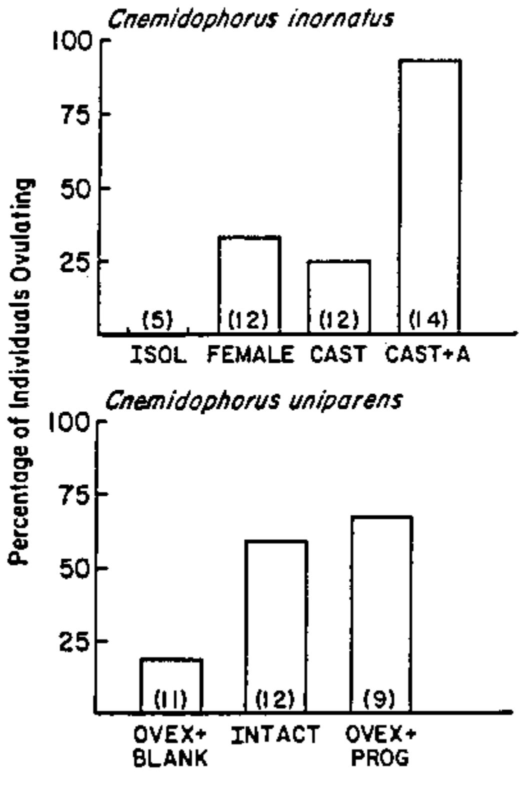


Figure 3. Behavioral facilitation of reproduction in gonochoristic and parthenogenetic species of whiptail (*Cnemidophorus*) lizards. Shown is the percentage of individuals ovulating when housed under different social conditions. ISOL = isolation; FEMALE = female cagemate; CAST = castrated male cagemate; CAST + A = androgen-treated castrated male cagemate; OVEX + BLANK = sham-treated ovariectomized cagemate; INTACT = intact cagemate; OVES + PROG = progesterone-treated ovariectomized cagemate (from Crews, 1988).

2. Behavioral facilitation of reproduction has been documented also in teiid lizards such as the whiptails (*Cnemidophorus* spp.). As in the green anole, in the little striped whiptail (*C. inornatus*), the presence, and more specifically, the reproductive status, of the male is an important feature of the female's housing environment. Females housed as isolates or housed with castrated, sexually inactive males, fail to ovulate (Crews et al., 1986)(Figure 3). Only those females exposed to intact sexually active males undergo complete ovarian growth and lay eggs. It is not known what aspect of the male is important for facilitating the stimulatory effects of the environment, although the behavior of the animals suggest that chemical signals are likely to be important.

3. The fundamental importance of complementary behavioral interactions (e.g., mounting and receptive behaviors) is seen particularly clearly in studies with the parthenogenetic whiptail, *Cnemidophorus uniparens*. In this species there are no male individuals and reproduction is via obligate parthenogenesis. Rather, the species consists entirely of females and sperm are not required for ovarian development. Interestingly, these parthenogens exhibit both male-like and female-like behaviors during specific stages of the reproductive cycle (Crews, 1989; Crews and Fitzgerald, 1980). These behaviors are seen both in the laboratory as well as in nature (Crews and Young, 1991). Experiments indicate that although male individuals are not essential for ovarian growth in the parthenogen, participation in pseudosexual interactions greatly facilitates the rate of ovarian growth (Crews et al., 1986) (Figure 3) as well as the total number of eggs produced during a breeding season (Crews and Moore, 1991; Crews et al., 1983). The specific stimuli responsible for this facilitation is not known, but the question is amenable to experimentation.

4. In the gekkonid lizard, the leopard gecko (*Eublepharis macularius*), females will only lay eggs if sexually active males are present (Figure 4). Further, the fertility of the male is important. That is, females housed with sexually active but vasectomized males will lay eggs, but the eggs often lack a shell coating (J. J. Bull, unpublished data). This suggests that not only is the behavior of the male important, but that at least in some species there must exist sensory receptors within the female's reproductive tract that are activated by sperm deposition. Specialized sperm storage ducts occur in many reptiles. This may be why in many reptiles the female can continue to lay fertile eggs for years in captivity in the absence of males. These data also suggest that while it is advisable in a captive breeding program to establish that each male is depositing sperm during mating, a fertile male is not an absolute requirement so long as the females mate successfully at least occasionally.

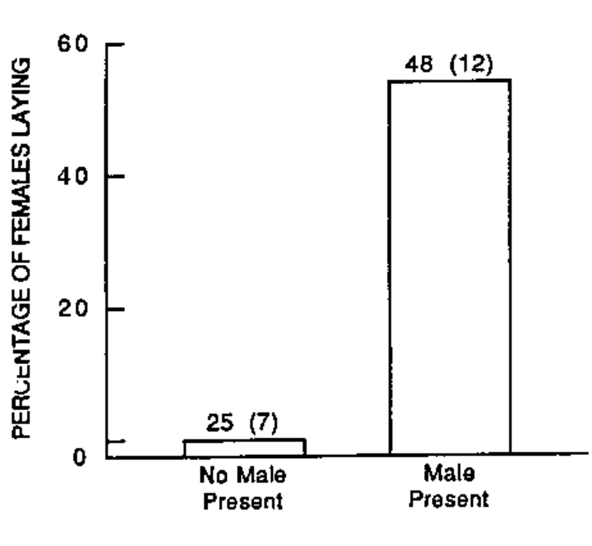


Figure 4. Behavioral facilitation of reproduction in the leopard gecko (*Eublepharis macularius*). Number of individuals represented outside parentheses; while number within represents the number of group cages.

Embryonic Determinants of Adult Phenotype

The importance of understanding early development in relation to captive breeding and conservation management programs cannot be understated. The embryo experiences a host of physical and biological stimuli independent of maternal control which can affect their development. For example, yolk is a significant repository of circulating hormones and as such reflects the hormonal profile of the mother at the time of yolk deposition (Bern, 1990). This means that the hormone levels in the laying female will be imposed on their offspring. Steroid hormones have traditionally been thought to have organizational effects during embryonic development, but they can affect the animal after birth and even into adulthood. Thus, it is important to keep in mind for captive breeding programs that factors which can adversely affect a females' hormonal profile could also have long-term consequences on the resulting young.

It is becoming evident that careful regulation and manipulation of the embryonic environment will aid in our efforts to maintain present species diversity and conservation efforts. In this section we consider how events and factors experienced by the embryo influence the growth, physiology, and behavior of the adult.

In oviparous reptiles, embryonic development is exquisitely sensitive to the temperature(s) experienced during incubation of the egg. Studies have revealed ranges of temperatures which determine sex in a number of reptilian species (see reviews by Bull, 1980, 1983; Raynaud and Pieau, 1985; Deeming and Ferguson, 1988; Ewert and Nelson, 1991).

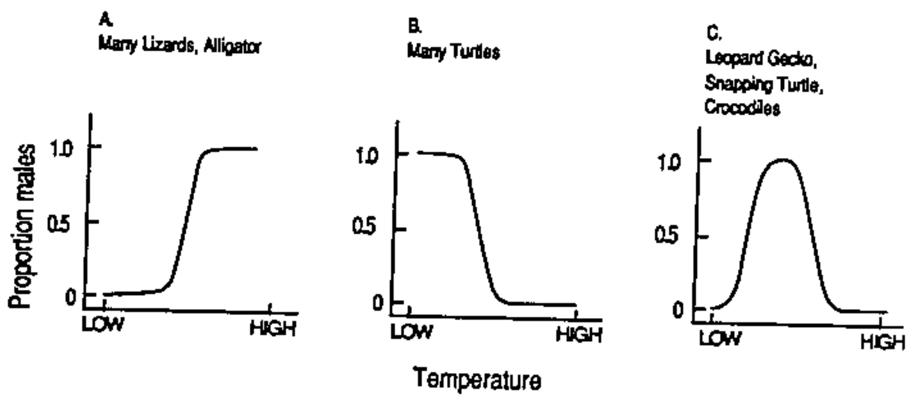


Figure 5. Response of sex ratio to incubation temperature in oviparous reptiles. In temperature-dependent sex determination, temperatures that vary by a few degrees can result in either all male or all female hatchlings being produced. Three patterns are recognized at present. (A) Females develop at low temperatures, males at high temperatures, as in some lizards and in alligators. (B) The reverse of A, males develop at low temperatures, females at high temperatures, as in most turtles. (C) Females develop at low and high temperatures, males at intermediate temperatures; this patter may be widespread, as it occurs in the leopard gecko (Eublepharis mocularius), the snapping turtle (Cheldra serpintina), and some crocodilians (adapted from Bull, 1980).

There are three general patterns of Temperature dependent Sex Determination (TSD) in oviparous reptiles (Figure 5). In some species, a range of higher temperatures produce males whereas a lower range of temperatures produce females. Other species show an opposite pattern in which higher temperatures produce females and lower temperature produce males. Still others show a pattern in which intermediate temperatures produce males and higher and lower temperatures produce females. It is important to note that in every instance:

(i) the effect of temperature is all-or-none,
(ii) the transition from male-determining to female-determining temperatures narrow, and
(iii) morphological intersexes rare, even at intermediate temperatures.

Temperature, hydric conditions, and hormones during incubation can influence embryonic growth, hatching success, neonatal viability and morphology, sex determination, and even adult physiology and behavior. In the American alligator (*Alligator mississippiensis*), relatively low incubation temperatures result in the production of females, intermediate incubation temperatures result in both males and females, and high incubation temperatures produce males. Joanen et al. (1987) examined the effect of incubation temperature on the post-hatching growth rate. Comparing individuals from intermediate male-biased incubation temperatures, males grow significantly faster than females in both total length and body weight; at the intermediate female-biased incubation temperature the females are heavier. This relationship between incubation temperature and growth is seen also within a sex, with females from 30.6 °C incubation conditions growing faster than females from 31.7° C. Overall, the effect of temperature on growth was such that, within a limited range, individuals from higher incubation temperatures grow faster than do individuals from cooler incubation temperatures. However, this interpretation is complicated by a differential "runt" effect between temperatures; that is, the temperature that resulted in the largest animals also had the lowest percentage of runts (delineated as the bottom 10% of the best growing group), while the two extreme temperatures (29.4° and 32.8° C) had the highest incidence of runts.

Incubation temperature can also affect thermoregulatory behaviors that have consequences for growth. Lang (1987) studied the effect of incubation temperature on body temperature (Tb) selection in the Siamese crocodile (*Crocodylus siamensis*). Eggs were incubated at 28° C, a temperature producing all females, or at 32.5° - 33.5° C, which produces all males. Individuals from the higher incubation temperature not only grow faster but select a higher Tb.

In all of these studies, animals were housed in social groups and hence social interactions, such as dominance and subordination, may translate into access to food, thereby influencing the results. Similarly, the temperature at which animals are raised (versus the temperature at which they were incubated as eggs) or possible sex differences in thermoregulatory behavior could have an effect. To avoid these problems, reasonable controls would be to raise subjects at a constant temperature prior to tests for thermoregulation and to rear each individual in isolation.

It is common knowledge among breeders of captive reptiles that incubation temperature can influence adult behavior. Recent studies with the leopard gecko (*Eublepharis macularius*) provides an excellent example of how temperature during embryogenesis affects subsequent development. In this species, mostly males are produced at intermediate temperatures (30.5 - 32.5° C), whereas only females are produced relatively low (26 - 28° C) and at near lethal incubation temperatures (34-35° C). In our studies we have raised leopard geckos in isolation at a temperature intermediate to the incubation temperatures.

As adults, leopard geckos have marked sexual dimorphisms in morphology. For example, a secondary sex character is the specialized secretory pores located anterior to the cloaca. In males, as well as females from high incubation temperatures, these pores are open, while in females from low incubation temperatures, they are closed. Head size also is sexually dimorphic, with males having wider heads than females. However, within each sex, the higher the incubation temperature, the wider the head of the adult (Crews, 1988).

It must be appreciated that in species with TSD, incubation temperature and sex co-vary. That is, in TSD differences between individuals could be due to the incubation temperature of the egg, the gonadal sex of the individuals, or both factors combined. If the contribution of each is to be assessed, they must be dissociated. Our studies with the leopard gecko have entailed removing the gonads of individuals on hatching (to determine the role of gonadal hormones in postnatal development), administering hormone to incubating eggs (to override the normal effects of temperature), and comparing the growth and behavior of individuals of the same sex but produced at different temperatures. Figure 6 indicates that in the leopard gecko, both incubation temperature and the sex of the animal have significant effects on body growth. Further, the presence of the ovaries, but not the testes, attenuates body growth. It should be noted that the opposite pattern is found in the red-sided garter snake; in this species males are smaller than females and the presence of the testes attenuates growth.

The endocrine physiology of the adult also appears to be influenced by the temperature experienced during incubation (Gutzke and Crews, 1988). Overall, circulating concentrations of androgens are significantly higher in adult males compared to adult females. Within females, however, androgen levels are significantly higher, and estrogen levels significantly lower, in females from high temperatures compared to females from low incubation temperatures. Indeed, most females from high temperatures appear to be functionally sterile, suggesting that the primary alteration is at the neuroendocrine level as it is in androgenized female rodents.

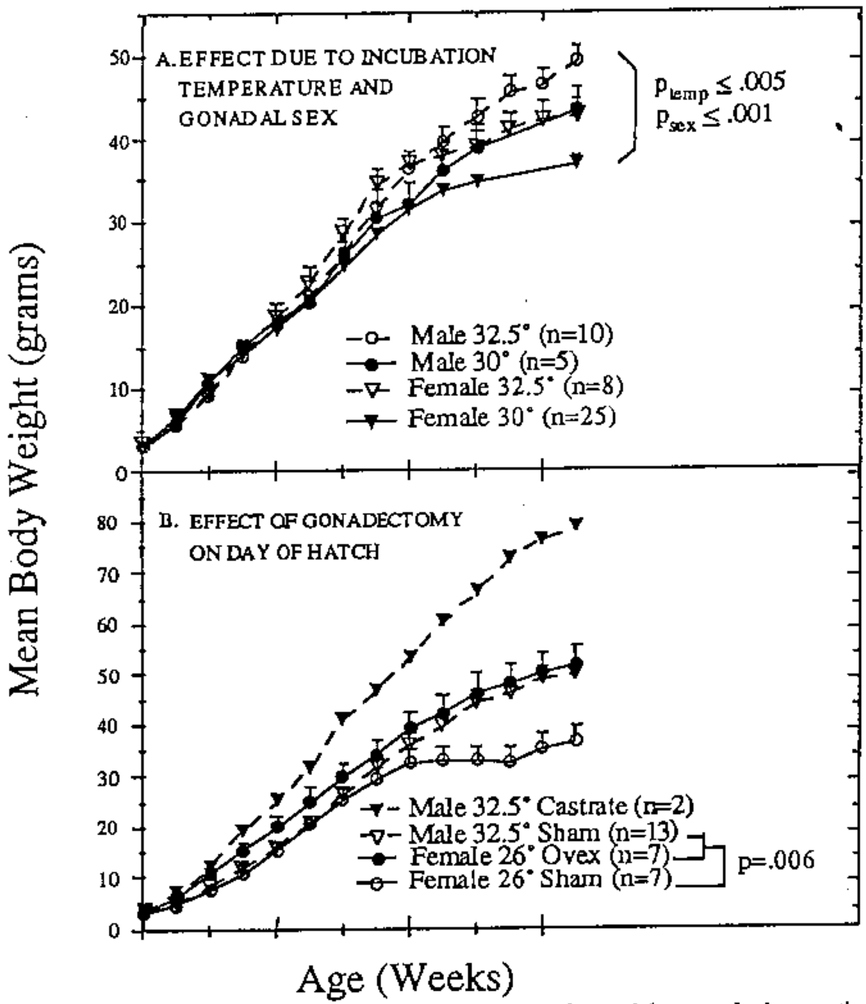


Figure 6. The relative influence of incubation temperature and gonadal sex on body growth in the leopard gecko, a species with temperature-dependent sex determination. Illustrated is the average body weight (± standard error) from different incubation temperatures or hormonal manipulations; 30.0° C produces a female-biased sex ratio whereas 32.5° C produces a male-biased sex ratio.. Each individual was measured every five weeks from hatching until adulthood. All animals are raised in isolation at an intermediate (29° C) temperature and fed a standard diet. Top: Males and females incubated at either 30.0° or 32.5° C. Bottom: Animals incubated at either 26° C or 32.5° C and then receiving a sham operation or surgical castration on the day of hatching. Each individual was weighed weekly from hatching until adulthood. All animals were raised in isolation while exposed to a 14:10 hr / 30°:18° C daily photothermal regimen and fed a standard diet. This sample size initially was believed to be nine castrated males, but laproscopy and RIA for androgens in the circulation revealed the majority to be incomplete castrations. Interestingly, only two female individuals were found to have a partial ovariectomy as adults. In one of these females, the records indicate that one gonad was lost in the body cavity after detachment. This ovary has attached to the liver and yolks follicles, but does not ovulate them. This is consistent with the literature indicating that an intact neural connection to the gonad is necessary for ovulation.

The sexual behaviors of individual leopard geckos from different incubation temperatures varies in a systematic manner, with the responses of females to male courtship showing the greatest difference (Gutzke and Crews, 1988). Females from low incubation temperatures readily exhibit receptivity when courted by a male. On the other hand, females from high incubation temperatures respond more like males than like females from low temperatures. They often will aggessively reject the male or attack him as would occur in a male-male encounter. This effect of a male-producing temperature on the female phenotype is reminiscent of the well-known masculinizing effects of androgen treatment in neonatal female mammals. In other words, high incubation temperature may be acting in a fashion analogous to androgen during development in mammals.

Captive Management of Reptiles with TSD

The occurence of TSD in many reptiles affords the unique opportunity to artificially control sex determination within a captive population. However, several basic questions must be addressed to optimize the captive management of reptiles with TSD. These questions include: (i) Which temperatures produce a particular sex? (ii) Do all temperatures producing a particular sex result in individuals of equal sexual competence? (iii) Which sex ratios are best for a captive population?

The first question is beginning to be answered in a number of species. It is becoming clear that species which show similar patterns of TSD can have different pivotal temperatures (= incubation temperature producing a 1:1 sex ratio) (Bull et al., 1982; Mrosovsky et al., 1984a; Wibbels et al., 1991). Because of this variability in the patterns and pivotal temperatures of TSD, manipulating the sex ratio of a given species would require that a variety of incubation temperatures be studied simultaneously to determine which specific temperature ranges produce a given sex ratio.

Are there certain optimal temperatures for producing sexually competent individuals? In the leopard gecko, the occasional females resulting from relatively high male-producing incubation temperatures are not reproductively competent (see above). Further, the "sexual potency" of an incubation temperature can vary (Bull et al., 1990; Wibbels et al., 1991). For example, in the red-eared slider turtle (*Trachemys scripta*), shifting eggs to a higher (female-producing) or a lower (male-producing) temperature will result in more skewed sex ratios. Such studies could prove difficult using turtles because of the length of time separating incubation and adult reproductive success. However, a lizard such as the leopard gecko, which matures rapidly and adapts well to captivity, could prove to be a model species for such studies.

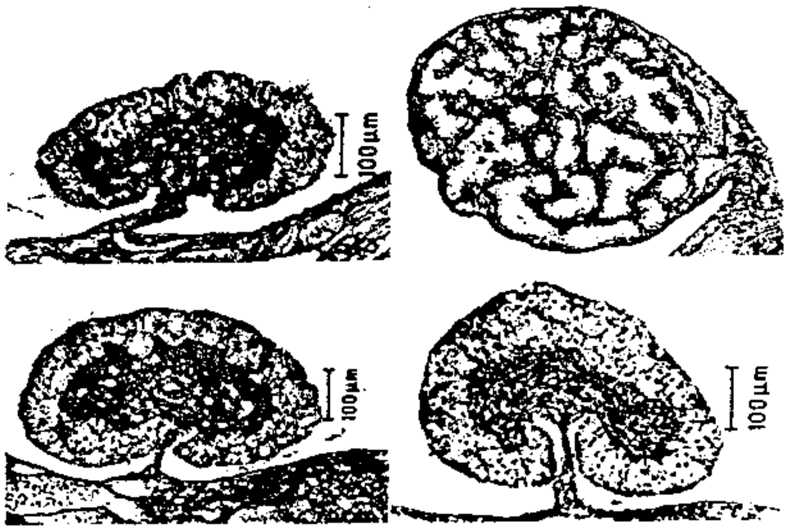
The ability to manipulate sex determination by temperature necessitates the choosing of an appropriate sex ratio for a given captive rearing program. This issue can be approached using two distinctly different strategies. In the first approach, one could attempt to duplicate the sex ratio of naturally occurring populations. The sex ratios in natural populations of reptiles with TSD do not always conform to the 1:1 ratio suggested by sex allocation theory (reviewed by Bull and Charnov, 1988; see also Limpus, 1985; Mrosovsky and Provancha, 1989; Wibbels et al., 1991). In fact, many female-biased sex ratios have been detected as well as at least one male-biased sex ratio (Limpus, 1985). The evolutionary basis of skewed sex ratios is unknown, although Bull and Charnov (1989) have proposed that factors such as thermal environment preferences and/or posthatchling growth rates could affect the fitness of a particular sex and thus select for biased sex ratios. Regardless, our present knowledge of TSD and the resulting sex ratios prevent us from assigning an evolutionarily stable sex ratio to a given population of reptiles with TSD.

While the effects of sex ratio on the reproductive output of a population of reptiles with TSD has not been empirically addressed, it seems that in situations in which reproduction is female-limited, an increased production of female offspring could significantly increase the reproductive output of a captive population. Thus, an alternative strategy would simply be to disregard sex ratios that occur in the wild and manipulate the sex ratio of the captive population in order to maximize reproductive success.

If one decides to generate a biased sex ratio, what incubation temperatures should be used? That is, should an incubation temperature that produces the desired sex ratio be utilized or should a proportion of the eggs be incubated at a male-producing temperature and the remainder incubated at a female-producing temperature? These questions can be addressed by studies investigating the effects of incubation temperature on sexual competence (as discussed above for the leopard gecko).

If a female-based sex ratio is desired, an alternative method would be the treatment of eggs with estrogen. A variety of past studies have shown that injecting estrogen into developing eggs results in ovarian differentiation regardless of incubation temperature (reviewed by Raynaud and Pieau, 1985; see also Gutzke and Bull, 1986; Crews et al., 1989). However, this method suffers from a low survivorship. A recent study has shown that topical application of estrogen to the egg shell acts in similar fashion (Figure 7) and has negligible mortality (Crews et al., 1991)(Figure 8). Studies with the leopard gecko indicate that such estrogen-induced females lay fertile eggs and exhibit normal nest-building behavior.

We presently are investigating the mechanism by which estrogen induces ovarian differentiation. Experiments indicate that estrogen and temperature act synergistically on sex determination, suggesting that they may act in a common pathway (Wibbels et al., 1991).



	Estrogen	Alcohol Vehicle
Male-producing temperature	♀	♂
Female-producing temperature	♀	♀

Figure 7. Effect of exogenous estrogen (10ug of estradiol-17B dissolved in 5ul of 95% ethanol) spotted on the shell of red-eared slider (*Trachemys scripta*) eggs during the temperature-sensitive window. Histological sections of the gonads at hatching are depicted. Note the clearly delineated cortical and medullary region (from Crews, 1991).

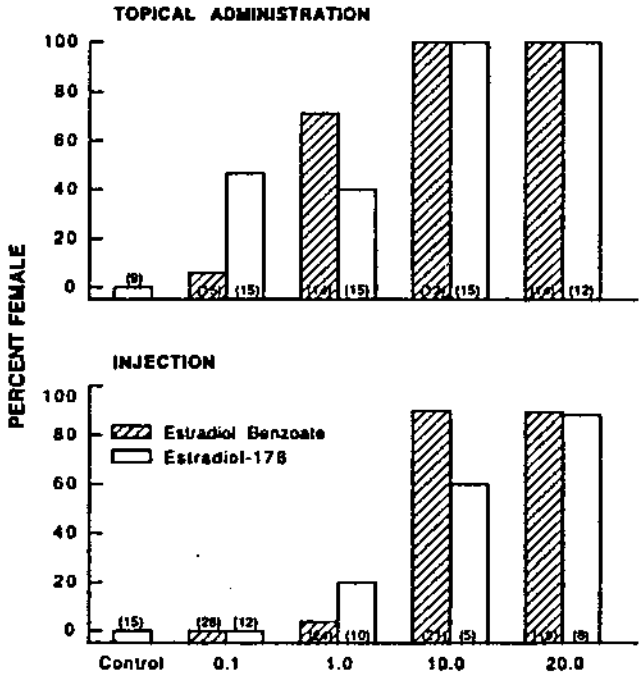


Figure 8. Effect of exogenous estrogen (10ug of estradiol-17B dissolved in 5ul of 95% ethanol) spotted on the shell of red-eared slider (*Trachemys scripta*) eggs during the temperature-sensitive window. Comparison of topical application and injection.

In our most recent work (Wibbels, Bull & Crews 1992) we have demonstrated that a similar technique can be used to at least partially override the female producing influence of temperature. Topical application of androgens did not override the feminizing influence of temperatures that produce only female offspring. However, in a series of experiments with red eared slider turtles (*Trachemys scripta*) we show that in eggs treated topically with androgens and incubated at temperatures that normally produce males and females in equal proportion, all the offspring hatch as males (Figure. 9). The gonads of males produced by topical androgen were indistinguishable from gonads of males produced by temperature manipulation and no hermaphroditic gonads were observed. The results indicate that sex determination in these embryos was bipotentially sensitive to sex steroids.

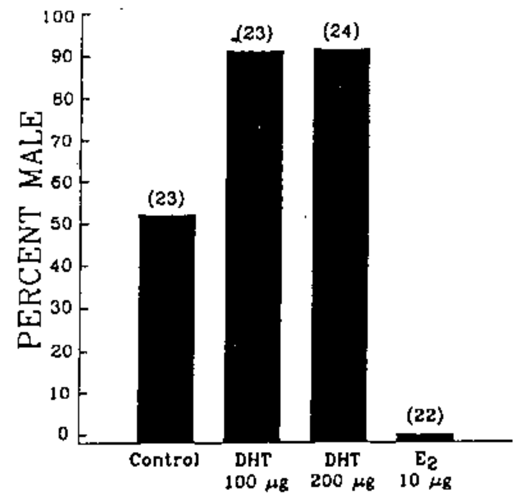


Figure 9. Percentage of male hatchlings of *Trachemys scripta* produced in response to DHT and estradiol-17B(E2) treatments. Eggs were incubated at a temperature regime that produces 50% males in this species (Control).

Discussion.

The conservation of endangered or threatened species of reptiles is a pressing problem. One important factor is the sex ratio of the breeding population (the secondary sex ratio) which is strongly influenced by the sex ratio at birth (the primary sex ratio). TSD thus has profound consequences for conservation programs. This has been most clearly demonstrated in sea turtle hatchery programs that are feared to have produced mostly male turtles, reducing the conservation benefits of these programs.

Many crocodilian programs involve manipulation of eggs, either from captive breeding or from ranching operations, the offspring from which are released back to the wild. Control of the sex ratio of these offspring is necessary. Captive breeding programs for severly endangered species can also benefit from the careful regulation of sex ratios in breeding stock to optimise both production and genetic diversity of captive populations for future restocking in the wild. There are also practical benefits to manipulating sex ratios. One sex or the other may grow faster or be more ameanable to captive conditions. Where sustainable use programs are being used as an incentive for the conservation of wild populations the efficiency of production for commercial use is an important component of economic viability and success.

The only available method until now for manipulating sex ratios in captive breeding groups has been to control the temperature of incubation. While this is a proven effective method, practical constaints limit its applicability. In remote areas technical support, equipment and reliable power supplies are scarce and temperature manipulation facilities may fail with disasterous consequences for conservation programs. The technique of spotting eggs with hormones to induce the desired sex of offspring provides an easy and inexpensive method. The procedure has no mortality associated with its application and has been demonstrated on a wide variety of reptilian species. The reproductive capacity of hormone induced offspring appears to be normal in the several species tested and the growth rate of these offspring is often enhanced. The procedure for conducting this process has a patent pending with the right assigned to a non-profit organization (Reptile Conservation International Inc.) devoted to the conservation of reptiles and any income derived from the procedure will be used to support further research and development.

We have described how the social environment can determine the level of reproduction in captive populations. It is also clear that environmental variables have effects on the development of embryos which can last into adulthood. Thus, maintainance of captive populations of endangered (or even extinct in the wild) reptiles should be mindful of these factors.

The development of an effective method to treat developing eggs topically with hormones allows sex determination to be manipulated independently of temperature. This opens the possibility of manipulating the other consequences of embryonic conditions, such as growth rate, without restricting the sex of the offspring. This technique has clear potential for both conservation and commercial applications.

The information presented here only scratches the surface of the problem. More studies are needed on the physiology of TSD and the physiological basis by which embryonic temperatures affect adult reproductive competence. Also needed are more studies of (i) the effects of sex ratio on the reproductive potential of captive as well as naturally occurring populations of reptiles and (ii) manipulation of sex ratio in the field by either physical manipulation (e.g., erecting or removing shade) or hormonal manipulation (e.g., hormone treatment of eggs in the nest).

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GROWTH RATES AND BODY CONDITION FACTORS FOR ALLIGATORS IN COASTAL LOUISIANA WETLANDS: A COMPARISON OF WILD AND FARM-RELEASED JUVENILES

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Growth rates and body condition factors for native wild and captive-raised juvenile alligators (*Alligator mississippiensis*) that had been released to the wild were studied using tag-recapture methods for 274 alligators over a four-year period. Alligators were grouped by sex, size class, source (farm-released vs. native wild), and as to whether they had overwintered or not. In most groups, the farm-released alligators grew significantly better than wild alligators matched for sex and size; in the remaining groups the post-release alligators grew as well as their counterparts, though not better. Overwintering tended to slow growth rates in both groups, but farm-released alligators still demonstrated superior growth over native wild alligators even after overwintering. Males tended to grow faster than females, though this trend was not always significantly greater. In no matched group did females grow faster than males. Growth rates diminished with increasing size class in native wild alligators (smaller alligators grew faster), but in farm-released alligators growth rates remained accelerated even at the larger size classes. Growth curves were constructed using known recapture data with three growth models (von Bertlanffy, Gompertz, and logistic); the calculated maximum attainable length and growth parameters were significantly larger ($p<0.01$) for farm-released alligators than wild using all three models. Body condition factors were not different in captive-raised post-released alligators than native wild alligators. Management implications for crocodilian restocking and utilization programs are discussed.

FEEDING HABITS OF JUVENILE ALLIGATORS ON MARSH ISLAND WILDLIFE REFUGE: A COMPARISON OF WILD AND FARM-RELEASED ALLIGATORS

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Stomach contents were analyzed from one hundred eleven juvenile alligators (*Alligator mississippiensis*, approximately 135-170 cm total length) to determine if alligators hatched and raised in captivity (until 120 cm size) then released to the wild would be capable of foraging successfully for food. Eighty farm raised alligators were released in April 1991 and captured during an experimental wild alligator harvest in July 1991 on March Island Wildlife Refuge and viscera removed. Stomach contents from thirty-one native wild alligators of similar size were also collected for comparison. Crustaceans were the most important prey item, with blue crabs (*Callinectes*) being the most frequently (70-80%) occurring item in both groups. Crawfish (*Procambarus*), grass shrimp (*Palaemonetes*), and mud crabs (*Sesarma*) occurred in 20-35% of stomachs in both groups. Fish and molluscs occurred more frequently in native wild alligators, whereas farm-released alligators consumed more birds and mammals. including nutria (*Myocastor*), muskrat (*Ondatra*), mink (*Mustela*), and rabbit (*Sylvilagus*). Insects were seen in approximately 15% of each group. Total prey weight and total weight of stomach contents were not significantly different between groups. Vegetation/plant material was seen in 95% of stomachs from each group, and probably ingested incidentally. 5% of native wild alligators and 7% of farm-released alligators had no prey items in the stomach. 86% of wild alligator stomachs contained endohelminths (averaging 14 worms each) whereas farm-released alligators only had worms in 47% of the stomachs examined, with 4 worms/stomach containing worms. Lateral fat bodies were twice as heavy in the farm-released alligators than the native wild alligators. These data suggest that alligators raised entirely in captivity (and provided food ad libitum), then released into the wild, are able to forage for food and hunt successfully as well as native wild alligators. Farm-released juvenile alligators may be more "advanced" in their feeding habits than wild juvenile alligators, as they were more likely to consume large prey items (nutria, muskrat, birds) normally not taken by alligators until the adult size class is reached.

LIPID AND FATTY ACID COMPOSITIONAL DIFFERENCES BETWEEN EGGS OF WILD AND CAPTIVE BREEDING ALLIGATORS (*Alligator mississippiensis*): AN ASSOCIATION WITH REDUCED HATCHABILITY

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A common problem in crocodilian farming is the reduced hatchability of eggs from captive breeding programmes. In the American alligator, the typical hatchability of eggs from captive breeding females is 50%, compared with 94% amongst wild eggs. The major problem is early embryonic death. We performed detailed analysis of the lipid and fatty acid compositions of the yolks of eggs from wild and captive breeding alligators from the Rockefeller Wildlife Refuge. Louisiana. There were extensive differences between the wild and captive bred egg yolks. The lipid of the yolks from the captive bred eggs displayed considerably lower levels of C20 and C22 polyunsaturated fatty acids and higher levels of C18 polyunsaturates, compared to the wild eggs. More specifically, overall levels of N6 polyunsaturates were increased at the expense of N3 acids in the captive eggs. C20 and C22 polyunsaturated fatty acids play a key role in embryonic development, e.g. of the nervous system. It is therefore likely that the yolk fatty acid compositional differences and the differences in hatchability between captive bred and wild eggs are associated. We therefore analysed the lipid and fatty acid compositions of typical alligator diets, including nutria, crocker fish and 3 commercial rations. The nutria and all 3 commercial rations were deficient in C20 and C22 polyunsaturated fatty acids and had high levels of C18 polyunsaturates: the levels bearing an uncanny resemblance to those found in the captive bred eggs! Fish on the other hand, had higher levels of C20 and C22 polyunsaturates. It is therefore proposed that the diets of breeding alligators need to be supplemented (or the commercial composition of the rations altered) to include specific species from the C20 and C22 polyunsaturated fatty acids. However, these fatty acids will need to be adequately protected with selenium and vitamin E, as occurs in natural fresh fish. Preliminary analysis of the captive eggs for selenium and vitamin E shows that they are also deficient in these compounds which may further potentiate the problem. Subtle dietary differences may be the cause of reduced hatchability in eggs from captive breeding programmes.

A RADIOTELEMETRY AND MARK-RECAPTURE EXPERIMENT TO ASSESS THE SURVIVAL OF JUVENILE CROCODILES RELEASED FROM FARMS INTO THE WILD IN ZIMBABWE

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ABSTRACT
Large numbers of Nile crocodile eggs are collected by crocodile ranchers from Lake Kariba, Zimbabwe. A small percentage of this harvest is returned to the wild at 1 to 1.5 m TL. This paper describes the initial stages of a survey to monitor the success of this process. Radiotelemetry and mark-recapture techniques are being used to estimate survival, growth and dispersal of the captive raised animals comparative to that of the wild population. There are indications of considerable mortality caused by cannibalism and human interference. Patterns of growth and dispersal after release are apparent. The results of this investigation have implications for sustainable harvesting programs for crocodiles throughout Africa and also for conservation programs in which restocking of depleted habitats is concerned.

INTRODUCTION
This project originates from CSG research objectives. The objective is to evaluate the success of the crocodile release program that is the current policy of the Crocodile Farmers Association of Zimbabwe (CFAZ) and the Department of National Parks and Wildlife Management (DNPWLM). The background and relevance of this project are outlined briefly;

- Commercial crocodile ranches collect eggs from the wild and rear these animals in captivity. Lake Kariba is the focus of these activities in Zimbabwe.

- Prior to 1987 each of the 5 crocodile ranches collected less than 3000 eggs each year - the quota being set by DNPWLM.

- Since 1987 unlimited egg collection has been encouraged, partly to estimate the size of the adult population and up to 40 000 eggs are collected each year.

-Empirical evidence and modelling indicate that a very large proportion of eggs can be removed sustainably, provided a number of juvenile animals are released each year. Survival values of wild and released crocodiles have been assumed for modelling and require field evidence.

- There has always been a provision for the subsequent release of juveniles as a condition of the permit for egg collection. Prior to 1990 this was not invoked, apart from small scale releases above Victoria Falls in the 1960s and at Sinamwenda in Lake Kariba in the early 1970s.

- Releases started in 1990 and a number of animals equivalent to 2 % of the number of eggs found 2 years previously are being released annually at a size which it was anticipated have a low level of mortality.

- The Zimbabwean policy of crocodile management has been emulated by several other African countries although none of these have yet reached the stage of releasing animals. Validation of the successful integration of released animals is thus essential for successful crocodile management in Africa as a whole.

This paper constitutes a progress report covering nearly six months of operation. As such it is descriptive and does not attempt to provide calculated estimates for the parameters studied. Insufficient data have been collected to provide more than indications of the pattern that may finally be expected.

KEY QUESTIONS AND METHODS

The key questions to be answered are;

1) What is the survival rate of captive raised animals released to the wild ?
2) How does acclimatisation to the wild habitat progress ?
3) What behaviourial changes occur among released animals ?

These questions are also addressed to the wild population to provide a basis for comparison.

The Gachegache estuary, Lake Kariba, was chosen as the initial study area as access is relatively easy and the area is representative of much of the Kariba environment, with recreational boating, line fishing, illegal gill netting and a resident human presence. Mapping of the estuary at the present low water level and placement of position markers at 250 m intervals along the shoreline was carried out before the release began (See Figure 1).

The captive raised animals released in this project were supplied by Lake Crocodile Park, Kariba (82 animals) and Rokari Crocodile Farm, Bumi (67 animals). A pool of animals for release had already been made by management at both farms. Selection for release was effectively random as none of the animals were identified and no previous history was known. Only competent animals without injury or deformities were selected for release.

Processing included basic data collection on each animal. Mass, seven measurements of body size and sex were recorded for each animal. These parameters were selected to investigate possible morphological co-variates of survival and to investigate possible differences between farm and wild raised animals.

Individual identification was made by attaching a numbered tag to the web of the left rear foot and by partial mutilation of a coded sequence of paired tail scutes. This duplication was

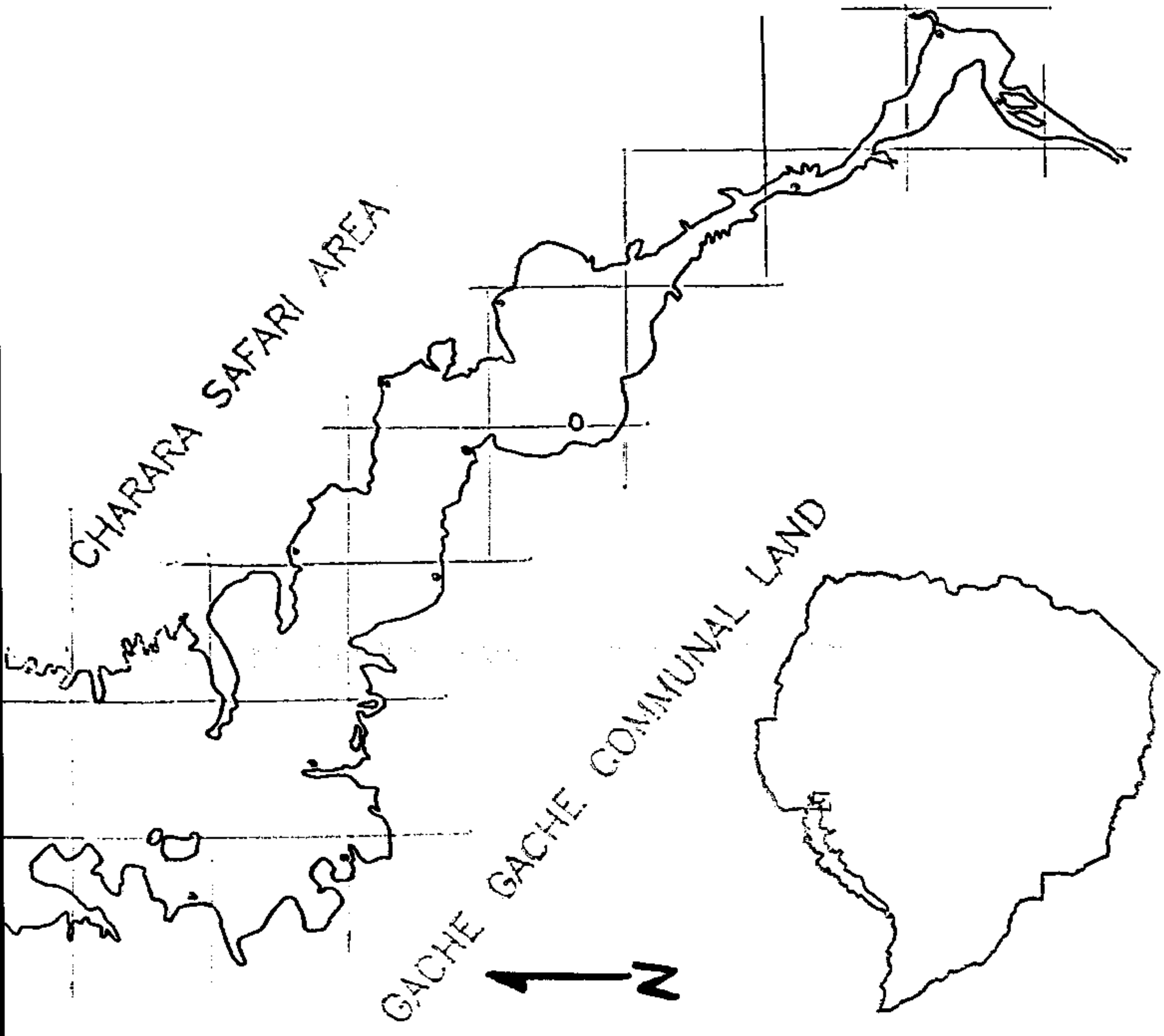

Figure 1. Location of the study area within Lake Kariba and detail of the estuary.

necessary as the endurance of the foot tags was unknown. An aluminium tag which carries an unique combination of reflective colours was also applied to both sides of the head of each animal by suture with surgical wire. This technique is essential in mark-relocation procedure as the head is the only part of the body that is consistently visible. Tagging had no apparent effect on the performance or survival of the animal. Head tags can be applied without causing trauma or bleeding. No mortality occurred as a direct result of tagging.

Animals were then held in damp jute sacks, transported by boat and released in batches at previously selected sites throughout the estuary. The releases were made in mid-February and early April 1992. The second batch was delayed for the arrival of the radios, transport across 70 km of lake and to allow initial monitoring of the first batch to proceed.

"Recapture" is in the form of resighting. The sampling procedure involves searching sections of the shoreline of the estuary at night with a spotlight and all crocodiles seen are classified by size. Tags become identifiable at approximately 10 m and the identity and location of tagged individuals is specifically recorded.

Physical recapture of tagged animals is attempted at intervals of > 60 days to reweigh and remeasure individuals for growth increments and to repair damaged or lost tags. Capture of wild crocodiles of similar size is attempted whenever possible during night sampling. Such animals are processed, tagged and released at the site of capture.

The data takes the form of a series of "capture" histories which are used to calculate survival estimates based on Jolly's closed model (Arnason and Baniuk 1978).

Radio transmitters were attached to 25 selected individuals before release. The transmitters (Model FRT-8; Lotek Engineering, Aurora, Canada) are small (160 g), sealed units designed for aquatic species. They are mounted dorsally on a neck collar with a 15 cm whip antenna directed backwards. Problems have been encountered with rotation of the collars although acceptable range is obtained even when this has occurred and with premature rotting of a degradable insert.

Each transmitter is located at approximately 3 day intervals. The date, location and activity of each fix is recorded, providing a similar series of capture histories. The data are often retrospective as animals are seldom seen and are inferred to be alive when subsequently found at another location. The data are analysed following a restricted version of the Kaplan - Meier proeedure described by Pollock, Winterstein, Bunck & Curtis (1989) and Pollock, Nichols, Brownie & Hines (1990).

CURRENT STATUS AND PRELIMINARY RESULTS

149 tagged animals were released in two batches - 82 in Feb '92 and 67 in April. 124 animals were tagged only with visible head-tags and the rest (25), all had radio transmitters attached (/ 15 with h/tags and 10 without). Monitoring started in late March and has continued more or less continually ever since.

1) Survival

A total of 374 locations have since been made on 89 individuals. The difference in technique is immediately apparent, for example only 2 animals have been located on 5 or more occasions while 17 radio-tagged animals have been located on more than 5 occasions, up to a maximum of 12 locations for an individual.

1.1) Mark-resight results

The resighting rate (Table 1), an index which reflects the proportion of tagged animals in the population, has been calculated. This is broken down by time in months after release and corrected for sampling effort.

Table 1. Resighting rate each month since release, calculated from the number of tagged animals seen, corrected for sampling effort.

Month	Km Sampled	Number Seen	Correction Factor	Resighting Rate	Comments
MARCH	29.75	15	1.43	21.45	1st batch
APRIL	26.50	49	1.60	78.40	
MAY	40.25	60	1.06	63.60	
JUNE	42.50	53	1.00	53.00	
JULY	18.75	19	2.27	43.13	

The decline in the resighting rate seen in Table 1 reflects the combined loss of tagged animals from mortality, emigration and tag loss. Emigration is discounted as considerable efforts have been made to locate tagged animals outside the study area, without success.

Tag loss is the biggest source of bias. Three means of estimating tag loss were built into the design - all animals carry both permanent marks (cut scutes) and temporary marks (head tags); at each sighting the condition and presence/absence of both head tags is specifically noted; and among the radio tagged animals, half have head tags and half have not, allowing for comparison when these animals are recaptured for measurement. Lost tags are replaced whenever an animal is handled and modified tags are now being applied which are less prone to working loose.

It is estimated from sighting that tag loss in the first 3 months after release was around 10 %. The cumulative effect of this loss on the pool of tagged animals available for sighting does not alone explain the decline seen in Table 1.

A separate analysis also indicates that the numbers available for resighting are decreasing through time. The ratio of first sightings of a tag to second or repeat sightings has dropped markedly each month since the release (Table 2).

Table 2. The ratio of first sightings of a tag to subsequent sightings of a tag, for one month period since release.

	1st Month	2nd Month	3rd Month	4th Month
First Sighting	27	26	9	3
Repeat Sighting	10	17	18	16

Such a decline through time would be expected as the number of first sightings approaches the total number released. In this case there are still more than 60 tags that have not yet been seen. Tag loss is assumed to affect previously seen and unseen tags equally.

These preliminary results indicate the possibility of considerable mortality - affecting up to half of the animals released. Another factor that suggests that mortality is considerable is that only 3 of the 54 animals released in the study area in January 1991 have been found during this study, and one of those is known to have died since.

1.2) Radio telemetry results
Twenty five animals carrying radio tags were released in April 1992. In the three months since release there has been unexpectedly high mortality (Figure 2).

Five histories of relocation ended with the collar being shed and these are not considered further. Of the 20 remaining, only 8 are currently known to be alive, while 6 are definitely dead and contact has been lost with the remaining 6, in circumstances which suggest they are also dead.

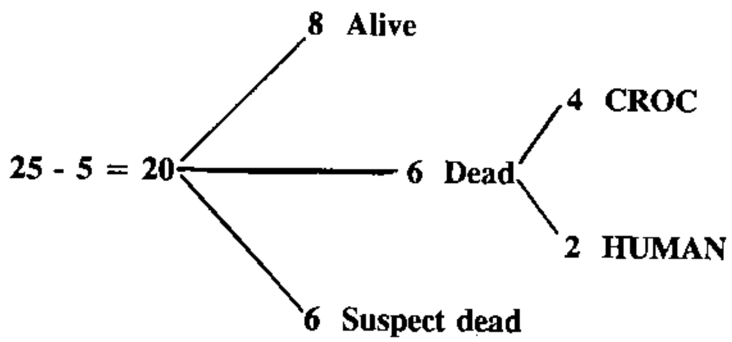

Figure 2. The present status of released radio tagged juvenile crocodiles in the Gachegache estuary.

The cause of death is interesting; 4 animals have definitely been predated upon by larger crocodiles. In all of these cases the radio signal was either received from a large adult male and moved with this animal, or contact was lost for period of up to 4 weeks after which the collar was relocated after regurgitation. This suggests the original assumption that release at 1.2 m TL would avoid cannibalism was incorrect. A further two animals were beaten to death by fish poachers after becoming trapped in a shallow pool at the top of the estuary as the water receded.

2) Acclimatisation - growth and condition
The sample size for this section of the results is fairly small (n = 30 or 20 % of the animals released). Recapture of specific animals on set dates for remeasurement is seldom successful considering the large area covered and the chance of successful capture. All the animals recaptured so far have been included, irrespective of the capture date (33 to 147 days after release) and all are first recapture.

This spread of capture dates introduces problems with interpretation because it includes growing and non-growing periods. Significant differences in growth rate occur in these periods in Kariba (Games 1990).

The limited data available however indicate considerable changes in linear dimensions and in mass (Table 3). The overall trend is increase in all dimensions except the circumference of the base of the tail. There is wide variation between individuals and an indication that those over 1.2 m TL increase more in linear dimensions than smaller animals. Mean change in TL for animals < 1.2 m TL is negative while animals > 1.2 m TL on average increased by nearly 30 mm. These growth rates are considerably higher than those found previously for released animals (Loveridge pers. comm.) but may relate to previous feeding in captivity and will decline with time.

Table 3. Mean change in body dimensions for recaptured animals over the period 33 to 147 days after release. (n = 30; all measurements in mm, except for mass (g))

	Mean Change	Std Dev.	Range
MASS (g)	+ 30	496.4	+1250; -1000
TOTAL LENGTH	+ 12.3	35.4	+93; -99
SNOUT-VENT	+ 9.9	18.7	+55; -30
BASE TAIL	- 4.6	7.7	+13; -20
HEAD WIDTH	+ 2.1	2.0	+8.9; +0.2
HEAD LENGTH	+ 4.1	4.8	+18; -3

Condition indices at the time of release are generally higher than when recaptured, only 2 of the 30 animals recaptured had higher condition scores after a period in the wild. This pattern is common to animal larger and smaller than the 1.2 m TL division described above and includes summer and winter data.

3) Movement and dispersal

The release sites were distributed along the length of the estuary, a pattern which is contrary to that found in the wild. In wild populations of C. niloticus the juveniles and sub-adults disperse downstream to more open sections of the water body, generally away from adult animals (Hutton 1984). This pattern of release sites was made intentionally in an effort to determine the most successful position as previous releases have been made without prior observation of the distribution of wild inhabitants of the release areas.

Most of the data on movement is from radio tagged animals. The data fits this pattern in that almost all of the radio tagged animals released in the top half of the estuary have subsequently been killed or have dispersed downstream. The displacement of an animal from the release site to the site of first location is very variable in direction and distance (Tables 4a,b).

Table 4a. Statistics of movement from release site to first location. (All distances in m)

Maximum distance	Minimum distance	Mean distance	Distance/day
6220	0	953	0 to 2780

Table 4b. Direction of movement from release site to first location (n = 89 animals).

Upstream	Downstream	No trend
28	33	28

The direction of first displacement from the release site is apparently random and it is suggested this is to be expected since these are naive animals, a directional trend may appear as they learn the local environment. The majority of long distance (>2000 m) movements before first location are downstream.

The trend in direction of repeated locations for the radio tagged animals and those head tagged individuals that have been located more than 3 times is mostly downstream, i.e 13 made a net displacement upstream, 20 went downstream and 8 moved very little from the release site.

This pattern in which some animals are very sedentary while others are very mobile may have significance as it appears that individuals which regularly move long distances are eventually lost to predation. The pattern certainly introduces a problem for mapping distribution and displacements and in calculating activity ranges - one type can be plotted on a scale of metres but the long distance movers require a scale in kilometres.

FUTURE DIRECTIONS

This project will continue at the present site to obtain data for a year after release. Dependant on funding, it is intended that a second field season will follow, using the indications and the lessons learnt so far to develop a "best possible" case. This will probably involve releasing larger animals, earlier in the hot season, at a site(s) previously found to be free of human disturbance and without a large adult crocodile population.

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Disease Trends on Crocodile Farms in Zimbabwe

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Introduction

The crocodile farming industry in Zimbabwe, reacting to market forces, showed rapid growth from 1986 to 1990. In the last two years however, this trend has ceased. Most farmers have now had some opportunity to gain experience in the techniques of raising crocodiles and a certain degree of standardization prevails in the industry. For example all farms, including those situated in hot areas, now hold hatchlings in heated ponds, generally at 32°C. These ponds are either indoors, often with little ventilation or natural light, or are covered at night. In addition, almost all farms keep rearing stock in similar heated facilites. Stocking densities are usually from 6 to 12 hatchlings per m^2 and about one-third of this for rearing stock. There still exists some variation in diet, which can include fresh fish, poultry and red meat from abattoir waste, hunting operations or from natural mortality of livestock. All farmers now realise the importance of hygiene and the effect of stress on the health of crocodiles, though opinions differ on how to control these factors.

With such developments in the industry it would be expected that mortality from disease should decrease, and indeed this has been the case. In the years 1980 to 1983 mean annual, hatchling mortality throughout the industry in Zimbabwe was 31,2%. In 1991 it was 11,7%. However, the importance of disease has not disappeared altogether. Previously-known diseases are still present and some have altered in their manifestation on the farm, while new conditions have been recognised and assumed some importance.

Present status of specified diseases and recent findings

Specified diseases include the major, communicable diseases of farmed crocodiles: that is adeno- and pox-virus infection, chlamydiosis, salmonellosis (Salmonella typhimurium infection), and coccidiosis. A list of farms infected with these diseases is maintained and in future, once the epizootiological factors have been further elucidated, it is possible that sales of live hatchlings from these farms may be restricted. Other diseases may have to be controlled by the use of vaccines. Some nutritional and other non-specified infectious diseases are also considered potentially important, because their aetiology is not fully understood; these will be also elaborated below.

Adeno-virus infection - the manifestation of acute adeno-virus hepatitis, enteritis and pancreatitis has been described previously (Foggin, 1987; Foggin, 1991). It has now been recorded on 24 out of 42 farms in production in Zimbabwe (57%). The disease is uncommon in crocodiles over five months of age and usually affects slower-growing individuals. More recently, it became obvious that the virus could cause chronic inflammation of the liver and that this is, in part, responsible for the development of runts. These chronic pathological changes include fibrosis of the portal tracts, bile duct hyperplasia and reduction of parenchyma tissue. Some affected individuals have shown icterus. On some farms a high proportion of runts have been shown to have been afflicted with this condition.

Pox-virus infection - this disease has been recorded in a number of countries (for literature review see Foggin, 1991) and has been adequately described. It was first confirmed in Zimbabwe in 1982 and is now known to be present on 13 farms. However this figure is likely to be erroneously low because, although morbidity is very high, mortality is low and specimens are not submitted as farmers can easily recognise the condition themselves. The significance of the disease now lies in the fact that it predisposes the skin to more serious fungal and bacterial invasion, described below, which may prove fatal. Trials with autogenous vaccine have given variable results. Unvaccinated individuals are likely to develop generalised pox when the live vaccine virus is introduced into the rearing environment.

Chlamydiosis - this is a recently recognised infection of crocodiles in Southern Africa (Huchzermeyer *et. al.*, in press), though it has been described in other reptiles (Newcomer *et. al.*, 1982). Retrospective examination of histological specimens, demonstrated that the infection has been present in Zimbabwe for some time and it has now been diagnosed on 15 farms. The usual manifestation is acute hepatitis, often associated with adeno-virus infection. Usually, there is gross enlargement of the spleen. The prevalence of asymptomatic carriers is unknown. Chalmydia infection may be a potential zoonosis, but there is no evidence that crocodile farm workers have been affected.

Bacterial disease - this remains the major cause of mortality from infectious disease in Zimbabwe. As previously reported (Foggin, 1987), gram negative enterobacteriaceae are usually involved. Necrotic enteritis, a particularly devastating form of bacterial disease, often follows adeno-virus infection or coccidiosis. Of most concern has been the high proportion of infections with Salmonella spp., a group which has public health significance. Over a four year period, 49,4% of bacterial isolates from crocodiles submitted for post mortem were identified as Salmonella spp. While Salmonella arizonae is often isolated incidentally and may almost be regarded as a normal intestinal bacteria of crocodiles, Group C Salmonella and Salmonella typhimurium appear capable of acting as primary pathogens. The practice of using poultry or livestock carcasses of animals which may have died from infectious disease, as a source of food for crocodiles, is likely to have contributed to the increasing prevalence of infection by these organisms.

Salmonella - contaminated crocodile meat is unacceptable for human consumption, yet close to 100% of normal, farmed crocodiles carry these bacteria (Madsen, pers. comm., 1992) and it could be anticipated that it would be difficult to produce crocodile meat free of these bacteria. Indeed, Madsen and Chambers (1991) found that 16,4% of tail-meat samples were contaminated with Salmonella, a figure that is somewhat lower than the contamination rate for crocodiles in Australia (Manolis et. al., 1991).

Coccidiosis - this disease was first diagnosed on crocodile farms in 1978, though it had almost certainly been present before. It has now been confirmed on 28 farms. Mortality from coccidiosis can still be very high, though it responds well to treatment with sulphachloropyrazine. Undersize individuals are most susceptible, and death is often a result of necrotic enteritis. In severe, acute cases, shizonts and sporocysts can sometimes be demonstrated in liver, lung and other viscera. Coccidiosis can also be a cause of runting because of the chronic nature of the inflammation that may be produced in the biliary system. Despite the fact that farmers are urged not to purchase hatchlings from infected farms, unless thay are removed straight from the incubator, a number of farms are infected every year by this practice.

Fungal and other dermatitis - dermatitis, other than that caused by pox, is a condition that has recently gained importance. It can occur in slaughter stock, as well as other age groups, and therefore hide quality may be affected. Ulcerative or crusting dermatitis, seen as brown lesions between the ventral scales, and excoriation of the epidermis in the intertriga are presenting features. Ophthalmia may also be present. Mortality may occur in severe cases, especially when the nares are blocked by exudate. Dermatophilus-like bacteria are demonstrated histologically in some lesions, while Fusarium spp. and other mycelia-producing fungi have been isolated in culture. A number of factors are believed to be responsible for this syndrome, and they include lapses in the standard of hygiene, the type of housing now used on most farms and nutritional factors. Trauma and pox may also be important.

Nutritional osteomalacia - is still seen on some farms every year, despite adequate inclusion of calcium and vitamin D_3 in the diet. Osteomalacia of the vertebrae can result in compression of the spinal chord and posterior paresis. Sudden death also occurs in well-grown individuals from low levels of calcium in the blood, and subsequent tetany. Because vitamin analyses cannot be routinely undertaken in Zimbabwe, it has not been possible to confirm if loss of vitamin potency in the premix is responsible for some cases of this syndrome. Certainly, calcium levels in supplements are found, at times, to be considerably lower than the stated analysis. There is some evidence to suggest that crocodiles which are marginally deficient in Vitamin D_3 do benefit from exposure to sunlight which chemically activates any precursors of Vitamin D which may be present in the diet. The relative role of these factors requires elucidation.

Vitamin E/selenium deficiency - this is a nutritional deficiency which has recently been recognised in Zimbabwe. It has occurred only where a diet of fish is fed and causes typical steatitis (yellow fat disease), as recognised elsewhere (Larsen et. al., 1983). Indoor housing appears to have contrihuted to the development of this condition because the high temperatures and humidity in these facilities cause rapid decomposition of the fish plus oxidation of the fat. A special vitamin E/selenium additive for inclusion in fish diets was formulated because the standard vitamin/mineral premix is not usually added to fish.

Gout - this was rarely seen on Zimbabwe crocodile farms until the last two years. The reason for the recent increase in incidence and the pathogenesis of the condition are not proven but are believed to be associated with the supplementation of higher levels of calcium (up to 2,5% on a dry matter basis) in an attempt to correct nutritional osteomalacia. The kidneys may become very distended with accumulated urates, resulting in destruction of most of the parenchyma. Less common is the accumulation of urates in the peri-articular tissue.

In conclusion, while disease plays much less of a role in the economics of crocodile farming than was the case ten years ago, there are a number of conditions that still require investigation and, at times, vigorous control measures. The veterinarian's input remains important, especially to increase the efficiency of production in an industry whose viability is now open to question.

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THE FEEDING ECOLOGY OF TWO NILE CROCODILE POPULATIONS IN THE ZAMBEZI VALLEY - A PROJECT SUMMARY

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INTRODUCTION

This short paper is a summary of a project on the feeding ecology of the Nile crocodile in the Zambezi valley in both Zimbabwe and Mozambique (Figure 1).

The primary objective of this study was to assess the effect of crocodiles on the fish populations of Lake Kariba. The lake supports both a successful crocodile management scheme, based on sustainable utilization, and a burgeoning artisanal or inshore fishery. There has been considerable expansion of the fishery since independence in 1980 (Murphree *et al.*, 1989) and consequently there is pressure to open up areas previously closed to fishing. Conflict between fishermen and crocodiles exists (Chimbuya and Hutton, 1988) with many of the problems centering around competition for the resource. This study represents the first attempt to estimate fish consumption by crocodiles from a natural system which may be more typical of other places in Africa, as previous studies were combinations of data from several localities (Cott, 1961) or from "atypical" populations (Graham, 1968; Hutton, 1984).

The crocodile is protected in Zimbabwe and all samples were taken from live animals which were subsequently released. A commercial cropping programme on Lake Cahora Bassa in Mozambique allowed the collection of data and samples from a shot sample (Games *et. al*, 1989)

STUDY AREAS

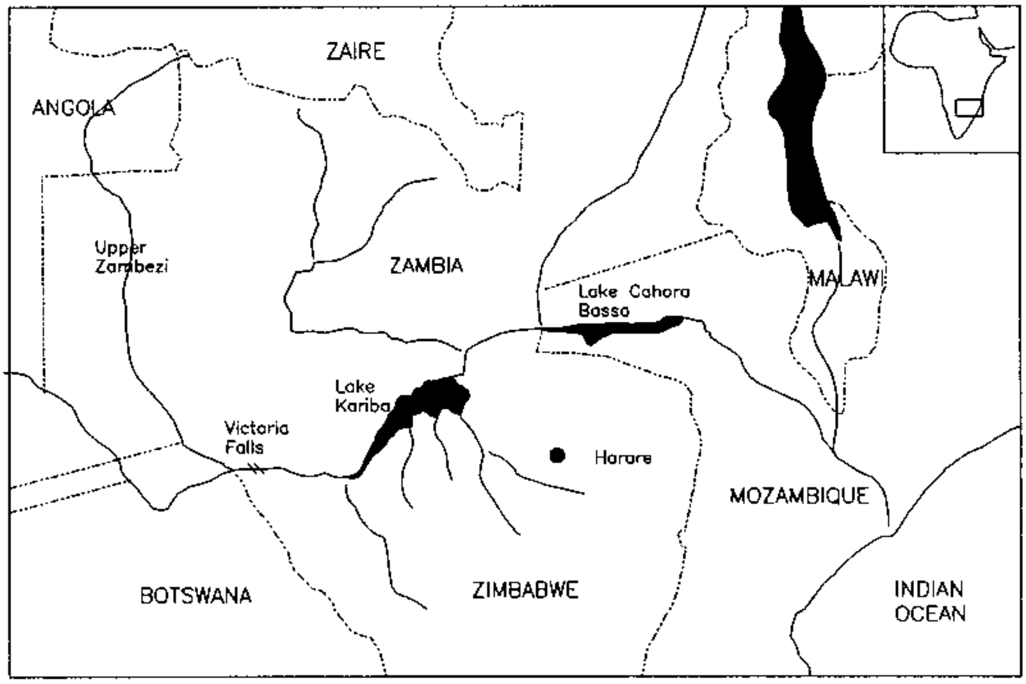
The Zambezi river rises in the highlands of Angola and Zambia and flows for more than 2 500 km through six countries before reaching the Indian Ocean. Two giant artificial lakes have been built on the river at Kariba and Cahora Bassa (Figure 1).

Lake Kariba has an area of 5 364 km^2 and a volume of 156.5 km^3 at a mean operating level of 485 m a.s.l. A succession of drought years since 1980 has depressed the mean operating level of the lake to 479 m a.s.l., where it remained throughout the study period. A study site was chosen in the Ume estuary which is protected on one side by the Matusadona National Park (Figure 2) and is relatively undisturbed by egg collection activities. Lake Kariba is one of the more intensively studied lakes in Africa and a large body of information on all aspects of its limnology and ecology exists (e.g. Balon and Coche, 1974; Bowmaker, 1973; J.M. Hutton Pvt. Ltd., 1991; Marshall, 1984)

The lake supports both inshore and pelagic (kapenta) fisheries. They are different not only in the habitat exploited, but also in capital input and yields. The kapenta fishery began in 1973 and in 1984 produced 10 404 t, almost 11 times as much as the more primitive and under-capitalized inshore fishery (Bourdillon, *et. al*, 1985).

Lake Cahora Bassa has a shoreline of approximately 1200 km^2 and a surface area of 2665 km^2 when at the planned operating level of 326 m a.s.l. (Bernacsek and Lopes, 1984). Since 1981 the mean operating level has dropped to 315 m a.s.l. and this has led to an unstable situation at the head of the lake close the Zimbabwean border (the Zumbo basin) with a fluctuating lake/river interface. Most samples were collected in this basin.

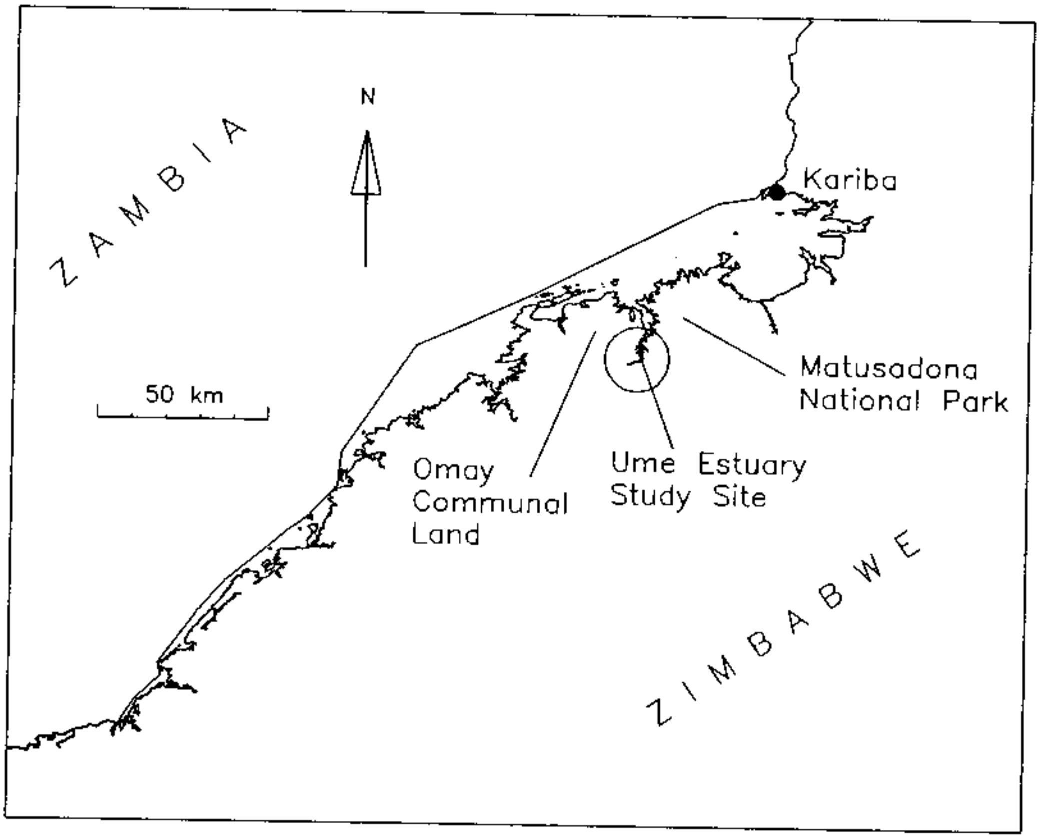
Figure 1: The Zambezi River showing Lakes Kariba and Cahora Bassa



NUMBERS AND POPULATION STRUCTURE

The age structure and size of two populations was estimated for the Zambezi river, the second study site being located 300 km downstream from Lake Kariba in Mozambique using methods summarised in Bayliss (1988) and Graham (1988). The investigation at the Mozambican study site was an opportunistic one with its principal aim to obtain a sample of larger crocodiles as these were proving difficult to catch in Lake Kariba. Extensive work went into estimating the size of the Mozambican population using several methods (aerial survey, spotlight counts, cropping and nest counts) were available and was possible to ascertain if they gave similar results. Population estimates from nesting data did agree with other methods and consequently this puts confidence in the population estimates from nest counts for Lake Kariba. The mean population estimate for the Zimbabwean side of Lake Kariba was 6 500 crocodiles of all sizes with approximately 3 500 of these being larger than 1.2 m total length (i.e. sub-adults and adults). This gives an estimated density of 3.51 animals per kilometre of shoreline. The maximum estimate using correction factors from Hutton and Woolhouse (1990) was approximately 11 500 animals with nearly 6 000 of these being sub-adults and adults. However, it should be remembered that in recent years attempts are being made to collect all eggs from areas outside the National Parks and this will affect recruitment into the population. Also Zimbabwes' release programme of farmed animals is underway and this will also affect the numbers and size and age structure of the population. Using the size structure of the Zambezi population in three broad categories was assessed from cropping and was compared with data from the literature. Mean figures of 48 % juveniles, 32 % sub-adults and 20 % adults were used for the final calculations.

Figure 2: Lake Kariba (Zimbabwe shore only) showing the Ume estuary



FEEDING

Using a new method of analysis for stomach contents (Webb and Hollis, 1990) this study showed some interesting dietary changes within the juvenile size class (animals < 700mm SVL). Lake Kariba does not support crabs and consequently juvenile crocodiles have to do without this potentially important nutrient source. The juveniles appear to feed on terrestrial insects, small mammals and frogs at low levels initially until they are about 300mm SVL when their intake increases dramatically (from approximately 0.2 g d^{-1} for juveniles <300mm SVL and increasing to a peak of + 1 g d^{-1} for juveniles >300mm SVL). This increase is associated with a shift from terrestrial to aquatic invertebrates in their diet. High water level were associated with increased amounts of food in the stomachs. This was contrary to what was expected as the high water period occurs during the cool season and it was suggested that any effects of the cool season are masked by the high temperatures in the Zambezi valley.

The importance of fish in the diet of crocodiles increases while they are between 700 mm SVL and 1300 mm SVL and, when estimated by weight, accounts for 98 % of the diet. This figure declines to around 33 % in adult crocodiles. There was no compelling evidence to support Cott's (1961) theory that they frequently eat clariids. It should be noted that this was the first study of feeding in large Nile crocodiles that did not require wholesale slaughter in the name of science (Gans and Pooley, 1976). The Mozambican data (taken from a commercial cropping exercise which this study did not initiate or support) confirmed these conclusions and helped to put confidence in the smaller sub-adult sample from Lake Kariba. Political problems in Mozambique unfortunately meant that sample was only collected during a single time of year but this makes the data more comparable with Cott's (1961) data.

DIGESTION

Rates of digestion were investigated in different size classes of crocodiles. The effect of temperature and integument type of the prey on digestion rate was ascertained in juvenile crocodiles. Fish were digested to 10 % of their original volume after 2 days in the stomach. This information was necessary in order to be able to assign an age to prey items found in wild crocodile stomachs and it was used to estimate feeding frequencies.

CONDITION

Condition in juvenile crocodiles was significantly affected by water level but not by season. Comparisons between the hot Zambezi valley and the cooler Lake Ngezi showed that the Ngezi animals (living in less than ideal conditions at the edge of their demographic range) were in better condition. It is hypothesized that this could be attributed to the presence of crabs in Lake Ngezi which make up 51 % of their diet at this locality (Hutton, 1984).

GROWTH AND AGEING

Using skeletochronology (Hutton, 1986; Games, 1991) it was shown that crocodiles grew faster in the Zambezi valley (both study sites) and matured some 15 years earlier than in Lake Ngezi. It appeared that juveniles grew slowly for the first two years and then the growth rate increased until about 1 m TL after which it declined again. Females matured at between 15 and 20 years of age. The growth curves constructed from femurs from Cahora Bassa were similar which suggests that they may be a true representation of growth in wild Nile crocodiles. It was estimated that a female crocodile in Lake Kariba will spend 6 % of her life as a juvenile, 19 % as a sub-adult and 75 % as an adult. As males grow quicker they will spend 6 % as juveniles, 11 % as sub-adults and 83 % as adults (average life span assumed to be 80 years).

FEEDING FREQUENCY AND COMPETITION WITH THE ARTISANAL FISHERY

Wild juvenile crocodiles ate small amounts of food compared to captive juveniles where they were fed *ad lib* but the data suggest that they were more efficient at converting it. Using the feeding frequencies an annual estimate of fish consumption from Lake Kariba was proposed (mean = 140.14 tonnes; upper estimate 225.39 tonnes). This was the first time that this had been done for a typical population. Graham (1968) attempted this for a population living Lake Turkana, Kenya, but admits that this may not be representative of other populations in Africa as the lake is surrounded by a desert. He also assumed a rate of feeding extrapolated from scanty data on captive animals.

If the boundaries of the fishing areas on the Zimbabwean side of Lake Kariba are examined in relation to concentrations of crocodiles it can be seen that they are generally mutually exclusive (Figure 3). There are some exceptions to this but it would appear that most of the crocodiles are concentrated in the river estuaries which are closed to artisanal fishing. The exclusion of the estuaries was not for the protection of the crocodiles but rather to protect the fish and allow them to breed in these areas.

If the estimate of total offtake is accepted then crocodiles (working with the upper estimate of the population size) are only eating the approximate equivalent of 10 % of what is removed by the artisanal fishery (6.3 % if the mean population estimate is used). It should be stressed that they are not taking 10% of the fishermens crop but rather an additional tonnage. Using a production estimate of fish tonnage per annum (44 091 t $year^{-1}$ for the littoral species in Lake Kariba; calculated by multiplying the standing crop by a production to biomass ratio which is specific to species - Hustler and Marshall, 1990; Mahon and Balon, 1977) it can be seen that the crocodile population is removing only 0.5 % of this amount. Looking at the problem from another aspect it is speculated that an average female crocodile will eat approximately 1 841 kg of fish in an 80 year life span while a male will consume 1 671 kg.

CONCLUSION

In conclusion it appears that there is no major competition between the crocodiles and fishermen for the fish resources of Lake Kariba. The crocodile industry is valuable and provides income at both the local and national level and also generates foreign currency (an estimated US $ 3 million in 1990). Further zonation of the shoreline to exclude fishermen from crocodile areas is not a desirable option but perhaps thought should be given to removing crocodiles from heavily fished areas, preferably by trapping as it is possible that these animals will eventually be caught in nets and drowned. Their removal will also be seen as an attempt to balance issues affecting the artisanal fishery as perhaps the major source of conflict between fishermen and crocodiles is the destruction of nets; these are expensive to replace and time consuming to repair. This exercise is already underway with the removal of 43 large crocodiles from sensitive areas in 1992.

Although there may be several sources of error in the estimate of intake of fish by crocodiles from Lake Kariba (e.g. numbers, feeding interval, mean prey size) it is evident that this study has achieved its major objective. Information of this nature will be extremely important when management decisions are made, especially as one can only expect the conflict (real or imagined) between crocodiles and fishermen to increase. Lake Kariba may be representative of other lakes which sustain African artisanal fisheries (eg. Lakes Victoria, Tanganyika and Malawi).

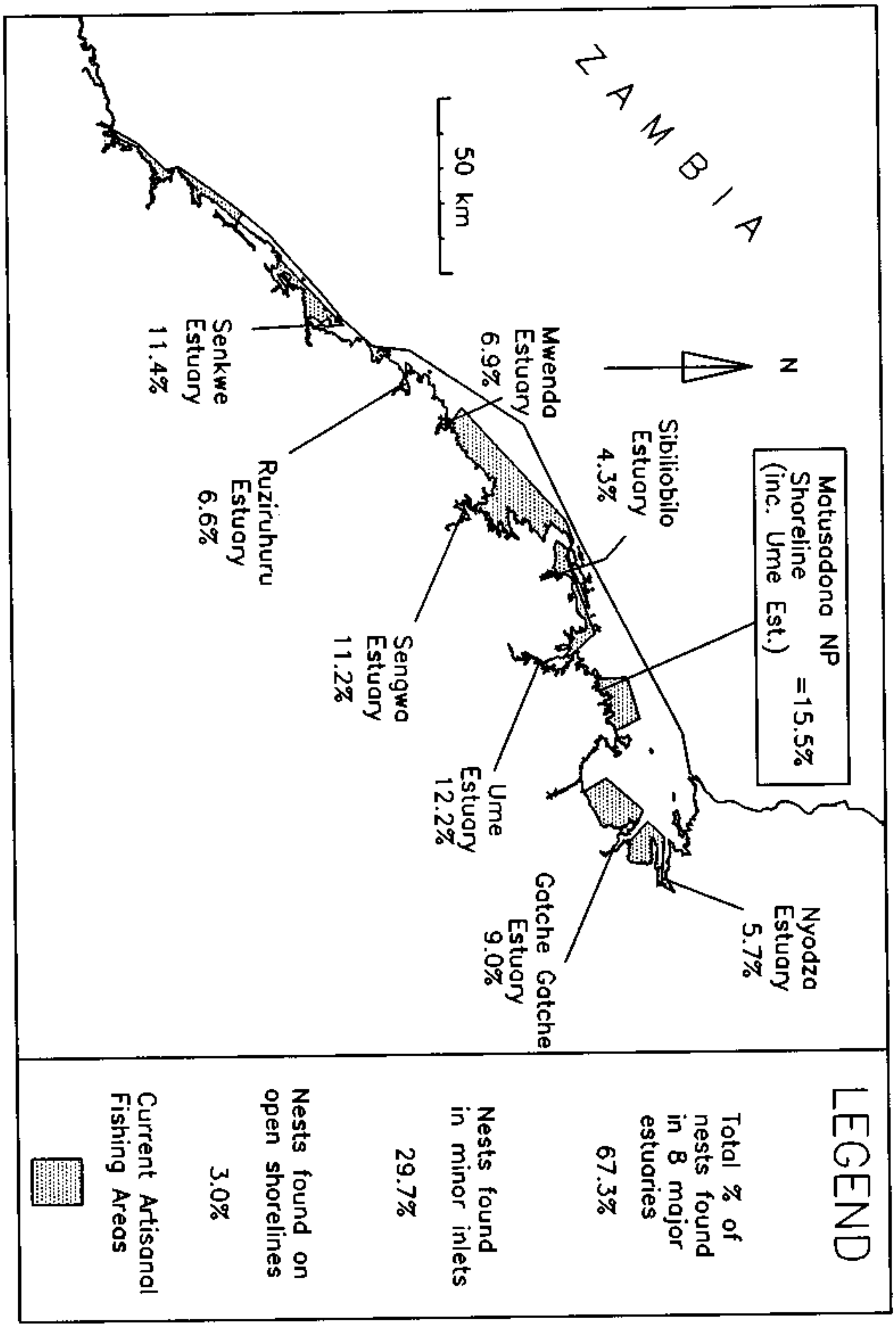


Figure 3: Lake Kariba showing the relationship between the inshore fishing concessions and the major crocodile concentrations

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THE STATUS AND DISTRIBUTION OF CROCODILES IN TANZANIA

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INTRODUCTION

Tanzania is one of the largest countries in eastern and southern Africa with an area of almost one million square kilometers. There are 13 major rivers and 5 large lakes and many of these are in protected areas.

Tello (1985) surveyed a number of rivers in the Selous but the results of this survey have not been obtainable. However, he estimated a total population of 74 000 crocodiles in Tanzania. Hirji (1986) surveyed Lake Rukwa and recommended the cropping of 10 000 animals per annum on very little supporting evidence. Katalihwa and Lema (1988) estimated a population of +76 000 crocodiles in Tanzania, largely on information taken from Tello's report.

In 1988, 1989 and 1990, supported largely by funding from the Tanzanian government, Internationaler Reptilleder-Verband E.V. (Germany), Sovete Nouvelle France-Croco (France), CITES, Hambo Crocodile project (Tanzania) and Tuele Arts (Tanzania), and fueled by Tanzania's desire to have adequate survey data to present at the CITES meetings, a number of surveys were carried out (Hutton and Kataliwa, 1988; Games and Severre, 1989; Games and Severre, 1990). This paper is a summary of the information obtained during the 1990 survey with some discussion of the 1988 and 1989 surveys.

The 1988 survey covered the Rufigi and Ruaha rivers in March when the rivers were still in flood. This was a preliminary survey for the CITES Nile Crocodile Project (Hutton and Games, 1992). In 1989 funding was made available for a countrywide survey but owing to unforseen circumstances only the Rufigi, Ruaha and Kilombero rivers were surveyed. This survey was carried out in October when conditions were ideal for surveying crocodiles.

The 1990 survey (again carried out in October) investigated crocodile densities in 13 rivers and 5 lakes. The survey was limited by time, funds and suitable aircraft and did not establish baseline data for a monitoring programme. The principal aim was to survey as much suitable crocodile habitat as possible and to assess crocodile abundance in broad terms.

METHODS

Three different aircraft and four different pilots were used during the 1990 survey. For most counts a single engine, four seater Cessna 182, with a pilot and two observers was used. Fuel was available from Dar-es-Salaam, Dodoma, Tabora, Aruasha and Mwanza. Drums of avaigation fuel were placed in the Ruaha National Park (Msembe) and the Selous Game Reserve (Beho-Beho). On one occasion a six seater aircraft (Cessna 185) was available and was used to assess correction factors for two observers using the method outlined by Magnusson, Caughley and Grigg (1978). Counting was carried out from alternate sides of the aircraft (either one side or the other had a better view of the water) at variable heights and speeds depending on the terrain and the morphology of the river. Some large rivers were counted from level flight, simultaneously on both sides of the aircraft.

Rivers and lakes were selected for survey from maps by their ease of access and reputed populations of crocodiles (information from Dept. of Wildlife officials and hunters). As very few of these rivers had been seen before by the survey team it was not possible to establish strata of similar character before the survey. Noticeable physical features and survey and flight times were recorded to aid subsequent stratification and sub-division. Precision estimates (expressed as the co-efficient of variation [CV]) were calculated from sub-divisions.

During the surveys an estimate was made of percent coverage of the available habitat. This was largely subjective but it allowed some correction between channels which were intensely sinuous and very difficult to follow and those which were broad and easy to follow. All density estimates used in tables are adjusted for the percentage coverage estimate.

Spotlight counts of crocodiles at night were carried out in the Selous Game Reserve. Crocodiles in three different sections of river and one lake were counted in the beam of a 50 000 candle power spotlight. These figures were used to correct the aerial surveys.

RESULTS AND DISCUSSION

AERIAL SURVEYS

A brief description of the rivers and lakes surveyed is shown in Table 1. Sections of the rivers that were surveyed are marked in Figure 1. The type of river was important as broad open rivers with sandbanks were easier to survey than intensely meandering channels with extensive overhanging vegetation. Crocodile densities varied greatly between 0 and 11.24 crocodiles per kilometer (Table 2). The following is a brief summary of each river surveyed.

Morogoro Region - Selous Game Reserve

The Selous Game reserve is situated on the south-east coastal plain and covers an area of approximately 43 000 km^2 (Tanzania Wildlife Department - Selous Census). The Rufiji is the largest river in Tanzania and its drainage basin covers most of southern Tanzania. The Ruaha, Kilombero and Luwego rivers are its major feeders (Figure 1). Parts of the Selous drainage were surveyed in 1963, 1988 and 1989 (Table 3).

Figure 1: Crocodile Survey - Tanzania 1990

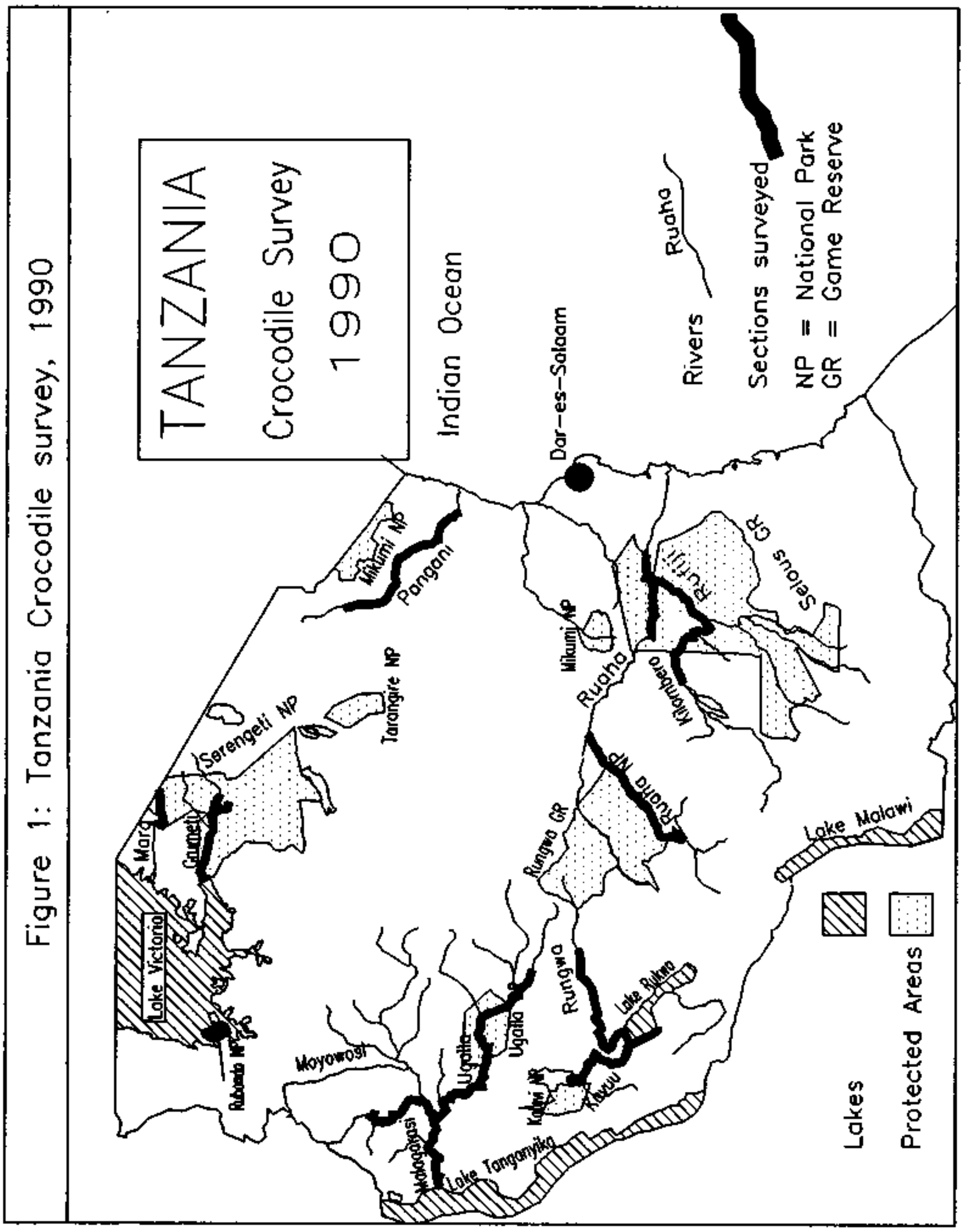


Table 1: Brief descriptions of rivers and lakes covered by 1990 aerial survey.

AREA	RIVER OR LAKE	DESCRIPTION
Morogoro Region Selous Game Reserve	Upper Rufiji	Wide, sandy river sometimes constricted through rocks. Extensive sandbars. Minimal tree overhang
	Lower Rufiji	Very wide and sandy river which flows into a palm swamp. River has changed course in last 10 years. No tree overhang
	Rufiji Lakes	There are five shallow lakes which have receded away from the shoreline vegetation.
	Ruaha	Relatively straight river flowing through low forested hills and over numerous rock bars. After emerging from a narrow gorge it becomes similar to the upper Rufiji but goes through narrow gorges immediately before its confluence with the Rufiji.
	Kilombero	The Kilombero river has three basic physical sections. Downstream from Ifakara it is a myriad of channels flowing through reeded sandbanks. The central section is a single channel flowing through a wide (and dry at this time of year) floodplain. There are a few islands and several rock bars. Close to the Shiguli falls the river is a braided channel flowing through wooded islands and over many rock bars.
Iringa Region Ruaha National Park	Lake Mtera	This is a very shallow lake in the area surveyed. Extensive areas of floating vegetation and drowned trees. Numerous fishermen.
	Ruaha	Two distinct sections. Upstream of Msembe is a moderately wide river flowing over rocks. The channel is often braided with occasional deep pools. The downstream section is wide and sandy with very few pools and very shallow.
Rukwa region	Rungwa	River is shallow and moderately sinuous. Alternating rocks and sand bars. Banks are lightly wooded. Initially the water was clear but became dirtier upstream. Channel becomes very narrow with lots of trees overhanging the bank about 65 km from the waterfall.
	Kavuu	Very sinuous and small river with moderate tree overhang. Water very shallow. Huge herds of hippo in available pools. People and cattle all the way up to the Katavi boundary but also a surprising amount of game.
	Lake Rukwa	Surveyed the north-western section of the lake. It has risen in the last few years and flooded large areas of forest and open woodland. The banks are heavily settled with farmers and fishermen.
	Lake Chada	Lake Chada is an extensive floodplain with no water at this time of year. At the moment there are an estimated 15 km of narrow channels which are packed with hippos and crocodiles. The area supports some spectacular herds of wildlife.
Tabora/Kigoma Region	Ugalla	Upper section not flowing - a series of large pools with moderate tree overhangs. Flows into an extensive floodplain before reaching the Mpande railway. Many fishermen in the area. After the bridge it flows through swamp to Lake Sagara. From lake Sagara to the Malagarasi it a single confined channel.
	Malagarasi	Upper Malagarasi is a single sinuous channel with a moderate tree fringe. It flows into a swamp near Lake Nyamagomo. After emerging from the swamp it flows through a single channel to the Ugalla confluence. After this the channel is braided over rock bars before flowing into steep gorges. The delta section is a single channel until reaching the lake.
Mwanza Region Lake Victoria	Lake Victoria	Not surveyed as the entire shoreline is heavily settled and cultivated.
	Rubondo Island	The island is heavily wooded (tropical forest) with this forest coming right down to the shoreline. There are small ares of papyrus but the main problem associated with seeing crocodiles from the air is the fringe of Mimosa along parts of the shore.
Mara Region Serengeti National Park	Grumeti/Orangi	Very sinuous rivers with a substantial tree overhang. River flowing but is basically a series of pools.
	Seronera	Narrow, sinuous river with a number of pools. Some obscuring vegetation along the banks.
	Mara	Sinuous and moderately wide (approximately 30 - 50 m wide). The river had a lot rapids and rocks which made spotting more difficult. There were sandy sections in places.
Kilimanjaro/ Tanga Region	Pangani	River is very sinuous with extensive tree overhang. Also extensive reeds. Very few sandbanks. Upper section has marsh areas away from the main channel.
	Lake Nyumba ya Mungu	Shallow dam with very open banks. Heavily populated with fishermen

Table 2: Crocodile densities in some Tanzanian rivers as indicated by aerial survey.

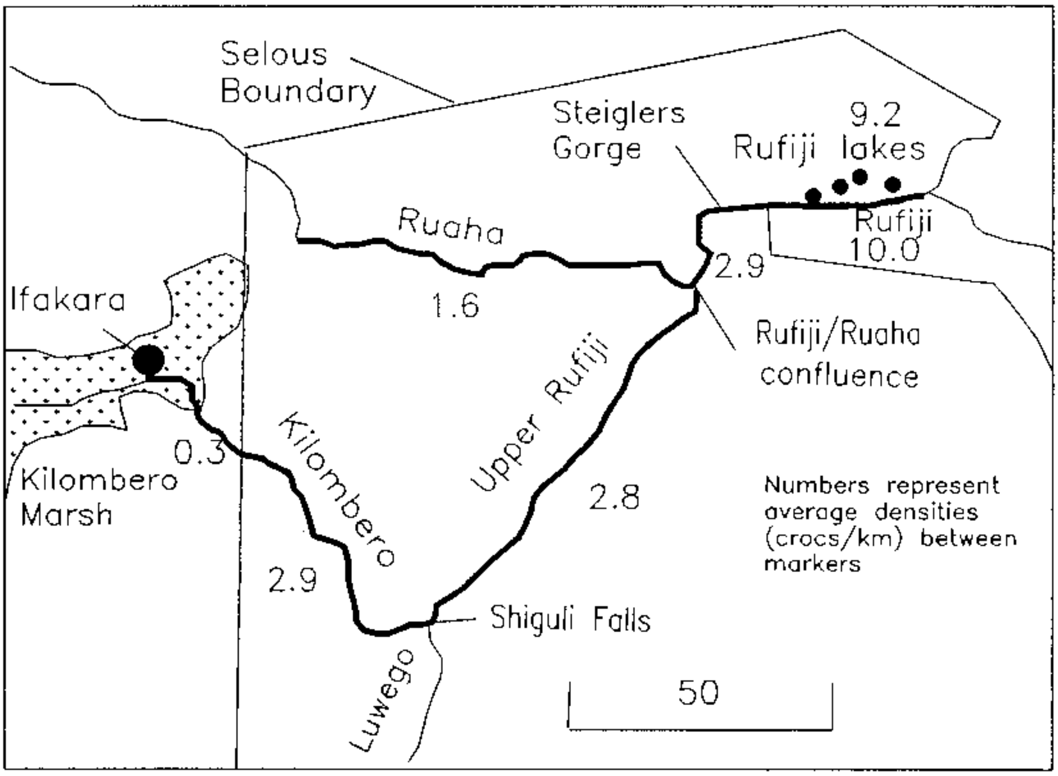
AREA	RIVER OR LAKE	TIME OF SURVEY	% COVERAGE	km SURVEYED	COMMENTS	CROCS/ km	ADJUSTED CROCS/km
Morogoro Region	Upper Rufiji	1200-1233	70	101	Overcast with light rain prior to survey	2.23	2.89
Selous Game Reserve	Lower Rufiji	1055-1110 1640-1650	70 70	50 50	Overcast with light rain prior to survey	7.46 8.32	9.70 10.82
	Rufiji Lakes	1115-1150	80	55	Overcast with light rain prior to survey	7.05	9.17
	Ruaha	1335-1405 1600-1635	60 60	104 104	Overcast with light rain prior to survey/ Heavy rain	1.12 0.91	1.57 1.27
	Kilombero	1234-1315	70	100	Overcast with light rain prior to survey	2.20	2.86
Iringa Region Ruaha National Park	Lake Mtera	0830-0840		35	Extensive reedbeds	0.00	0.00
	Ruaha	0840-0909 0922-0950	60 70	95 75	Cloudless day Cloudless day	0.11 3.59	0.15 4.67
Rukwa region	Rungwa	1125-1210	60	165	Moderate cloud cover	0.33	0.46
	Kavuu	1434-1454	50	94	Moderate cloud cover	0.02	0.03
	Lake Rukwa	1335-1415	20	80	Moderate cloud cover	0.04	0.07
	Lake Chada	1454-1505	50	15	Moderate cloud cover	7.49	11.21
Tabora/Kigoma Region	Ugalla	0850-1028	60	300	Moderate cloud cover	0.48	0.67
	U. Malagarasi	1242-1335	60	175	Moderate cloud cover	0.50	0.70
	L. Malagarasi	1030-1107	40	95	Moderate cloud cover	0.05	0.08
Mwanza Region	Lake Victoria						
Lake Victoria	Rubondo Island	1055-1140	70	140	100 % cloud	0.48	0.62
Mara Region	Grumeti/Orangi	1545-1630	50	107	Overcast	0.55	0.83
Serengeti National Park	Seronera	1630-1645	50	30	Overcast	0.26	0.39
	Mara	0940-1006	70	60	Overcast with drizzle	0.68	0.88
Kilimanjaro/ Tanga Region	Upper Pangani	1230-1305	10	125	Light cloud	0.09	0.17
	Lower Pangani	1602-1705	50	230	Light cloud	0.01	0.02
	Lake Nyumba na Mungu	1305-1315		25	Light cloud	0.00	0.00

Rufiji River (Figure 2)

The Rufiji was divided into two strata. The Upper Rufiji is a wide sandy river with moderate crocodile densities between 2.1 and 4.94 crocodiles/km (mean = 2.89; Table 1). In 1963 densities were estimated to be between 1.95 and 3.51 crocodiles/km (Graham and Bell, 1963) while Hutton and Katalihwa (1988) estimated a density of 0.98 crocodiles/km while the river was in flood.

The lower Rufiji (within the Selous) is a very wide sandy river which flows into a palm swamp. The main channels have extensive sandbanks but the river changed its course in 1980.The new channels are generally narrower and some have mud banks. Estimates of crocodile densities are high and range from 0.91 to 34.78 crocodiles/km (mean = 10.82; Table 1).

Figure 2: Selous crocodile survey - 1990



Rufiji Lakes (Figure 2)

North of the main Rufiji channel are five lakes one of which is fed by thermal springs. Travelling from west to east the lakes are named Tagalalla, Manze, Nzerakera, Siwando and Mzizima respectively. Some of these shallow lakes are connected to the river allowing movement of crocodiles. Density estimates were high ranging from 2.99 crocodiles/km in Lake Mzizima to 18.07 crocodiles/km in Lake Tagalalla.

Ruaha River (Figure 2)

The Ruaha river within the Selous Game Reserve has two strata. The upstream end flows over rock bars while the central section is wide and sandy. Before entering the Rufiji it again flows over rocks. Crocodile densities were moderate - 1.57 crocodiles/km - with a range of between 0.5 to 2.74. This is comparable with previous counts (1.56 crocodiles/km - Hutton and Katalihwa, 1988 and 1.77 crocodiles/km - Games and Severre, 1989; Table 3).

Kilombero River (Figure 2)

The Kilombero river is fed by the Kilombero swamp (5 500 km^2 approx) and is contained within a single channel for most of its course within the Selous. This channel is interspersed with rock bars and has mud banks. The upper section (Ifakara bridge to Bomalanga meanders through a broad floodplain with extensive sandbanks. Crocodile densities ranged between 1.04 and 8.88 crocodiles/km (mean 2.86; Table 2) within the game reserve but dropped to 0.34 crocodiles/km once outside the houndary.

1989 survey

The density (crocodiles\km) for the 1989 survey are presented in Figure 3 as some areas were not covered in the present survey.

Figure 3: Selous crocodile survey - 1989

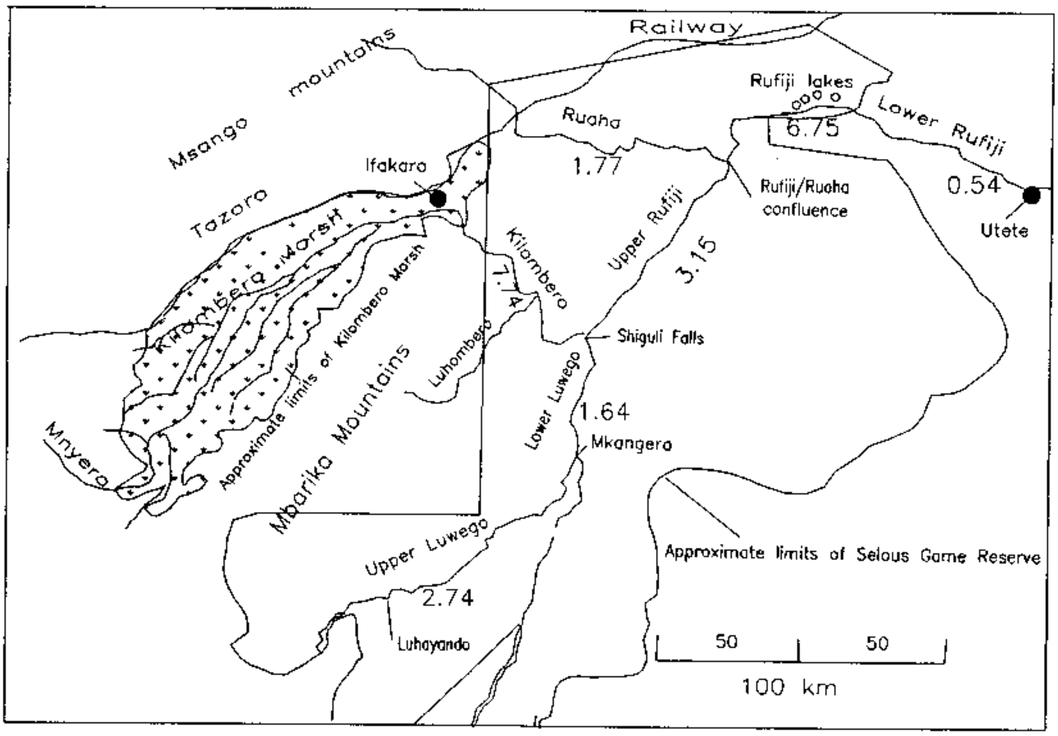


Table 3. **Summary of crocodile densities in the Selous Game Reserve as estimated by aerial survey.**

	Graham/Bell 1963	Hutton/Katalihwa 1988	Games/Severre 1989	Games/Severre 1990
Upper Rufiji	1.95 - 3.51	0.98	3.15	2.89
Lower Rufiji			6.75	11.83
Rufiji Lakes			3.35	8.46
Ruaha		1.56	1.77	1.57
Kilombero		0.28	7.74	2.86
Upper Luwego			2.74	
Lower Luwego		0.33	1.64	

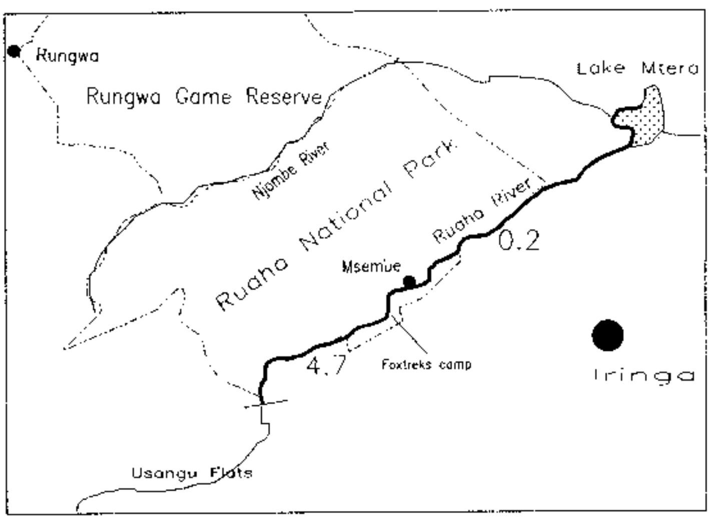
Iringa Region - Ruaha National Park

Ruaha River (Figure 4)

This river can be divided into two strata. Upstream of the park headquarters at Msembe (Figure 4) the river is moderately wide flowing over rocks. There were occasional deep pools. Downstream of Msembe it is a very wide and sandy meandering river. The water is very shallow and there are few pools. Crocodile densities were medium in the upstream section (4.67 crocodiles/km) and low in the downstream section (0.15 crocodiles/km).

Most of the crocodiles were congregated in large pools upstream from Msembe (31.72 crocodiles/km) and once past the Foxtreks camp (Figure 4) densities were low (0.86 crocodiles/km). There was a noticeable decrease once the park boundary was reached.

Figure 4: Upper Ruaha crocodile survey - 1990



Lake Mtera (Figure 4)

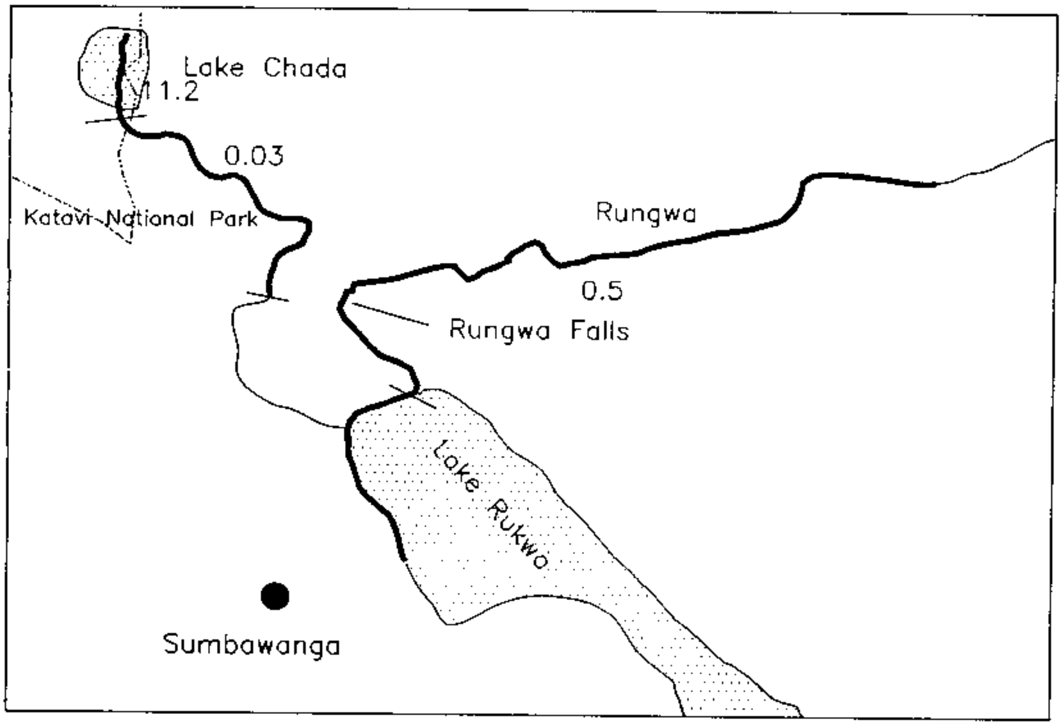
This is a new lake which supports a high density of fishermen. No crocodiles were seen during a survey of approximately 35 km of the western end.

Rukwa Region - Katavi Plains National Park

Lake Rukwa (Figure 5)

The level of Lake Rukwa has recently risen and this was evidenced by drowned trees along the shoreline. Channels of the Rungwa and Kavuu rivers were located by the drowned tree fringe which extended out into the lake. Part of the western and northern shores were surveyed but only three crocodiles were seen. Lake Rukwa has the reputation of supporting a large crocodile population (e.g. Hirji, 1986) and more than 17 000 crocodiles are thought to have been shot here (Hutton and Katalihwa, 1988). Lakes are notoriously difficult to survey and a survey of Cahora Bassa in Mozambique in 1987 showed very few crocodiles in an area that was later to support a cropping exercise of 3 000 animals (Games, Zohlo and Chande, 1988). Further investigation of Lake Rukwa is clearly needed.

Figure 5: Lake Rukwa, Lake Chada, Kavuu and Rungwa crocodile surveys - 1990



Rungwa River (Figure 5)

This river has three distinct strata. Between Lake Rukwa and the Rungwa falls it is a wide meandering sandy river. For approximately 65 km upstream of Rungwa falls it is a moderately wide river flowing over sand and rock bars. The banks are lightly wooded. Upstream of this point it becomes a very narrow and sinuous channel with an extensive tree overhang, which made sighting crocodiles difficult. There was a low overall crocodile density (0.46 crocodiles/km) with lower densities being found in the upstream strata (0.21 crocodiles/km). The downstream strata between the falls and the constricted channel had a higher density (0.87 crocodiles/km).

Kavuu River (Figure 5)

This is a very sinuous and small river with a moderate vegetation overhang which is fed from Lake Chada and the surrounding floodplains. There were people and livestock all the way from the Katavi National Park boundary to Lake Rukwa but there was also a surprising amount of wildlife. Crocodile density was low and estimated to be 0.03 crocodiles/km.

Lake Chada (Figure 5)

Lake Chada is a large floodplain area within the Katavi Plains National Park. When surveyed there were an estimated 15 km of channels and pools which were full of hippopotami. Crocodile density was estimated to be 11.21 crocodiles/km.

Tabora/Kigoma Region - Ugalla Game Reserve

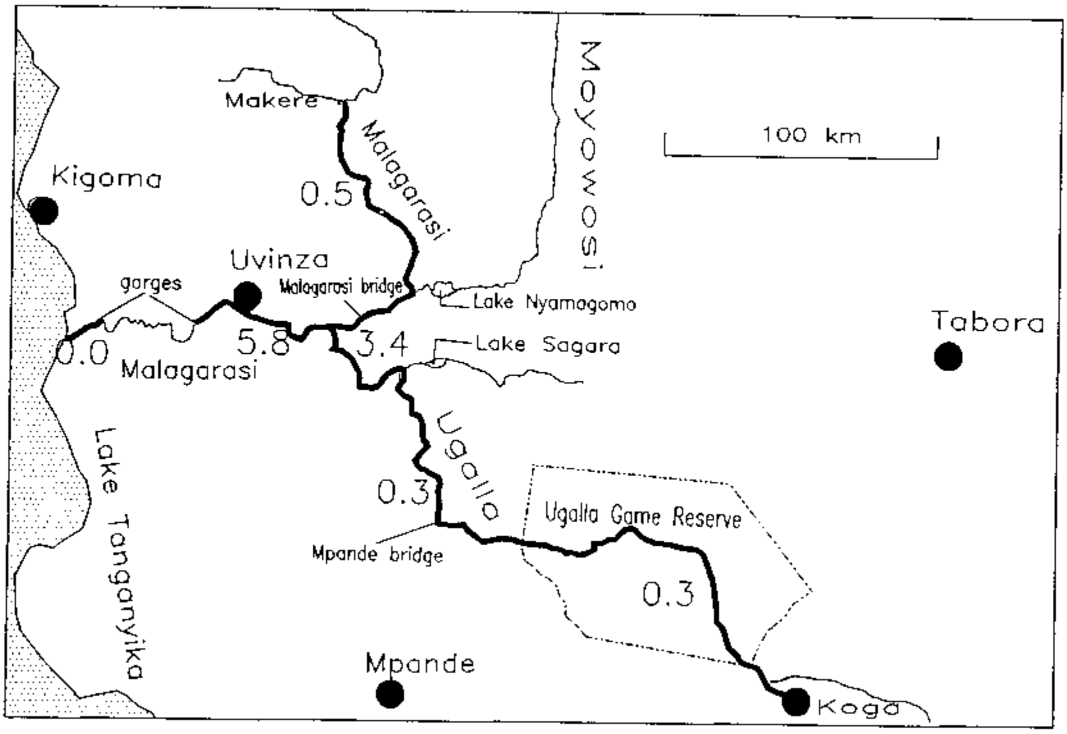
Ugalla River (Figure 6)

The upstream section of this river is a series of deep pools. These eventually coalesce into a single channel flowing through a broad floodplain. After reaching the Mpande railway bridge the river flows into a series of swamp areas which culminate near Lake Sagara. Crocodile densities in these two sections was estimated to he 0.31 crocodiles/km. Downstream of Lake Sagara it flows through a single channel before joining the Malagarasi. Crocodile densities were estimated to be 2.38 crocodiles/km in this section. The average density for the Ugalla was estimated to be 0.67 crocodiles/km.

Malagarasi River (Figure 6)

The Malagarasi river can be divided into five strata, two of which were not surveyed. In the upstream section it is confined to a single meandering channel. Crocodile densities were initially low (0.17 crocodiles/km) but increased as it approached the papyrus swamp (1.16 crocodiles/km) near Lake Nyamagomo. The papyrus swamp was not surveyed. On emerging from the swamp it flows through a single steep-sided channel to the Ugalla junction. The average estimated density here was low (0.84 crocodiles/km) but most of these were found in a very short section near the Ugalla junction where the density was estimated to be 5.75 crocodiles/km. Between the Ugalla junction and Uvinza the river flowed over rocks and through a wide braided channel system. Crocodile densities were low (0.18 crocodiles/km) in this section. Shortly after Uvinza the river flows through a series of spectacular gorges which were not surveyed. No crocodiles were counted in the final 30 km of river between the end of the gorges and the delta on Lake Tanganyika. The whole of this section is densely populated with fishermen and subsistence farmers. The average density for the Malagarasi was 0.39 crocodiles/km.

Figure 6: Ugalla and Malagarasi crocodile surveys - 1990



Mwanza Region - Rubondo National Park

Rubondo Island - Rubondo National Park

The entire island is a national park and is situated a few kilometers offshore. The island is covered with tropical forest to the narrow beaches. Crocodile densities were low (0.62 crocodiles/km) but a masking fringe of Mimosa made crocodile spotting difficult in some areas. The highest densities were found on the south-eastern shoreline (0.95 crocodiles/km).

Lake Victoria

Although not formally surveyed the flight path was over the Speke Gulf shoreline. The whole area is densely populated and cultivation extends to the lake. It is doubtful that there are many crocodiles along this shoreline.

Mara Region Serengeti National Park

Grumeti/Orangi River (Figure 7)

This is a narrow, tightly meandering river with a thick tree fringe and overhang. Overall crocodile densities were low (0.83 crocodiles/km) but most of these were contained within a short section near the Kirawira research station where densities were estimated to be 8.75 crocodiles/km. Most of the sections surveyed were within the Serengeti National Park.

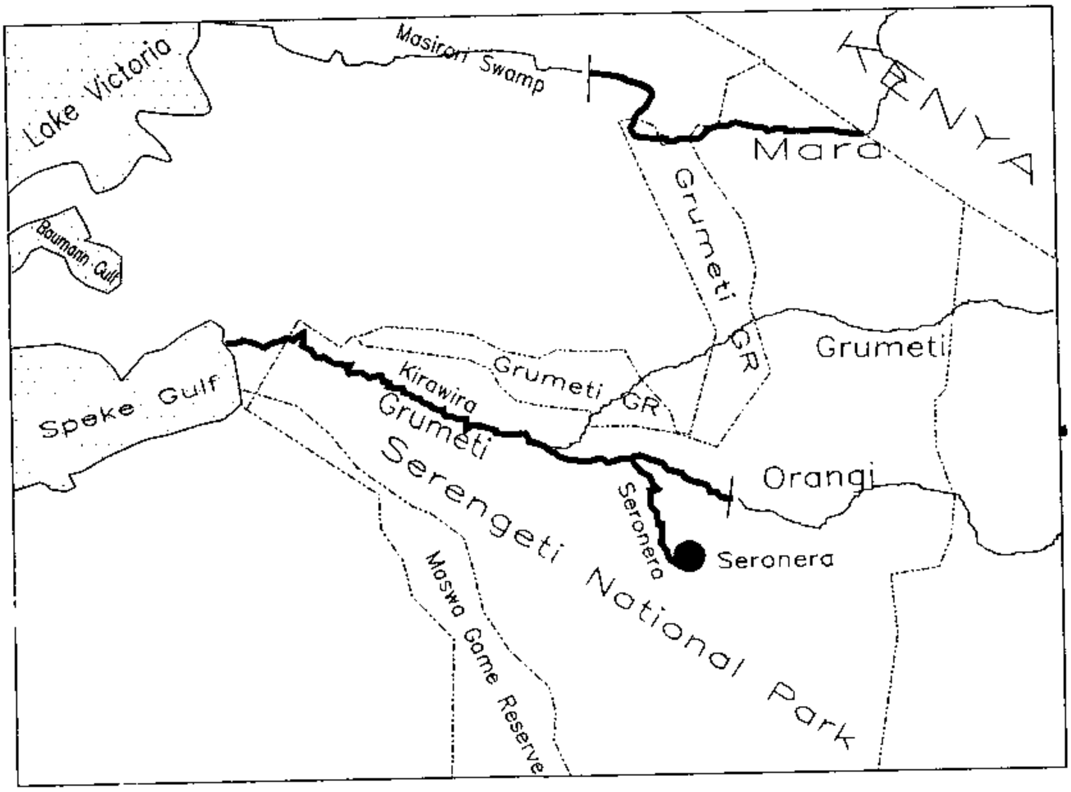
Seronera River (Figure 7)

This is a short and very narrow tributary of the Orangi river which had a low estimated density of crocodiles (0.39 crocodiles/km). All of the river was within the Serengeti National Park.

Mara River (Figure 7)

This is a meandering, moderately wide river with part of its course within the Serengeti National Park. There were many rock and sand bars. Within the National Park the average density was estimated to be 0.88 crocodiles/km but was as high as 1.37 crocodiles/km near the Kenyan border. No crocodiles were seen outside the National Park.

Figure 7: Serengeti crocodile survey - 1990



Kilimanjaro/Tanga Region

Pangani River

This is a very sinuous river with an extensive tree and reed overhang. There are very few sandbanks and the river can be divided into two strata. The upstream section flows through an extensive floodplain which was still holding water. Crocodile density was estimated at 0.17 crocodiles/km. The downstream section is similar to the upstream section but there are no swamp areas. Density was estimated to be 0.02 crocodiles/km.

Lake Nyumba ya Mungu

This is a new lake which, like Lake Mtera, is heavily settled with fishermen. No crocodiles were seen.

OBSERVER CORRECTION FACTORS

On one occasion it was possible to carry out a tandem count which allows some estimation of observer error. The correction factor for observer 1 (Games) was estimated to be 1.8 and for observer 2 (Liyimo) it was estimated to be 4.2. This means that any sightings by those observers should be multiplied by these correction factors if the aim is to speculate about a possible total population estimate.

SPOTLIGHT COUNTS AND CORRECTION FACTORS

Night counts were carried out in the Kilombero and Rufiji rivers and in Lake Tagalalla (Tables 4, 5 and 6).

In the Bomalanga area of the Kilombero river both banks were counted for 6 km. This channel was surveyed from the air two weeks later. The night count showed 132 crocodiles while the aerial survey located 41 crocodiles. This means that the correction factor is 3.22. It is doubtful that this can be extrapolated to the entire length of the Kilombero as much of the channel flowing towards Shiguli falls is very different in character (the Bomalanga area is a myriad of channels flowing through reeded sandbanks while the rest of the river flows down a single channel contained within steep mud-banks). This section is probably more similar to sections of the lower Rufiji.

Two sections of the lower Rufiji were surveyed for crocodiles at night. In a 12 km stretch of the river from the Kidai ferry to opposite Lake Tagalalla 304 crocodiles were counted. During this survey only the northern bank was surveyed. It was estimated from 1:50 000 (1966) maps that there were 32 km of shoreline between these two points. A correction of 2.6 would yield an estimate of 790 crocodiles. A total of 195 crocodiles were counted from the air in this section which would indicate a correction factor for the aerial count of 4.1. A similar correction is calculated for the section of river from Rufiji river camp (reserve boundary) to Lake Nzerakera. The night count (both banks) revealed 168 crocodiles while 39 animals were counted from the air giving a correction factor of 4.3.

The entire shoreline of Lake Tagalalla was surveyed at night and 816 crocodiles were counted. An aerial survey showed 181 animals which is a correction factor of 4.5.

Table 4. Details of night counts in the Kilombero river, Tanzania, 1990 (CV = 19%).

Section	Length (km)	Nos. Crocs	Crocs/km	d^2
Camp-Junction	2	36	18	324
Junction-Tree	1.5	36	24	576
Tree-Single Channel	2	27	13.5	182.25
Channel-Game camp	2	15	7.5	56.25
Game camp-end	1.5	18	12	144
Total	9	132	75	1282.25

Table 5. Details of night count - Lake Tagalalla (CV = 2.19%).

Section	Length (km)	Nos. Crocs	Crocs/km	d^2
Camp-Entrance	7	435	62.12	3861.734
Entrance-Camp	6	381	63.5	4032.250
Total	13	816	125.62	7893.984

Table 6. Details of night counts on the Rufiji river

Section	Length (km)	Nos. Crocs	Crocs/km
Kidai-Tagallala	9	304	33.77
Nzerakera-Rufiji	12	168	16.6

The channel lengths and lake-shores surveyed during the aerial count in the lower Rufiji total 105 km. It is estimated that 30 - 50 % were not covered, especially where the river has forged a new course. The lower estimate would put the shoreline and channels at 135 km. Speculation on the total amount of crocodiles in the lower Rufiji alone is as follows:

Total number of crocodiles seen from the air	804
Channel correction (1.3)	1 045
Night count correction (4.2)	4 390

The numbers of crocodiles during a night count can be as little as 10 % of the total population but is usually between 30 and 60 % (Hutton and Woolhouse, 1989). This would give upper and lower estimates of 7 024 and 5 707 respectively.

GENERAL

There were a number of problems associated with this survey. All of these tend to indicate that the count were underestimates and they are detailed below.

Observers, although proficient and experienced on large mammal counts, were new and inexperienced in counting crocodiles. The correction factor for the one observer tested during a tandem count was 4.1.

Many of the rivers were surveyed during the middle of the day. This was because of the long distances involved, both transit and survey. It is known that many crocodiles will return to the water during the middle of the day (e.g. Cott, 1961) where they are more difficult to spot from an aeroplane.

The tightly meandering nature of many of the rivers surveyed meant that the percentage covered was less than ideal. This possibly leads to under-estimation which I have attempted to correct (albeit subjectively) by estimating a percent coverage for each river. Densely wooded or reeded banks with overhanging trees also obscured the view of some of the rivers.

Owing to several delays this survey continued into the first of the "short rains". This meant that some surveys were carried out either while it was raining or under very overcast conditions. Although there is no data it is considered that crocodiles are more difficult to spot under these conditions.

If any survey of crocodile densities is to be used for monitoring trends in a population then it should have some measure of precision. The co-efficient of variation (CV), which is the standard error expressed as a percentage of the count, is a common method (Graham, 1988). In crocodile counts estimation of the CV can be achieved in two ways but it should be stressed that these CVs are not comparable between methods.

1). The double counting or tandem method is the simplest and requires that one observer record three categories of sightings - crocodiles seen by himself and not the other observer, crocodiles seen by the other observer but not by himself and crocodiles seen by both observers (Magnusson, Caughley and Grigg, 1978; Graham, 1988). In practice this means that one observer must point out every crocodile seen to the observer/recorder or both observers independently record sightings on maps.

2). The second method is to divide the river into sub-sections and use these as sample counts to estimate the CV (Graham, 1988).

Sample counting is problematic as some rivers are lacking noticeable features to form the sample boundaries and it would be very difficult to replicate these in subsequent surveys. The CV's obtained by this method become very large if there is uneven distribution of crocodiles along the river. Tandem counting has the advantage that observer errors can be estimated and a correction factor calculated. It allows some estimation of variance between observers and the CVs are used to decide if counts are precise enough to indicate trends.

Density estimates were very variable and would be a pointless exercise to take a mean figure and extrapolate to the whole country. One fact which emerges from this survey is that densities are considerable reduced outside protected areas and this was noted for a number of rivers (e.g. Kavuu/Lake Chada, Rufiji, Kilombero, Ruaha, Mara, Grumeti). This indicates that protection is having a beneficial effect, at least on the crocodile population.

The low densities (often 0.00) found outside the protected areas also indicates that crocodile populations will continue to decline when in competition with humans. One possible way to stop this decline is to utilize these populations for ranching and farming operations. Lake Rukwa is one such population that may benefit from such a management policy.

SPECULATION ON EGG PRODUCTION FROM THE LOWER RUFIJI WITHIN THE SELOUS GAME RESERVE

The number of breeding females within a population is related to the total size of that population and this fact is often used to estimate population size from counts of nests (Chabreck, 1963; Graham, 1988). Having speculated on the total size of the population in the lower Rufiji it is then possible to speculate on egg production. The number of crocodiles less than 1.2 m total length is estimated to be approximately 50 % of a Nile crocodile population. The number of breeding females within an average Nile crocodile population is estimated to be ¼ of those crocodiles longer than 1.2 m total length (Games, 1990). Clutch sizes vary greatly but the average for Lake Kariba on the Zambezi river is 45 eggs. If the above figures are taken to be representative of the Selous population then egg production for the lower Rufiji within the reserve can be estimated by:

Lower estimate of crocodile numbers	5 707
Numbers longer than 1.2 m total length	2 854
Number of breeding females	696
Lower limit for average clutch size	30
Estimated egg production	20 880

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ANNEX

THE POSITION OF TANZANIA WITH REGARD TO THE UTILIZATION OF WILD CROCODILES AND CROCODILE RANCHING OF THE NILE CROCODILE

ABSTRACT/TRANSCRIPT

2.1 Policy for Crocodile Management

Tanzanias crocodile policy states that crocodiles shall be conserved as stipulated by local conservation laws and CITES guidelines for conservation

It is intended that all crocodilian modes of utilization benefit local communities. This approach serves to enhance efforts directed to curb illegal trade and dealings in crocodilian parts and derivatives

2.2 The Management Plan for the Nile crocodile

The management plan is tailored to accommodate protection and utilization of the Nile crocodile

3.1 The Status of the Nile Crocodile in the Wild

3.1.1 Distribution

Tanzania bas an estimated 4000 km or river and 2800 km of lake shoreline. Crocodiles are known to occur in many of these systems.

3.1.2 Population Status

Tello (1985) estimated a total population of 74 000 crocodiles in Tanzania and Hirji (1986) estimated a population of 10 000 in Lake Rukwa alone. Aerial surveys have been carried out in recent years (Hutton and Katalihwa, 1988; Games and Severre, 1989; Games and Severre, 1990) but these were aimed at density estimates rather than total population estimates.

3.1.3 Habitat

Crocodiles occur in stable habitats and especially in protected areas where human activities are limited.

3.1.4 Legal Trade

Local trade in crocodile parts does not exist in Tanzania.

Reports prior to 1961 indicate that there was a thriving international trade in skins (Game Division reports, 1961). During the early 1980's all crocodile skins entering the market were closely monitored. Today wildlife legislation and CITES regulations have put trade in crocodile products under levels of utilization that are not detrimental to the wild populations.

3.1.5 Illegal Trade

Anti-poaching efforts have been strengthened so that wildlife will continue to exist and be utilized in accordance with the paradigm of sustainable development. It is on account of this that illegal trade of crocodile parts or derivatives has been stamped out.

3.1.6 Crocodiles as Problem Animals

There is no doubt that crocodiles are a threat to humans and livestock in Tanzania. It is likely that protection and trade controls have possibly resulted in some local populations of crocodiles increasing and consequently posing an increased threat to people and animals.

An estimated 60 people lose their lives to crocodiles annually as well a large number of goats, sheep and cattle. Known areas of conflict are the Pangani river (Tanga region), the Ruvuma river (Mtwara region), the Mara and Grumeti rivers (Mara region) and Lake Rukwa (Rukwa region).

Tanzania would like to invite members of the Crocodile Specialist Group to visit, witness and advise on the matter of allowing continued harvests from the wild population as a means of control.

5.0 Conclusion

It is imperative to recognise the following:

- that the growing crocodile population continues to be a threat to human life and livestock
- Tanzania has strengthened law enforcement efforts at enormous costs which must be realised through trade in species whose populations are not endangered. The crocodile deserves no exception
- that there is a need for members of the Crocodile Specialist Group to visit Tanzania and witness threats posed by crocodiles to humans
- Tanzania needs support in its efforts to downlist the wild crocodile population
- crocodile ranching will continue as described in the proposal presented at the Eighth Conference of the parties to CITES.

STANDARDIZED GRADING & WORLD WIDE TAGGING: IMPLICATIONS FOR TRADE

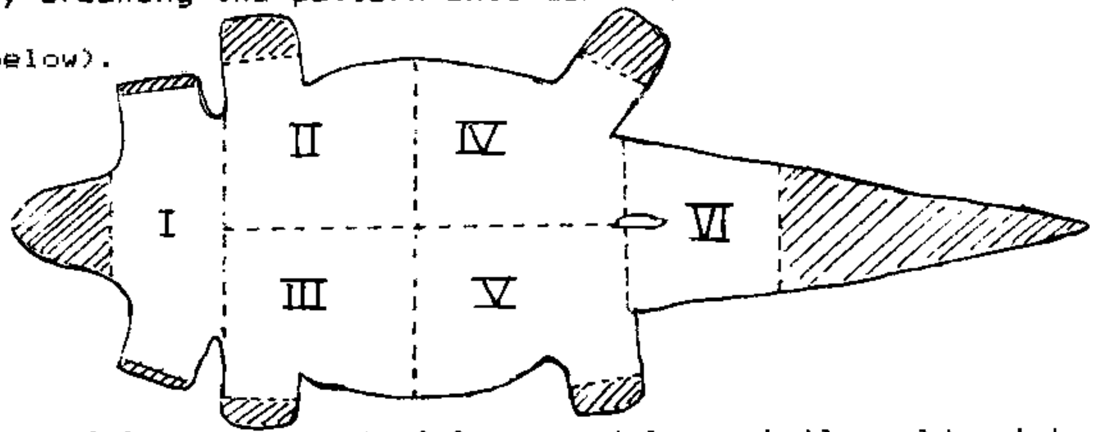
DAVID B. HAIRE, III

In order to secure credibility and maintain strength and legitimacy in any organization is to establish a mission statement, act responsibly, and welcome accountability. The IUCN/CSG is very clear in its mission statement of crocodilian conservation. While recognizing the right of the industry to exist and the role it plays in conservation itself. Responsibility and accountability goes without saying. But there are, and will always be opportunities and needs to improve. Standardized international grading of crocodilian and world wide tagging of all marketable crocodilian hides are imperative in building and maintaining strength and credibility within the organization and market.

In initiating my idea of a standardized grading system, I am not suggesting to discount, rewrite, or remove such efforts of the Japan Reptile Association or similar works of those like King & Wilson. Who have published excellent and concise descriptions in explaining correct grading procedures.

There is a need for a simple operable grading standard that would be internationally understood. One which would be conducive to effectively placing market value to crocodilian hides without requiring lengthy descriptions or complex evaluations.

For years, classic skins have been synonymous with high fashion expensive handbags made primarily from belly/flank areas. This section of the skin has historically been the area considered in grading and ascertaining value. But with increased manufacturing of high fashion belts and small leather goods, along with the need for quality gussetts and bottom for bags and cases, the need arises to include more than belly areas in grading crocodilians and assessing value. As with the JRA standard I, too, agree that the throat area and upper 1/3 of the tail should be considered in the grading of crocodilian's skins. Grading could be easily evaluated by breaking the pattern into six sections. (As shown below).



Gular area, end of legs, and lower tail would not be considered for grading. If missing completely they would indicate a defect in the section adjacent to them.

Grade and value would be determined by the amount of quadrants which contain defects.

Base price would be determined by the market and would apply to skins of good hide substance and normal width to length proportions, without possessing any marked degree of putrefication and scale slip. These conditions when present, would reduce base price from 25% to 100%. While any other defects would further discount the hide value.

This system could be modified to effectively grade whole caiman skins. Only the areas of commercial value within the quadrents would be considered. Large caimans which posses heavy ossification, only flank, leg, cheeks and chin areas should be considered. While small caiman of such species as Fuscus which can be de-ossified during tanning should be graded as classics are. While osteoderms are characteristic in caiman and some hard belly species of classic skins such as the African crocodile cataphracis and should not be considered as denoting damage. They should do so when considerable presence in any of the quadrents of the large soft belly's i.e. large American Alligators and Nile Crocodiles.

Size would be recorded in either linear inches from chin to tail or in width by centimeters at 1/3 down the belly at about the fifth bone.

Skins should be pulled and released to measure, but not overly stretched or held to measurement.

Values for fresh skins with good hide substance would be as follows:

Skins completely free of defects - Full Base Price

Skins with one or two quadrants
containing defects - 75% Base Price

Skins with extreme damage in two
quadrants or three quadrants
containing defects - 50% Base Price

Skins containing extreme damage in
three quadrants or four or more
quadrants containing defects - 25% Base Price
to Complete
Rejection

Defect would be anything which occurs within the pattern denoting damage, natural and man-made or any marked disruption of the normal pattern-i.e. deformities, irregular umbilical, etc.

If required an agent could provide further descriptive information to explain corresponding grade of hide offered by denoting the quadrants where defects occur.

TAG NO.	SIZE (CM)	GRADE	HEAD I	BODY II	BODY III	BODY IV	BODY V	TAIL VI
92001832	34	I						
92001833	32	II		X				
92001834	33	III	X			X	X	
92001835	31	II			X			X
92001836	30	I						

This information could be supplied if necessary for a customer to understand the value of the hides - although designation of grade should be adequate to access market value.

Again, this is only my assertion to simplify the means to convey the value of classic skins.
By no means does it attempt to approach the efforts of qualified grading standards of previous systems. But if grading can be done simply and effectively by the average person engaged in the business, then it will be more likely to be employed by the industry as a mandatory standard procedure.

Universal tagging of all marketed crocodilian skins will not only legitimize the market, but will aide in giving identification of graded skins by providing a CITES tag number with a corresponding grade.

Legitimizing the trade in as much as by allowing untagged groups of crocodilian hides found in warehouses, tanneries, and manufacturing facilities by inspectors to to be easily recognized as illegal shipments. Records included with shipment showing corresponding tag amounts equaling total amount of skins would decrease chances for extra unlisted skins to be included. This way false harvest and export numbers would be lessened.

Tags should be CITES approved and similar in material, mechanics, shape and order of marking. So they will be easily attached, impossible to remove without breaking and easily read as to species, country of origin, and individual CITES tag number.

Some tag designs are such that they are easily detached after affixing them to the skin. Also, I doubt that significant benefit is realized in the manufacturing of tags within country of species origin. Since the tag represents legitimacy in the industry, it is imperative that all tags manufactured be capable of withstanding tanning and finishing procedures while maintaining its function of identification.

Tagging represents the check in the industry. In order to represent the balance there needs to be a central location for receiving spent tags from finished skins, after being cut for manufacturing of products. Any crust or finished skin left in inventory yearly should be included in an annual CITIES report sent to the same central collecting center as spent tags. This would enable monitoring of skins through the industry from raw to finished product.

Some exceptions and problems will occur, but this will tend to further legitimize the trade - making it more responsible.

Standardized tagging and grading will add international responsibility, accountability, and understanding to the crocodilian skin trade. But the industry needs to continue to pursue positive ethical practices which will bring attention to those who do not comply in the ethical, responsible, conservating trade which holds first and foremost the sustainability of the resource.

Many times I have been confused in the past as to how the base prices have been set for crocodilians from year to year. Generally, supply and demand are the key factors in establishing market prices. But with fluctuations occurring yearly, too extreme highs and lows, implies other factors exist in determining market price of this limited product.

In speculation, I feel, the following assumptions give some explanation for the irregularities in the trade.

(1) If one can acquire sources for illegal raw material at attractive prices, then by pushing the price of legally taken skins upwards in competitive buying, they not only protect their investment but make it more profitable. Even if prices are pushed for other species, due to similarities of species alone will increase the value of initial illegal investment.

(2) Caiman hunters in Columbia receiving the

equivalent to six dollars U.S. for skins to be marketed from 30 to 60 dollars U.S. by businessmen who can secure tags and export papers, have no less incentive when selling at the same levels to the black market which are able to sell at levels considerably less than the middle man selling legal ones.

(3) When observing so many low quality skins being produced from damaged and putrefied raw material it would be unlikely that the buyer would show a profit unless a good portion of the material was acquired at below market prices illegally.

(4) Under-cutting legal market competitors could easily be achieved by purchasing a percentage of crocodilian production from illegal sources.

Buyer #1 buys 20,000 pcs. @ $60/hide legal
average cost $60/hide

Buyer #2 buys 15,000 pcs. @ $60/hide legal
10,000 pcs. @ $20/hide illegal
average cost $44/hide

(Even with 10% complete fall-out from putrefication due to poor handing)
average cost <$46/hide

(5) Price and demand could be artificially inflated for legal crocodilians when needed to front and show false legitimacy for tanneries utilizing

illegal skins in their productions.

We have to rely on the market and industry to maintain the credibility of itself. For without demand there would be no incentive to harvest illegally taken skins. Once a sincere acquaintance from Guatemala at the last CSG meeting told me that the poor in his country will produce what they are paid to. In fact, these people have little concern with the conservation of anything but the immediate need for their family's existence. Until theirs and others need for basic quality of life is sustainable no other forms of conservation are relevant.

In closing, there are no quick fixes for any conservation issues facing the world today, especially those things that increase human wealth. But persistence in further education, simplified functionability, responsibility, and accountability, will the conservation and consumptive use of crocodilian and all natural resources become synonymous and sustainable.

It is essential for those in the industry to secure checkpoints in the market insuring legitimacy of the industry and protecting their investment in the legal trade. Furthermore, while maintaining the mission statement of the IUCN/CSG we should always strive to find some common ground to agree on when differences between members arise.

This will insure that our efforts are not destroyed from within. And our strength will be in our diversity and unification.

CROCODILE SKIN INDUSTRY IN ETHIOPIA: STATUS AND CONSERVATION PROGNOSIS

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Background

The modern crocodile skin industry in Ethiopia dates from 1983 when an agreement was signed by the United Nations Food and Agriculture Organization (FAO) with the Ethiopian Ministry of Agriculture to provide assistance with the development of a commercial venture to ranch Nile crocodiles (Crocodylus niloticus). Construction of a ranch at Arba Minch, located between Lakes Abaya and Chamo in southwestern Ethiopia was begun in mid-1984 and the first wild crocodile stocks were collected in 1985 (Table 1). FAO project input has included capital equipment outlays, external training for veterinary and wildlife staff, and consultant services to evaluate progress. Arba Minch Crocodile Farm (AMCF) is administered by the Ethiopian Wildlife Conservation Organization (EWCO) and was designed to provide a source of foreign exchange through the development of an viable industry that would also

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afford employment for native citizenry and benefit the local economy.

Table 1. Wild crocodile stocks used for Arba Minch Crocodile Farm at Arba Minch, Ethiopia, 1985-1992.

	1985	1986	1987	1988	1989	1990	1991	1992
No. of nests								
identified	4	87	206	132	204	292	74[a]	0
opened	2	72	126	76	204	225	63	0
% utilized	50	83	61	58	100	77	84	0
No. of hatchlings								
collected	181	2713	2500	2587	6000	7140	2121	0
1 yr survival rate (%)	50	5	88	87	71	29	--[b]	0

[a] - Reduced count due to lack of space on farm.
[b] - Figure unavailable.

Performance Evaluation

Ethiopia became a signatory to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1989 and a quota system for Ethiopian crocodile products was approved at the 7th and 11th meetings of the Parties (Table 2).

Table 2. Quotas for Ethiopian crocodiles approved by CITES.

Year	Ranch skins	Hatchlings live	Hunting trophies	Adults live	Curios from ranching	Total
1990	6500	2500	50	20	300	9370
1991	6000	2500	50	20	300	8870
1992	4500	2500	50	20	300	7370
1993	2500	1000	30	0	300	3830
1994	2000	1000	30	0	300	3330
1995	4000	1000	30	0	300	5330

A total of 17,000 ranched skins was approved for export during 1990-1992. To date the number of ranched skins produced has fallen far short of that goal. The first harvest at AMCF occurred in 1990 when 2,074 crocodile skins were shipped to Japan. No exports took place in 1991 as a planned harvest was suspended due to the marked drop in international prices for raw salted crocodilian skins. The lack of harvest contributed to a space problem at AMCF and the ranch is now overcrowded. Consequently, hatchling collection was reduced in 1991 and ceased altogether in 1992. The current stock is about 10,000 animals, of which 4,000 three-to-four year old individuals (30-40 cm belly width) are scheduled for harvest.

In terms of husbandry, performance has left much to be desired. Survivorship of hatchling stock (21,121) during 1985-1990 was only 52% at one year of age. Such mortality is unacceptable biologically and economically in a commercial ranching operation. Growth rates of stock at AMCF have been well below that demonstrated for crocodilians elsewhere where better husbandry is used. Despite these drawbacks, AMCF has produced a modest profit to date (Table 3), although significant improvement could be realized with better management.

Table 3. Budget summary for Arba Minch Crocodile Farm, 1986-1992 (modified from Allen-Rowlandson, 1991). Prices are in Ethiopian birr (ETB2.05 = US$1.00).

Year	Expenses	Income	Balance
1986-87	58913.22	0.00	- 58913.22
1987-88	163328.50	0.00	-163328.50
1988-89	190443.93	0.00	-190443.93
1989-90	307120.10	983016.00	675895.90
1990-91	323120.47	0.00	-352775.43
1991-92	387745.00**	1435000.00**	1047255.00
Totals	1430671.20	2418016.00	957689.82

** - predicted values.

Nb. - Projected 1992 income assumes sale of 4000 skins at $5.00 cm belly width with an average skin size of 35 cm.

Future Outlook

From an economic standpoint, AMCF is at a crossroads. Although administered by EWCO, EWCO is severely constrained in its charge in that it derives no revenues from the management of AMCF. Profits are returned to the central national treasury, thus depriving EWCO of incentive for sound fiscal, husbandry, or labor management. Funds and manpower from EWCO are sometimes diverted from other areas of responsibility to keep the project operational. AMCF would almost assuredly be better managed by a private concern or corporation that would provide a more predictable operational cash flow and the professional expertise needed to guide labor and commercial husbandry. Such a recommendation in the past might have been contrary to the previous political interests. However, prospects might perhaps be better now for such a conversion since the installation of the Transitional Government of Ethiopia.

In terms of crocodile conservation, AMCF has had a negligible impact. Restocking of hatchlings to the wild has occurred only when space was unavailable to house them within AMCF. Some benefit to crocodile nests against depredation was afforded during previous years when surveys were conducted and nests guarded and monitored for egg collection (Hailu, 1990). However, this practice is now discontinued and no surveys of wild crocodile populations have been made since 1987. Trophy hunting for crocodiles is still of no importance within Ethiopia and will probably remain so for the near future. The monitoring of crocodile curios is problematical at best. While the quota for Ethiopia is very small, the trade in curios (and other wildlife products) remains in the effective hands of the taxidermy industry for which there is no control at present. Protected and endangered wildlife species are regularly sold in Addis Ababa shops having been "certified" as legal by local taxidermists. This loophole should be closed and certification of wildlife products should be performed by EWCO.

Although the war that deposed the previous regime ended in 1991, much administrative and jurisdictional realignment will continue within Ethiopia for the next several years. This fact, as well as previously existing shortcomings at AMCF, will necessitate close scrutiny of the project by organizations such as the Crocodile Specialist Group for the foreseeable future. The potential for improvement in the management at AMCF is considerable as is that for the management of wild crocodilian stocks in general within Ethiopia.

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A PRELIMINARY ASSESSMENT OF THE CHANGES IN EGG PARAMETERS AND LAYING PERFORMANCES OF INDIVIDUAL CAPTIVE BRED *CROCODILUS NILOTICUS* FROM THEIR FIRST LAYING SEASON (1983 - 1992).

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Introduction

A preliminary assessment, was made to try to establish the pattern of changes which occur in egg production and hatchling success, within a group of ***Crocodylus niloticus*** females, bred and reared under controlled conditions of Baobab Farm (Kenya). The history of these crocodiles is known as they have been monitored since being day old hatchlings. Their individual egg production and hatching success was recorded from their first laying season to present.

Background Baobab Aquaculture

Baobab Farm, located 10 km North of Mombasa on the Kenya Coast, introduced Aquaculture in 1971 as part of an integrated process of land reclamation. The site is a worked out coral limestone quarry of the Bamburi Portland Cement Company. The excavations stopped 50 cm (± 20cm) above the ground water. There is an abundant supply of water which varies in salinity from 0.5-15 ppt according to the dry or wet season and the tidal influence of the nearby Indian Ocean. The ground water has a near-constant temperature of 26 °C (± 1°C) throughout the year (Haller, 1988).

Background of Crocodiles

Crocodiles were introduced into the Integrated Aquaculture System to fill a gap in the Bamburi quarry ecosystem; making use of all animal waste protein from Baobab Farm. The number of crocodiles held is determined by the amount of protein available. Only in this context was crocodile utilisation justifiable from our point of view of wildlife conservation.

Origin of Parent Stock

In October 1975, on a Tilapia collection trip to Lake Turkana, five crocodiles, ranging between 32-86 cm in size, were collected for a growth experiment. Their food was waste Tilapia and meat from animal carcasses. The growth performance was very encouraging, with an average increase in length of 2.1-2.8 mm per day (Haller, 1976). In 1976 five day old hatchlings from the Tana River were presented to the Farm for rearing, these forming the basis of the present parent stock on the Farm. Their egg production and hatching success was monitored, these trends and some possible explanations are discussed in this preliminary paper. The first eggs (non viable) were laid in 1983, 7 years after hatching.

Original Parent Stock Breeding Pen

The crocodile breeding enclosure covers an area of 1700 m^2. It consists of two small ponds of 365 m^2 and 128 m^2,(Haller, 1988; Haller 1991) respectively, with sand banks. 6 adult female and 1 male crocodile, are used in the breeding enclosure. Of the breeding stock, 5 of females originate from the Tana River (T1/76, T5/76, T6/76, 1T3/76 and T7/76) and 1 female (R8/75) and 1 male (R10/75) originate from Lake Turkana.

RESULTS/DISCUSSION

Age of laying

During 1983, at an age of 7 years, the first 2 captive reared animals (collected in 1975/76) started laying eggs of a mean weight of 46.7g. By 1984 3 females were laying and continued to do so, until in 1988. An additional 2 females started laying, at an age of 12/13 years. Finally by 1989 all 6 females had commenced laying, the last to start laying at an age of 13 years. All females continued to lay every season once they had commenced their breeding cycle.

The data for 1986 is discarded in this paper as the supervision and accuracy of the recording is under question.

The results indicate that captive bred females can start egg laying as early as 7 years old at a length of around 2 m, but the majority only start laying between the ages of 12 to 13 years, with size 2.35m. It has been mentioned earlier that female laying is dependent on length and not necessarily on age. According to the results (Table 3), age seems to be the more prominent factor.

The age of a crocodile is very easily confused, if the exact hatching date **is** not know. The above females showed growths of 6.6 cm yr^{-1} after reaching 2 m in around 1983. This would mean that a length difference of 66 cm between animals would correlate to a 10 year difference in growth. These results tend to indicate that it is the age of the female rather than her length which is the determining factor on the quantity of eggs produced.

Number of eggs laid

The mean egg numbers of all the females put together have progressively increased over the last 10 years. In 1983 a total of 13 eggs were laid, while in 1992 it had increased to 199 eggs (Table 2). The first laying in 1983 saw only two females laying, with nests of 5 and 8 eggs (av.6.5), by 1992 with six nests the clutch sizes varied from 27 to 43 eggs, with a mean of 33 eggs per female (Table 3).

The largest female (T1/76) and the last one to start laying at an age of 13 years, remarkably produced the largest clutch numbers from the first laying season (33 eggs in 1989) to the present date (43 eggs 1992). It produced more eggs in the first laying season than the females who had already been laying for 6 years. Does this trend mean that the older the female is before starting to lay, the greater will be the initial clutch sizes ? Is egg number dependent on female size ? What mechanism triggers the females first laying season ? Can they control this ? Or is it just genetically determined.

The individual females have all shown increases in egg production with their increase in age. However, some individuals have had drops in their egg production over 2 year periods eg. T6/76 laid 30 eggs in 1989, then the following 2 years the egg production dropped, producing 23 and 19 eggs respectively, but then increasing again in 1992 to 28 eggs (Table 3). During this same period another female exhibited the same trend. T5/76 produced 29 eggs in 1989, thereafter only producing 28 and 24 eggs respectively, before raising its production to 27 eggs in 1992. T3/76 also showed a similar pattern two years previous. Could this indicate that these females were not in top condition, therefore had a drop in egg production ? The interesting factors however are that the suspected slow loss of condition over the two years and then a recovery in the third year, but still not achieving an egg production as high as 4 years previously (Table 3). Could this slow loss of condition be as a result of the slow metabolic rate of the crocodilians at that age ? If it does show a loss of condition, this indication could be useful reproduction management tool, to single out weak animals and examine them.

The low egg clutch number in 1988 of 14 eggs by R8/75 was due to the nest being raided by monitor lizard.

Egg Weights/Egg Lengths/Egg Widths

In general it is has been seen that there is an increase in egg size with the age of the female.

The first eggs (non viable) were laid in 1983, with mean weights of 46.7 g. The first viable eggs were laid in 1985, by only one female (T3/76) with mean eggs weights of 65.8 g, however the mean egg weights of the three females together that year was considerably lower (56.6 g).

The mean egg weights steadily increased as the females got older, by 1991 the egg weights had reached a mean overall weight of 96.5 g. However, an exception occurred in 1992 where there was a slightly lower overall mean of 96.2 g. A drop in mean egg weight had never occurred previously. Could this drop have been linked with the male being in poor condition ? Could the processes of egg formation and development (eg. weight) have been effected by the fertility/or weakening of the male. Is it possible for females to reabsorb the eggs like in some fish?

The farm captive bred females produced heavier mean egg weight than wild females whose eggs were collected along the Galana River in 1992 (Table 2). From the age of 13 years to 16 years the egg weights have increased (from 89.1 to 96.5 g) compared to 88.7 g from the Galana River, (the mean being taken from 442 eggs, 14 nests). The mean clutch sizes however being similar, 33 and 32, in the captive and wild females respectively.

When the total clutch egg biomass of each of the individual female was compared, with the drop in egg numbers exhibited by the above 3 females, the trend seems to conform with the above theory, that the reduction in individual female egg numbers indicated the loss of condition of T5/76 ,T6/76 and T3/76.

Rejecting the above theory and saying that egg clutch numbers could not be correlated or dependent with female condition, would mean that the expected total egg biomass should have remained the same or have increased, for the individual females, with the reduction in egg numbers during this period. This however was not the case. Calculating egg clutch biomass, showed that as the egg numbers decreased during this period, so did the egg biomass. As the egg numbers increase again, so did the egg biomass. A reduction in egg numbers by the individual females does not seem to correlate with an increase of the individual egg sizes.

Only T5/76 showed an increase in egg biomass in 1990 from 1989 with the reduction in eggs. This could be ignored as production only dropped by 1 egg in the following year, but otherwise it follows the same trend as T6/76 and T3/76.

The mean combined egg lengths of the individual females have increased progressively over the last 10 years, starting with mean lengths of 6.8 cm and increasing with millimetre differences yearly to 7.6 cm in 1992. The individual female mean egg lengths have increased overall, but at this stage there is still a great deal of variability in egg lengths from year to year.

The largest individual female mean egg lengths of 8.2cm were obtained in 1988 by R8/75 (Appendix 1), a whole 1 cm larger than the individual mean for that year. This did coincide with an apparently low egg production down from 33 eggs in 1987 to 14 eggs in 1988, however this low egg number cannot be substantiated as the nest had been raided prior to collecting. But the mean egg weights did not seem to be compensated (increase in weight) by this length. Could this imply that the eggs had large air spaces ? This requires further investigation.

The mean breadths of all the individual female eggs also showed increases, as the females get older. From 1988 a progressive increase is seen (Appendix 2), with widths of 3.9 to 4.2 to 4.3 to 4.5 and 4.6 cm in 1992. However there are still increases and decreases from year to year as the individual females get older.

Combining the mean nest egg lengths and widths over the years at this stage, it is difficult to see a direct correlation. Even if an index is used combining length, width and weight, a clear pattern is not seen. It would be useful if an index or model could be obtained finally, to estimate the ages of the females in captivity and also in the wild. Although this might not be feasible, it deserves further investigation.

Hatchling Success

Young females (aged 7 to 9 years) in their first laying season usually produce a very high percentages of infertile eggs (up to 100%), those being fertile usually died shortly after hatching. Interestingly older females whose first laying season was at a much later (aged 12 to 13; T6/76, T7/76 and T1/76) had very high hatchling survival rates 90, 94 and 100 % respectively (Table 1).

The mean hatching success of the six females have showed a steady increase from 1985 to 1990, (60 to 82.7 %). There has been a drop in hatching success ever since; in 1991 (72.4 %), to a all time low of 59.8 % in 1992, the large percentage being unfertile (Table 1).

This figure is even lower than when the farm first started obtaining viable eggs in 1985. The 442 eggs collected from the Galana River in 1992 showed a hatching success of 90.5 %. Indicating that incubation procedures were satisfactory. The reduction in hatching success could be linked with the poor condition of the male (R10/75) who over the last 2 years has lost considerable physical condition.

It also seems like it from the data (Table 1) that the majority of the hatchling clutches, which are the first to hatch each year (early March) showed the greatest percentage of hatchlings. This again could be linked with the fertility of the male in that the last females to get mated had a poorer chance of having fertile eggs. This point however needs much deeper investigation, as there are one or two exceptions to the above.

The paper mainly discussed and attributed the females low egg numbers and biomass of T5/76 and T6/76 during the dates 1990 and 1991, to a loss of condition of the females. Why then only during their lowest egg numbers, 24 and 19, respectively and there supposed low condition, do both the females have a 100 % hatching success ???? Only 1 other Baobab female has had a 100 % hatching success in the 16 years, and that being T1/76 during its first laying season.

TABLE 1 BAOBAB CROCODILE FARM ORIGINAL PARENT STOCK STATISTICS SHOWING HATCHING DATES, HATCHING SUCCESS AND STATE OF UNHATCHED EGGS (WHETHER DEAD IN SHELL, UNFERTILE, OR ROTTEN/DAMAGED)

FEMALE NO	LAYING YEAR	TOT.EGG LAID	HATCH DATE	TOTAL HATCHED	HATCH %	REMARKS
T1/76	1987					
	1988					
	1989	33	01.03.89	33	100	
	1990	34	07.03.90	32	94	2U
	1991	38	01.03.91	25	66	3D, 3U, 7R
	1992	43	03.03.92	38	88	2D, 3U
T5/76	1987	14	03.03.88	8	57	4U, 2R
	1988	18	18.03.88	10	56	1D, 7R
	1989	29	14.03.89	20	76	8U, 1R
	1990	28	26.03.90	22	79	3U, 3R
	1991	24	01.03.91	24	100	
	1992	27	06.04.92	16	59	1D, 7U, 3R
T6/76	1987					
	1988	29	03.03.88	26	90	3R
	1989	30	08.03.89	26	87	4R
	1990	23	07.03.90	20	86	2D, 1R
	1991	19	02.03.91	19	100	
	1992	28	27.03.92	23	82	1D, 3U, 1R
R8/75	1987	33	29.02.87	31	94	1D, 1U
	1988	14	25.03.88	6	42	8R
	1989	29	26.03.89	20	69	1D, 2U, 6R
	1990	29	05.04.90	24	83	3U, 2R
	1991	30	12.03.91	15	50	1D, 12U, 2R
	1992	32	13.04.92	9	28	3D, 15U, 5R
T3/76	1987	31	17.03.87	12	39	9U, 10R
	1988	24	15.03.88	18	69	8R
	1989	24	30.03.89	19	79	3U, 2R
	1990	29	26.03.90	20	69	2D, 5U, 2R
	1991	32	14.03.91	16	50	8D, 1U, 7R
	1992	33	09.04.92	20	59	11U, 3R
T7/76	1987					
	1988	17	07.03.88	16	94	1R
	1989	25	29.03.89	2	8	1D, 5U, 17R
	1990	31	02.04.90	24	77	7U
	1991	32	18.03.91	27	87	2D, 2U, 1R
	1992	36	19.03.92	13	37	4D, 14U, 5R

* D = Dead in shell U = Unfertile R = Rotten/Damaged

TABLE 2 BAOBAB CROCODILE FARM ORIGINAL PARENT STOCK EGG PRODUCTION AND HATCHING SUCCESS SUMMARY 1983 - 1992

YEAR	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	COMPARISON WITH WILD EGGS AND HATCHLING
Nests	2	3	3	2	3	5	6	6	6	6	14
Av. Size		12	15	13	26	21	28	29	29	33	32
Tot. Eggs	13	32	45	26	78	105	170	174	174	199	442
Eggs hatched	3	4	27	2	51	73	120	144	126	119	400
% Success	-	-	60	7.7	65.4	69.5	70.6	82.7	72.4	59.8	90.5
Croc. Nos	All died	All died	10 - 37	All died	903-971	01 - 73	-	-	Nest No.	Nest No.	
Egg Wt(g)	46.7	50.8	56.8	55.3	76.3	84.1	89.1	91.6	96.5	96.2	88.7
Egg L(cm)	-	6.8	6.8	6.8	7.1	7.2	7.35	7.4	7.5	7.6	7.2
Croc. Wt(g)	33.9	32.9	46.7		50.8	57.3	60.7	58.2	61.7	62.6	62.5
Croc. L(cm)	23.2	23.7	23.0	22.7	27.0	28.0	29.1	28.5	28.8	29.2	28.0

Adapted from Haller (1988)

TABLE 3 EGG PRODUCTION OF INDIVIDUAL BAOBAB FARM PARENT STOCK (HATCHED 1975/1976) FROM THEIR FIRST YEAR OF LAYING

FEMALE NO	ORIGIN	AGE	EGG PRODUCTION DATA									
			1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
T1/76	TANA RIVER	7							33	34	38	43
T5/76	TANA RIVER	7	5	8	11		14	18	29	28	24	27
T6/76	TANA RIVER	7						29	30	23	19	28
R8/75	L. TURKANA	8		8	10		33	14	29	29	30	32
T3/76	TANA RIVER	7	8	21	24		31	28	24	29	32	34
T7/76	TANA RIVER	7						17	25	31	31	35

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APPENDIX I

BAOBAB CROCODILE FARM ORIGINAL PARENT STOCK , EGG LENGTH STATISTICS 1984 - 1992

FEMALE NO	ORIGIN	DATE HATCHED	1984 AV.L (cm)	1984 RANGE (cm)	1984 SD	1985 AV.L (cm)	1985 RANGE (cm)	1985 SD	1986 AV.L (cm)	1986 RANGE (cm)	1986 SD	1987 AV.L (cm)	1987 RANGE (cm)	1987 SD
T1/76	TANA R.	1976												
T5/76	TANA R.	1976	7			6.5	6.3-6.8					6.5	6.2-7.0	0.27
T6/76	TANA R.	1976												
R8/75	TURKANA	1975	7.2	6.2-7.6		6.6	6.3-7.1					7.5	7.2-7.9	0.18
T3/76	TANA R.	1976	6.2	5.9-6.5		7.2	6.9-7.7					7.2	6.5-7.7	0.29
T7/76	TANA R.	1976												

BAOBAB CROCODILE FARM ORIGINAL PARENT STOCK , EGG WEIGTH STATISTICS 1984 - 1992

FEMALE NO	ORIGIN	DATE HATCHED	1984 AV.WT. (g)	1984 RANGE (g)	1984 SD	1985 AV.WT. (g)	1985 RANGE (g)	1985 SD	1986 AV.WT. (g)	1986 RANGE (g)	1986 SD	1987 AV.WT. (g)	1987 RANGE (g)	1987 SD
T1/76	TANA R.	1976												
T5/76	TANA R.	1976	42.7			57.2	49.4-61.6					74.3	65.1-83.6	4.92
T6/76	TANA R.	1976												
R8/75	TURKANA	1975	57	43.3-64.3		47.5	30.0-59.2					78.6	69.5-85.0	2.75
T3/76	TANA R.	1976	52.6	31.4-58.1		65.8	58.1-73.8					76	72.6-80.9	2.23
T7/76	TANA R.	1976												

BAOBAB CROCODILE FARM ORIGINAL PARENT STOCK , EGG BREADTH STATISTICS 1984 - 1992

FEMALE NO	ORIGIN	DATE HATCHED	1984 AV.BR. (cm)	1984 RANGE (cm)	1984 SD	1985 AV.BR. (cm)	1985 RANGE (cm)	1985 SD	1986 AV.BR. (cm)	1986 RANGE (cm)	1986 SD	1987 AV.BR. (cm)	1987 RANGE (cm)	1987 SD
T1/76	TANA R.	1976												
T5/76	TANA R.	1976	3			3.8	3.6-4.1					4.1	4.0-4.2	0.08
T6/76	TANA R.	1976												
R8/75	TURKANA	1975	3.8	3.6-4		3.9	3.8-4.0					4.2	3.9-4.3	0.11
T3/76	TANA R.	1976	3.7	3.5-3.9		3.9	3.7-4.0					4.1	3.6-4.5	0.21
T7/76	TANA R.	1976												

APPENDIX II

BAOBAB CROCODILE FARM ORIGINAL PARENT STOCK , EGG LENGTH STATISTICS 1984 - 1992

FEMALE NO	ORIGIN	DATE HATCHED	1988 AV.L (cm)	1988 RANGE (cm)	1988 SD	1989 AV.L (cm)	1989 RANGE (cm)	1989 SD	1990 AV.L (cm)	1990 RANGE (cm)	1990 SD	1991 AV.L (cm)	1991 RANGE (cm)	1991 SD	1992 AV.L (cm)	1992 RANGE (cm)	1992 SD
T1/76	TANA R.	1976				7.7	7.4-8.4	0.24	7.4	7.1-8.3	0.31	7.8	7.5-8.5	0.2	7.8	7.1-8.4	0.25
T5/76	TANA R.	1976	6.5	5.9-7.3	0.38	7.1	6.5-7.6	0.18	7.5	7.3-7.8	0.13	7.4	7.2-7.7	0.12	7.5	7.3-7.8	0.13
T6/76	TANA R.	1976	7.8	7.2-8.6	0.31	7	6.7-7.3	0.15	7.2	7.0-7.5	0.12	7.3	7.2-7.5	0.1	7.3	6.9-7.8	0.19
R8/75	TURKANA	1975	8.2	7.8-8.7	0.26	7.6	7.0-8.2	0.29	7.4	6.8-8.4	0.28	7.6	7.2-8.1	0.23	7.9	7.6-8.5	0.23
T3/76	TANA R.	1976	7.1	6.7-7.6	0.26	7.2	6.8-7.8	0.24	7.7	7.4-8.3	0.21	7.6	7.3-8.2	0.24	7.5	6.6-8.1	0.26
T7/76	TANA R.	1976	6.4	6.2-6.8	0.21	7.5	6.9-7.8	0.21	7.2	6.8-7.8	0.25	7.5	6.9-8.0	0.21	7.5	7.0-8.2	0.27

BAOBAB CROCODILE FARM ORIGINAL PARENT STOCK , EGG WEIGTH STATISTICS 1984 - 1992

FEMALE NO	ORIGIN	DATE HATCHED	1988 AV.WT. (g)	1988 RANGE (g)	1988 SD	1989 AV.WT. (g)	1989 RANGE (g)	1989 SD	1990 AV.WT. (g)	1990 RANGE (g)	1990 SD	1991 AV.WT. (g)	1991 RANGE (g)	1991 SD	1992 AV.WT. (g)	1992 RANGE (g)	1992 SD
T1/76	TANA R.	1976				85.8	81-90	3.22	90.8	80-100	5.07	97.5	94-102	2.04	96.1	90-104	3.19
T5/76	TANA R.	1976	84.1	72-94	5.65	92.3	86-100	3.17	102.6	93-110	4.04	98.3	94-102	2.96	100.4	89-115	4.6
T6/76	TANA R.	1976	83	69-91	3.69	86.3	80-90	2.92	81.2	76-94	2.81	97.2	94-102	2.08	94.5	91-100	2.75
R8/75	TURKANA	1975	89	83-93	2.72	90	85-98	3.01	93.9	88-102	3.49	99.4	92-108	4.23	97.1	91-101	3.38
T3/76	TANA R.	1976	84.4	78-92	3.49	88.5	82-94	3.79	92.8	90-95	1.08	95.6	90-102	3.52	97	79-103	4.18
T7/76	TANA R.	1976	80.1	76-87	2.9	91.5	80-98	4.24	88.5	74-98	6.57	90.7	80-97	4.09	92	80-101	6.23

BAOBAB CROCODILE FARM ORIGINAL PARENT STOCK , EGG BREADTH STATISTICS 1984 - 1992

FEMALE NO	ORIGIN	DATE HATCHED	1988 AV.BR. (cm)	1988 RANGE (cm)	1988 SD	1989 AV.BR. (cm)	1989 RANGE (cm)	1989 SD	1990 AV.BR. (cm)	1990 RANGE (cm)	1990 SD	1991 AV.BR. (cm)	1991 RANGE (cm)	1991 SD	1992 AV.BR. (cm)	1992 RANGR (cm)	1992 SD
T1/76	TANA R.	1976				4.1	4.0-4.5	0.12	4.1	4.0-4.2	0.08	4.4	4.2-4.5	0.76	4.4	4.1-4.7	0.12
T5/76	TANA R.	1976	3.5	2.8-4.2	0.32	4.1	4.0-4.5	0.11	4.5	4.3-4.6	0.07	4.6	4.5-4.7	0.7	4.7	4.5-4.9	0.09
T6/76	TANA R.	1976	4	3.8-4.2	0.09	4.2	4.0-4.3	0.09	4.3	4.0-4.5	0.11	4.6	4.4-4.9	1.08	4.6	4.4-4.6	0.05
R8/75	TURKANA	1975	4.1	4.0-4.3	0.09	4.2	3.9-4.5	0.16	4.3	4.1-4.5	0.09	4.6	4.5-4.8	0.83	4.4	4.1-4.5	0.11
T3/76	TANA R.	1976	4.3	3.9-4.5	0.14	4.2	4.0-4.6	0.15	4.3	4.0-4.5	0.09	4.3	4.1-4.5	0.96	4.7	4.4-4.8	0.08
T7/76	TANA R.	1976	3.8	3.5-4.5	0.24	4.3	4.0-4.5	0.13	4.2	4.0-4.3	0.09	4.4	4.2-4.5	0.89	4.5	4.3-4.7	0.09

A Report On An Initial Survey Effort to Assess the Status of Black Caiman *Melanosuchus niger* in the Amazon Region of Ecuador

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Background

Melanosuchus niger occurs throughout the Amazon region from the Amazon river mouth in the east to Ecuador in the west (Groombridge 1987). It has apparently been seriously reduced in much of its range by over hunting (Groombridge 1987, King 1989). Small populations of Melanosuchus niger were known to exist in the Amazon region of Ecuador in the 1980's (Plotkin et.al. 1983). They were reported to be common in the lower Rio Aguarico, Rio Yasuni and Rio Lagartococha near the Peruvian border (Groombridge 1982). Asanza, in (Thorbjarnasen 1992) reports that populations occur in the Cuyabeno region, Limoncocha and Zancudococha. However, there are very little published survey data and no information on country wide status, nor is there an infrastructure in place to monitor population levels.

M. niger is presently on the CITES Appendix I list of endangered species, and under this classification commerical trade is prohibited. Before the species can be traded internationally a request for a change in the listing to Appendix II (to permit trade) must be presented to the Conference of the Parties of CITES by the Ecuador Management Authority. The request must contain status data as well as proposed management actions.

An initial survey to evaluate the status of the black caiman Melanosuchus niger in the Amazon region of Ecuador was conducted in March, 1992. This survey was funded by Mr Pablo Evans, a businessman interested in ranching black caiman in Ecuador. A proposal submitted to Mr Evans and the government of Ecuador to evaluate the feasibility of ranching black caiman provided the impetus for these surveys. The original proposal contained the following three objectives. 1) To determine the population status and distribution of Melanosuchus niger within the Amazon region of Ecuador. 2) To generate information and recommendations concerning the management of M. niger in the wild, including a long term monitoring system. 3) To provide Mr Pablo Evans with recommendations regarding the feasibility of ranching and/or farming M. niger in Ecuador; the survey we are reporting on is the first step toward achieving objective # 1.

Study areas for the initial survey consisted of lagoons, back waters and disjunct oxbows associated with the Rio Napo (from Coco to Rocafuerte), and the Rio Lagarto Cocha.

Methods

The objective of these surveys was to locate areas of potential caiman habitat, conduct initial population inventories and establish permanent survey routes. Routes were established during daylight hours and general habitat features (eg, surrounding vegetation) were recorded. Samples of significant emergent vegetation were collected for subsequent identification. Beginning and ending points of routes were documented with a Global Positioning System (GPS) and GPS points were recorded around the perimeter of lagoons to map these areas. Erratic elevation readings with the GPS did not allow for dependable water level elevation readings. However, in some cases water depths were measured at known points, and in all cases observations by local residents concerning water levels were recorded.

Other parameters measured included water and air temperatures and general observations concerning rainfall.

Surveys were initiated approximately one hour after sunset utilizing either a motorized five m. aluminium boat or three to five m. dugout canoes. Animals were spotted with a 200 000 candlepower light and recorded by .3 m size classes. When species could not be determined, animals were placed into an unknown category by size class. These animals were added to known species counts in the same proportion that the known animals were observed. Additionally, broader size classes were established for those animals which could not be sized accurately.

Even though we had beginning, intermediate and ending points of the majority of the routes our lack of a good map/photograph prevented an exact determination of transect length. But in order to establish an approximate length of each route, we calculated the distance between beginning, intermediate and ending points.

Also, five immature black caiman were captured, measured and released and one adult female black caiman was captured in a Murphy trap, measured, and released. Measurements were also obtained from two animals taken for their abdominal fat, by a local fisherman. Primarily, these animals were measured to verify our size classifications.

In addition, we initiated efforts to acquire LANDSAT photographs of the study area to aid in the assessment of habitat. These have been purchased but have not been received.

Results

During the 13 days of the survey, we inspected lagoons and other caiman habitat along approximately 240 km of the Rio Napo and Rio Lagarto Cocha. We established 12 separate survey routes and conducted at least one night light survey along each route.

Because the variation inherent in night light counts cannot be quantified when only one survey is conducted the data presented here are of limited value. However, we are presently in the process of replicating the counts on a monthly basis to quantify annual variation in numbers of caiman observed. But until those data are analyzed we must rely on the survey results as they are to provide some preliminary insights into population status.'

Crocodilians were observed along all 12 survey routes and black caiman were observed in some proportion along every route except one. The variation in the ratio of M. niger to Caiman crocodilus is not readily explainable by obvious habitat differences. But it ranged from .00 to 1.00 of the total number observed being identified as M. niger (Table I).

Of the animals sized, 62% were 1.8 m or smaller, most of which probably represent the sub-adult size class, while 27% fell into the 1.8 to 2.7 m class and 9% were the very large animals (greater than 2.7 m) (Fig. 1). Even though 24 hatchlings were observed the fact we were unable to access areas that appreared to be good production habitat probably caused a significant under-estimate of the proportion of hatchlings in the population.

A significant proportion of the habitats surveyed were surrounded by flooded forest/heavy cover making observability a problem. Also, there were some populations that appeared to be much more wary than others suggesting that human activity may cause behavioral changes which will affect observability.

The numbers of black caiman observed/km ranged from 0 to 14.7 and the number/hr. from 0 to 40.8 (Table II). Actual transect lengths in most cases may be longer than the calculated straight line lenghts presented resulting in a slightly elevated density/km. However, comparison of these data with other such surveys in other parts of the world still will put the Ecuador data in perspective. (King et.al. 1990) reported on night light counts of Crocodylus acutus in Honduras and found densities ranging from 0 to 2.3/km. (Wood et.al.1985) analyzed 78 transects in Florida that had been surveyed for alligators Alligator mississippinesis from 1 to 13 years. Eight of the 78 routes (10.2%) had mean densities exceeding 13 animals/km. and 54 transects (69%) had mean densities of less than 5/km.

Conclusion

This survey is a first step toward providing an initial assessment of black caiman status in Ecuador. However, before further progress is made the following needs must be met.

(1) Population data that will be published by other researchers should be combined with the data from this project to provide a more complete picture of status.

(2) In order to interpret the night light data thus far gathered, the effects of annual variation in water levels and other environmental factors on counts must be addressed. We have provided some short term training for one Ecuadorian biologist and the initial 12 surveys are presently being replicated on a monthly basis.

(3) We observed viable populations of black caiman. However, the quantity of habitat available in the Amazon region of Ecuador is unknown; we believe LANDSAT imagery will allow us to identify and quantify caiman habitat throughout the region.

(4) Other river systems exist in the region, particularly the extensive area south of the Rio Napo. Ásanza (pers. comm.) reports black caiman in this area. Before we can establish a basis for countrywide assessment of the status of black caiman, systematic survey data should be obtained from these unsurveyed areas.

A long-term biologically sound crocodillian management program in Ecuador will require a continued research effort to establish the necessary database. In addition to the previously mentioned projects, immediate priorities should include research dealing with (1) reproductive cycle of black caiman (2) mortality and growth (3) continuing efforts to improve population monitoring and (4) interspecific competition between Melanosuchus niger and Caiman crocodylus.

Simultaneous with the field research, systematic investigation into the practical aspects of captive rearing of black caiman should begin.

This should also include identifying the role that indigenous people may play in the program and developing a plan where, if a ranching program is feasible, the conservation benefits will be maximized.

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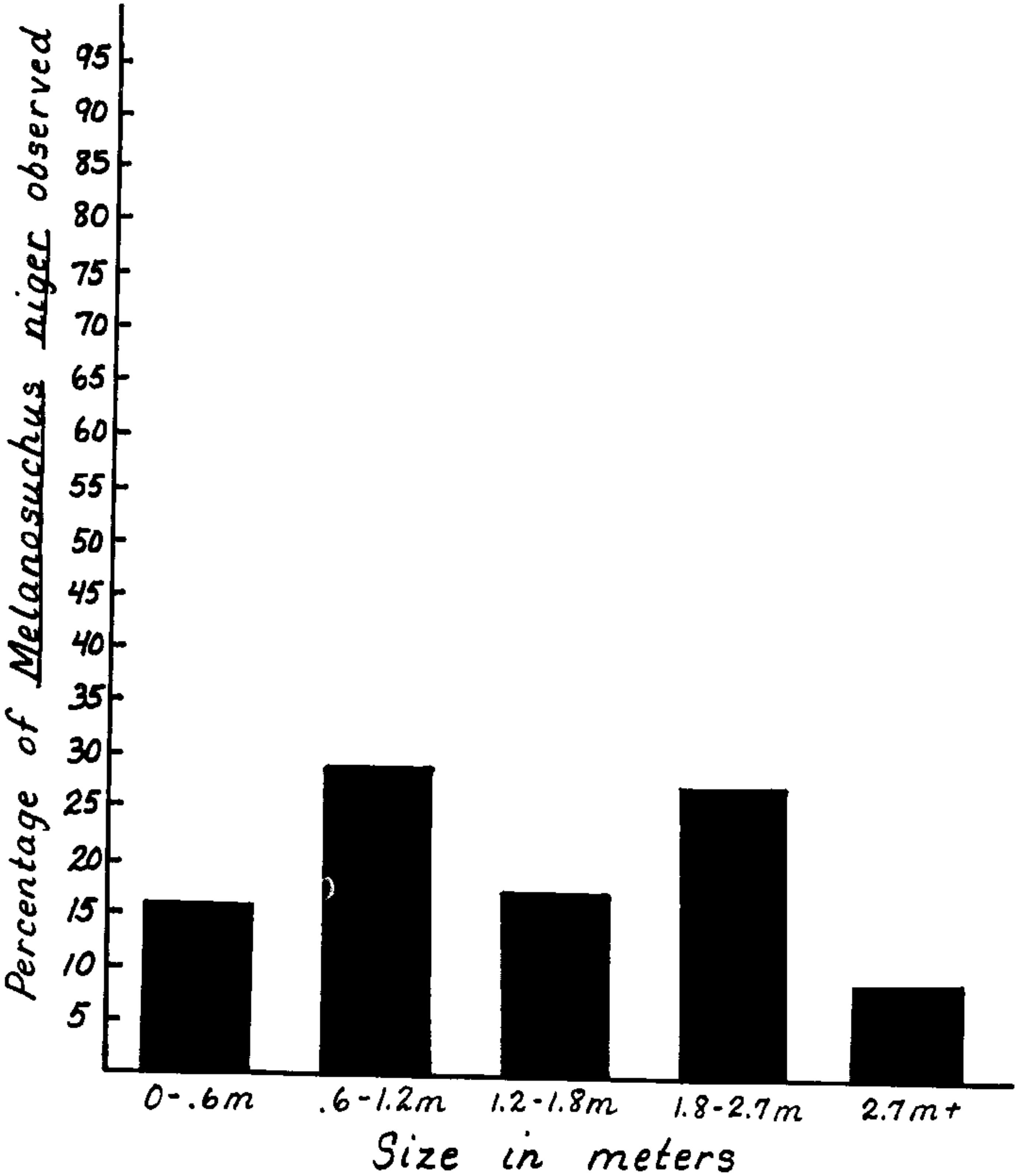

Fig. 1. Size structure of *Melanosuchus niger* populations in the Rio Napo region of Ecuador.

Table I Percentage(1) Melanosuchus niger and Caiman crocodilus observed along survey routes in Ecuador.

Route	M. niger	C.Crocodilus	% M.niger
Hatun Cocha	17.0	67.0	25.0
Liman Cocha	83.0	2.0	98.0
Draga Lagoon	1.0	0.0	100.0
Rio Lagarto	49.0	51.0	49.0
Rio Lagarto	3.0	73.0	3.9
Anango	16.0	2.0	88.9
Manduri	3.0	10.0	23.0
Challua	22.0	0.0	100.0
Imuya	53.0	48.0	52.5
Huarmi	11.0	0.0	100.0
Yuturi(2)	0.0	12.0	100.0
Taracoa	17.0	0.0	100.0

(1) Based on proportion of identified number.

(2) One M. niger observed during daylight hours.

Table II Melanosuchus niger observed per km and per hour along survey routes in Ecuador.

Survey Time (hr.)	Route	Survey Length (km)	Survey Caiman/km	Survey Caiman/km
3.33	Hatun Cocha	10.50	1.62	5.10
2.38	Limon Cocha	9.40	8.83	34.87
0.88	Draga Lagoon*	- -	- -	1.14
2.27	Lagarto Cocha River-South	4.70	10.42	21.59
1.72	Lagarto Cocha River-North	3.20	0.94	1.74
1.00	Anango	2.00	7.50	15.00
1.00	Manduri	0.51	3.92	2.00
1.60	Challua	2.60	8.46	13.75
1.30	Imuya	3.60	14.72	40.77
0.50	Huarmi*	- -	- -	22.00
2.00	Yaturi River	6.70	0.00	0.00
2.58	Taracoa*	- -	- -	6.59

* Unable to measure transect length because of equipment malfunction.

Parasites of Captive and Farmed Crocodiles in South Africa

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At present there are 40 crocodile farms in South Africa breeding and producing the Nile crocodile, *Crocodylus niloticus*. Wild-caught breeding animals, imported from neighbouring countries, often carry parasites which require intermediate hosts, while intensively reared young stock are more likely to be affected by parasites with direct development. The material for this study came from routine post mortem examinations.

Hepatozoon pettiti is transmitted by tsetse flies, *Glossina* spp., which feed on crocodiles. The tsetse flies in turn are swallowed when biting in the gaping mouth. Schizonts are found in the liver, while gamonts invade circulating red blood cells. Oocysts of an *Eimeria* sp. from hatchlings and yearlings presented a pitted outer wall like those of *E. caimani* and *E. paraquayensis* of the spectacled caiman, *Caiman crocodilus*. The sporulated oocysts were found entrapped in the inflamed mucosa and submucosa of the intestine. *Giardia*-like flagellates were found in the small intestine of hatchlings.

A strigeoid trematode *Pseudoneodiplostomum thomasi* (Jones, 1992 pers. com.) was found in the jejunum of a wild-caught adult male crocodile. Mature forms of the crocodilian ascaridoids *Dujardinascaris dujardini*, *D. madagascariensis* and *Hartwichia rousseloti* were found in the stomach of crocodiles; these nematodes probably all utilize fishes as intermediate hosts.

Large numbers of **rhabditids** were found in the bile ducts of the liver of a dwarf crocodile, *Osteolaemus tetraspis*. It is believed that these parasites were too numerous and their habitat too specialized for them to be opportunistic parasites.

Pentastomes, *Sebekia* spp. (Riley, 1990, pers. com.), are often found in the lungs of wild-caught crocodiles. They also utilize fishes as intermediate hosts.

No **cestodes** are known from crocodiles. **Filarioids**, which have been described from African crocodiles, were not found in the present material.

CROCODILAN RIDDLES

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In 1989 the Onderstepoort Veterinary Institute (OVI) opened a Crocodile Diagnostic Unit, which provides a fulltime diagnostic service to crocodile farmers in South Africa and even beyond its borders. Part of the service is a computerized literature collection of veterinary items related to crocodiles and other reptiles presently comprising ±800 titles. Useful surveys of crocodile diseases include papers by Foggin (1987) and Ladds & Sims (1990).
During routine post mortem examination three apparently hitherto undescribed conditions were found, which resisted our efforts of elucidation. They are presented here with the aim to elicit comments. These conditions were named provisionally: Rhino-Gastritis or White Nose Syndrome, Thymic Necrosis and Pharyngitis or Tonsillitis.

Rhino-gastritis
Since June, 1991, Rhino-gastritis has been diagnosed in 52 crocodiles with a mean length of 116cm (±14,4cm) from two crocodile farms in the Transvaal. Clinically the affected animals show inappetence and develop a whitish area around the nostrils (White Nose Syndrome, Fig. 1). On post mortem examina-

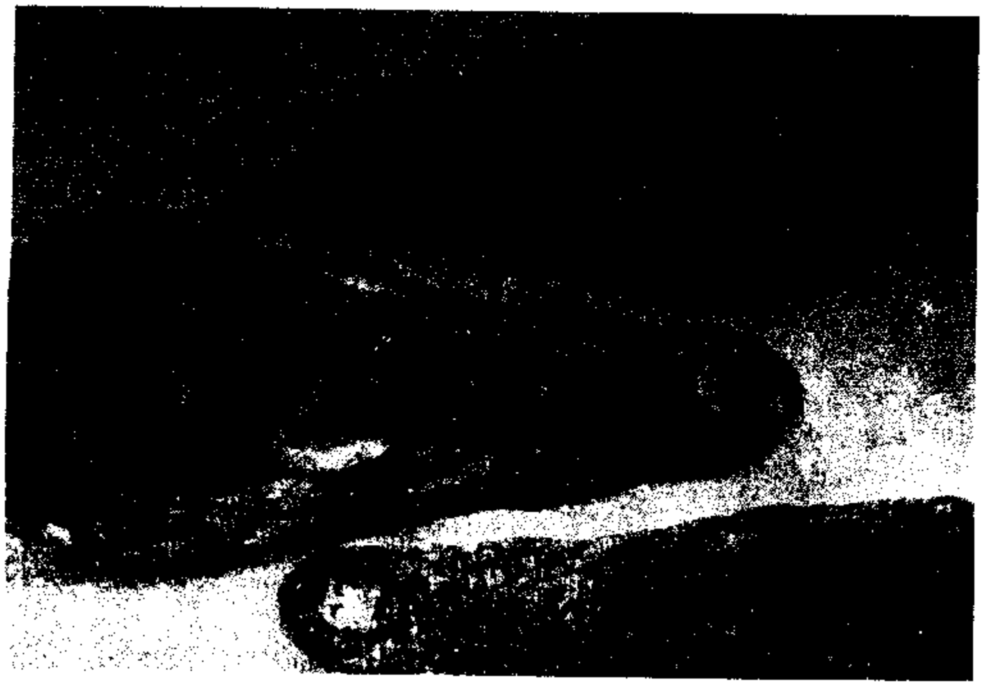

Fig. 1. Rhino-Gastritis: Whitish areas developing around the nostrils of affected crocodiles - White Nose Syndrome.

tion the stomach is found not to contain any food, but water, mucus and hairs and/or feathers. After removal of the contents the mucosa shows numerous small ulcers of 2-4mm diameter, spread throughout the entire surface or concentrated in the pyloric area and the duodenal pouch (Fig. 2). In addition there is a mild rhinitis in the nostril area and sometimes a glossitis.

Fig. 2. Rhino-Gastritis: Small stomach ulcers.

Histopathologically there is ulceration of the stomach mucosa with multifocal lymphocytic infiltration, multifocal lymphocytic infiltration in the dermis and mucosa of the nostril and in the mucosa of the tongue. The most striking feature, however, is a severe polyarteriitis with thickening of the intima and lymphocytic infiltration of the muscularis and adventitia, affecting arteries in various organs and parts of the body (Figs. 3 & 4).
Bacteriological and virological investigations have given negative results so far. The vascular lesions suggest a severe chronic auto-immune reaction which possibly persists long after the disappearance of the original causal agent.

Thymic Necrosis
Thymic Necrosis has been found mainly in apparently normal slaughtered crocodiles but also in diseased crocodiles of similar size or age, affecting 14 out of 25 specimens from 4 farms. It does not appear to be linked to any clinical condition.
In the Nile crocodile the thymus glands are found cranially and caudally to the thyroids on both sides of the trachea close to its bifurcation (Fig. 5). In a well nourished animal they appear

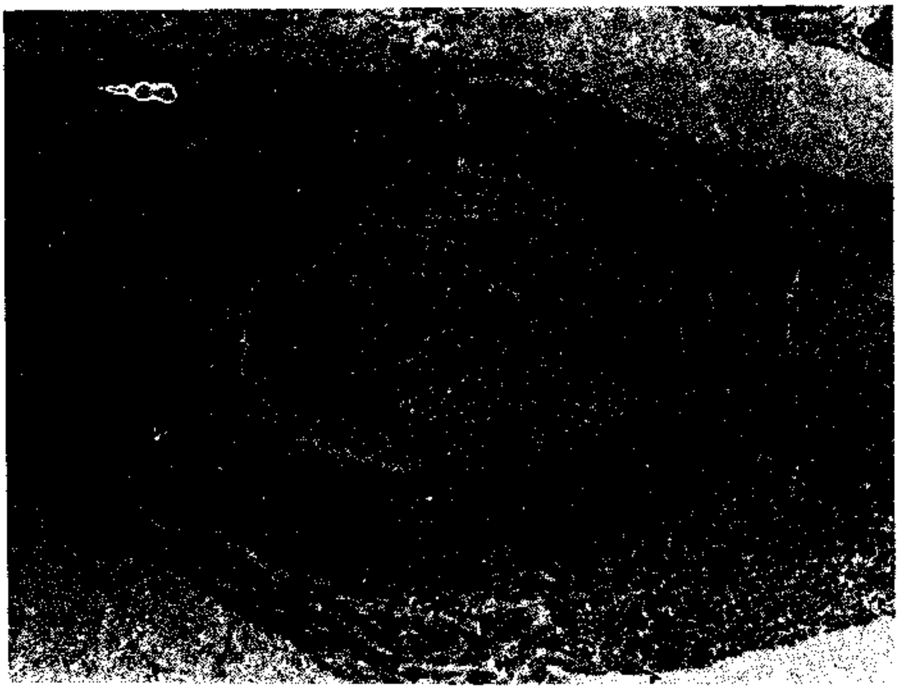

Fig. 3. Rhino-Gastritis: Arteriitis with intima proliferation and lymphocytic infiltration of muscularis and adventitia.

Fig. 4. Rhino-Gastritis: Arteriitis with intima proliferation and lymphocytic infiltration of the adventitia.

indistinguishable from the surrounding fat tissue. The necrosis is not discernable macroscopically.

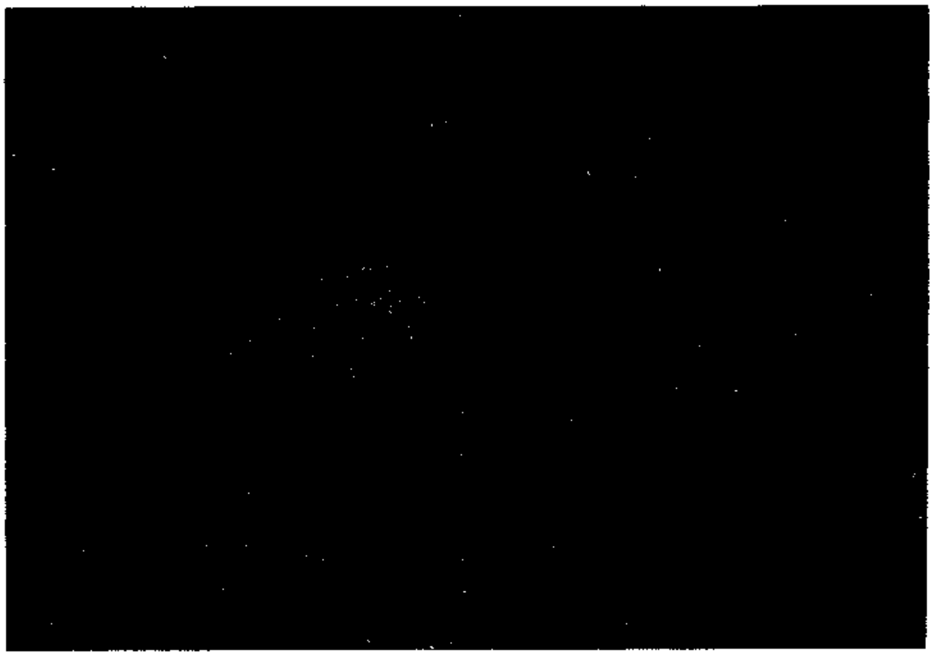

Fig. 5. Organs of the thorax in situ: h: heart, li: liver, lu: lung, t: thyroid, th: thymus tr: trachea.

Histopathologically there are foci of necrosis with the formation of heterophilic granulomas in the medulla close to the centre of the lobules (Fig. 6). Different stains failed to reveal the presence of micro-organisms. This condition could possibly form part of the normal process of thymic involution, although unlikely with the severity of inflammation, or it could have been caused by stress from intensive production methods. In the latter case there might be ill effects with regard to the immune system.

Pharyngitis

The basihyal valve, particularly its dorsal part, normally contains lymphatic tissue, which can be assumed to serve a role similar to the tonsils of man and other mammals.

A few members of a group of small one-year-old crocodiles, which had been transported by road over a very long distance, died after the event and showed severe swelling and reddening of the basihyal valves and the pharynx (Fig. 7). Again microbiological investigations gave negative results. Since then the condition has been observed sporadically in single cases of mortality. Because of the supposed tonsil-like function of the dorsal part of the basihyal valve the condition has also been referred to as tonsillitis.

Fig. 6. Thymic necrosis: Thymus with necrotic area surrounded by granuloma tissue.

Fig. 7. Inflammation of dorsal basihyal valve and pharynx.

While one would prefer to report the results of successful investigations, a need was felt to bring the above-mentioned conditions to the attention of veterinarians and researchers working in the same field, in the hope that some discussion and/or correspondence might ensue.

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Cox Lagoon: A Preserve for *Crocodylus moreletii* in Belize?

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ABSTRACT

Cox Lagoon is a 4 km extension of Cox Creek located approximately 40 km west of Belize City, Belize, Central America. The open fresh water of Cox Lagoon is surrounded by swamp forest, sedges, palms and marsh with grasses. Morelet's crocodiles, *Crocodylus moreletii* concentrate in the lagoon and can be observed in daylight hours. Other significant wildlife inhabiting the area include jabiru storks *Jabiru mycteria*; king vultures, *Sarcoramphus papa*; tapirs, *Tapirus bairdii*; howler monkeys, *Alouatta pigra* and jaguars, *Panthera onca*. The wetlands of the Cox Lagoon area have been determined to be critical habitat but the property has been in receivership for 10 years. Currently, the Belize Finance Ministry is responsible for the disposition of the 14,600 ha Big Falls Rice Farm which contains Cox Lagoon. We propose that 13,000 ha of the farm be protected with a management plan catering to ecotourism and featuring *C. moreletii*.

INTRODUCTION

Populations of Morelet's crocodiles, *C. moreletii* have been generally depleted in Mexico, Guatemala and Belize (Messel et al., 1992). In Belize, Abercrombie (1980) found *C. moreletii* to be depleted in areas of human settlement but abundant in inaccessible areas. Historically, a number of forces have combined to preserve *C. moreletii* in Belize: much habitat is inacessible by road, thus limiting interactions between crocodiles and humans; subsistence hunters have not united to hunt crocodiles and commercial hunters have not intensely focused on crocodiles (Hope and Abercrombie, 1986). For 10 years crocodiles have been protected from commercial exploitation by the Wildlife Protection Act. In 1982 the act initiated a moratorium which forbids the dealing for profit in any wildlife and additionally bars the hunting of 34 species of animals including C. moreletii.

In northern Belize, Mussel Creek and its upper branches (Cooks Lagoon, Mucklehany Lagoon, Upper Batlass Creek and Cox Lagoon) have been proposed as a preserve for rare water birds and crocodiles (Hartshorn et al., 1984). Abercrombie (1980) identified Cox Lagoon as a candidate for a crocodile reserve. Currently, we are recommending that 13,000 ha of Big Falls Rice Farm (BFRF) including Cox Lagoon be protected as a government preserve featuring C. moreletii. With an ecotourism management plan, a Cox Lagoon crocodile preserve would have a broad spectrum appeal for canoeists, hikers and naturalists.

LOCATION OF BFRF

The unimproved dirt road to BFRF intersects the Western Highway near mile marker 24 on Land Parcel (LP) 49 of Retaliation property. Road distance from the Western Highway to BFRF is 4 km. BFRF contains 14,700 ha in three parcels of land: LP 47 Coquericot- 5700 ha; LP 50, Big Falls and Monkey Run- 4500 ha and LP 53, Erindale- 4500 ha (Figs. 1-2). Cox Lagoon is contained by LP 50 and 53.

DESCRIPTION

Average annual rainfall in the region is 1300-2000 mm; soils are composed of siliceous limestone with flints and characteristically have low fertility and slow internal drainage; BFRF is in the subtropical moist forest life zone and characteristically supports mahogany, caoba sapote, sapodilla, breadnut, allspice, chicle, bullhoof, ironwood, cohune and nargusta (Hartshorn et al., 1984). Access to BFRF is provided by a network of unimproved dirt roads. Cleared land covers 24% of the property and includes 12% farmable land. Wild and wet lands cover the remainder of BFRF. With swamp and marsh, its wetlands provide important habitat for wildlife. Cox Lagoon, a 4 km extension of Cox Creek, appears to be in pristine condition with abundant wildlife.

HISTORY

In the period before 1982, huge investments were made on the property for the purpose of rice production but these investment efforts failed to make rice a profitable crop. In 1982, the Panamanian Bank Obdella placed BFRF in receivership and named Godwin Hulse manager. Total price of BFRF was three million U.S. dollars. Because of loss of capital, rice production ceased in 1987 and since then farm facilities have declined. Currently, one large generator and pump are still operational and approximately 1800 cattle provide the only farm product with 10-14 shipped weekly.

In the past, access to BFRF was effectively monitored by farm staff. Currently, there is an apparent increase in subsistence and recreational hunting. Near Cox Lagoon, temporary bush camps are being used as bases for squatters growing small crops and poachers illegally hunting protected wildlife. In dry season subsistence hunters walk to Cox Lagoon from the road or paddle dugouts from Cox Creek. Recreational hunters use bicycles and autos to patrol roads. On 27 Feb., 1992 while examining two human bodies that we had discovered on the road to BFRF, police questioned recreational hunters driving an automobile. They identified themselves as employees of the Belize land department and said that they were shooting at animals crossing the road. It is probable that if the number of refugees and Belizeans irresponsibly using the resource increases diversity of wildlife on BFRF will decrease and the value of BFRF as a preserve will equally diminish.

WILDLIFE LIST

A. Methods

This list was prepared from 40 hours of observations on 7-10 March, 1990 and 90 hours of observations on 21 February-7 March, 1992. Ten km of roads and 5 km of Cox Creek and lagoon were monitored. From 17°25'50"N, 88°33'20"W in Cox Creek to 17°28'25"N, 88°31'45"W in Cox Lagoon, spot light counts of crocodiles were conducted from a 6 m canoe with one observer, one recorder and one paddler. Crocodiles were counted from 1830 to 2100 h on 28 Feb., 1990 and from 2000 to 2230 h on 21 Feb., 1992. Environmental parameters: the moon phase was crescent in 1990 and full with clouds in 1992; water temperature at 10 cm was 24°C in 1990 and 25°C in 1992; water level difference in the two periods was 12 cm.

MAMMALS

Felis pardalis, ocelot- tracks observed
Felis yagouroundi, jaguarundi
Panthera onca , jaguar- tracks observed
Urocyon cinereoargenteus, gray fox
Tapirus bairdii, Baird's taipir- Two were observed in the lagoon; one complete skeleton found in hunter's camp.
Mazama americana, red brocket deer
Odocoileus virginiana, white tail deer
Alouatta pigra, black howler monkey
Nasua nasua, coati-mundi
Potos flavus, kinkajou
Didelphis virginiana, Virginia opposum
Philander opossum, 4 eyed opossum
Agouti paca, gibnut

Molossops malagai, Mexican free-tailed bat
Noctilio leporinus, fishing bat
Saccopteryx bilincata, white-lined bat
Uroderma bilobatum, tent-building bat
Lutra longicausus, river otter
Tamandua mexicana, tamandua

BIRDS

Podilymbus podiceps, pied-billed grebe
Phalacrocorax olivaceus, neotropic cormorant
Anhinga anhinga, anhinga
Ardea herodias, great blue heron
Bubulcus ibis, cattle egret
Butorides virescens, green-backed heron
Casmerodium albus, great egret
Cochlearius cochlearius, boat billed heron
Egretta caerulea, little blue heron
Egretta thula, snowy egret
Egretta tricolor, tricolored heron
Tigrisoma mexicanum, bare-throated tiger heron
Jabiru mycteria, jabiru stork
Mycteria americana, wood stork
Eudocimus albus, white ibis
Anas discors, blue winged teal
Carthartes aura, turkey vulture
Coragyps atratus, black vulture
Sarcoramphus papa, king vulture
Pandion halizetus, osprey
Busarellus nigricollis, black-collored hawk
Buteo magnirostris, roadside hawk
Buteo nitidus, gray hawk
Buteogallus anthracinus, common black hawk
Elanoides forficatus, swallow-tailed kite
Harphyaliaetus solitarius, solitary eagle
Rostrhamus sociabilis, snail kite
Spizaetus tyrannus, black hawk eagle
Falco rufigularis, bat falcon
Herpetotheres cachinnans, laughing falcon
Aramus guarauna, limpkin
Aramides cajanea, gray-necked wood rail
Laterallus ruber, ruddy crake
Heliornis fulica, sungrebe
Jacana spinosa, northern jacana
Charadrium vociferus, killdeer
Actitis macularia, spotted sandpiper
Himantopus mexicanus, black-necked stilt
Columba flavirostris, red-billed pigeon
Columbina minuta, plain-breasted ground-dove
Columbina passerina, common ground dove

Columbina talpacoti, ruddy ground dove
Leptotila verreauxi, white tipped dove
Amazona autumnalis, red-lored parrot
Amazona xantholora, yellow lored parrot
Aratinga astec, Aztec parakeet
Crotophaga sulcirostris, groove-billed ani
Otus guatemalae, vermiculated screech owl
Nyctibius grandis, great potoo
Nyctidromus albicollis, common pauraque
Otophanes yucatanicus, Yucatan poorwill
Amazilia candida, white-bellied hummingbird
Amazilia tzacatl, rufous-tailed hummingbird
Phaethornis superciliosus, long-tailed hermit hummingbird
Trogon citreolus, citreoline trogon
Ceryle alcyon, belted kingfisher
Ceryle torquata, ringed kingfisher
Chloroceryle aenea, pygmy kingfisher
Chloroceryle amazona, Amazon kingfisher
Chloroceryle americana, green kingfisher
Pteroglossus torquatus, collared aracari
Campephilus guatemalensis, pale-billed woodpecker
Dryocopus lineatus, lineated woodpecker
Melanerpes auriforons, golden-fronted woodpecker
Melanerpes pygmaeus, red-vented woodpecker
Lepidocolaptes souleyetii, streak-headed woodcreeper
Xiphorhynchus flavigaster, ivory-billed woodcreeper
Thamnophilus doliatus, barred antshrike
Camptostoma imberbe, northern beardless tyrannulet
Megarhynchus pitangua, boat-billed flycatcher
Myiobius sulphureipygius, sulphur-rumped flycatcher
Myiozetetes similis, social flycatcher
Pitangus sulphuratus, great kiskadee
Todirostrum cinereum, common tody-flycatcher
Tyrannus vociferans, Cassin's kingbird
Petrochelidon fulva, cave swallow
Petrochelidon pyrrhonota, cliff swallow
Tachycineata albilinea, mangrove swallow
Psilorhinus morio, brown jay
Thryothorus maculipectur, spot-breasted wren
Uropsila leucogastra, white-bellied wren
Thryothorus pleurostictus, banded wren
Dumetella carolineansis, gray catbird
Melanoptila glabrirostris, black catbird
Mimus gilvus, tropical mockingbird
Hylocichla mustelina, woodthrush
Seiurus motacilla, Louisiana waterthrush
Vireo griseus, white-eyed vireo
Vireo pallens, mangrove vireo
Vireo solitarius, solitary vireo

Dendroica dominica, yellow-throated warbler
Dendroica magnolia, magnolia warbler
Dendroica petechia, yellow warbler
Dendroica tigrina, Cape May warbler
Geothlypis trichas, common yellow throat
Mniotilta varia, black and white warbler
Setophaga ruticilla, American redstart
Wilsonia citrina, hooded warbler
Agelaius phoeniceus, red-winged blackbird
Amblycercus holosericeus, yellow-billed cacique
Cassidix mexicanus, great-tailed grackle
Dives dives, melodious blackbird
Gymnostinops montezuma, montezuma oropendola
Icterus prosthemelas, black-cowled oriole
Zarhynchus wagleri, chestnut-headed oropendola
Eucometis penicillata, gray headed tanager
Habia fuscicauda, red-throated ant tanager
Sporophila torqueola, white collared seedeater
Sporophila aurita, variable seedeater

REPTILES

Dermatemys mawii, hickety turtle - In the lagoon, remains of adult turtles were found in two hunters' camps; predators destroyed eggs at three nest sites.
Pseudemys scripta, bakatura turtle
Basiliscus vittatus, striped basilisk
Leptodeira septentrionalis, cat-eyed snake
Drymarchon corais, cribo

Crocodylus moreletii, Morelet's crocodile

2-28-90	10	juveniles (.4-1 m estimated total length)
	27	subadults (1-2 m etl)
	2	adults (> 2m etl)
	39	
2-21-92	18	juveniles
	7	subadults
	9	adults
	44	

If there was an actual increase in adult crocodiles and a decrease in the number of subadults over the two year period, it might indicate that subadults are being excluded from a breeding area (Hunt 1977; Messel 1987). In Belize, it is possible that egg incubation periods coincide with the April-June nesting period in Chiapas, Mexico (Perez -Higareda 1980). During our activities in Cox Lagoon we did not locate nests but near Mussel Creek, John Polisar (pers. comm.) found a nest mound with eggs. Apparently, most Belizean hunters are unable to identify or locate crocodile nests (Hope and Abercrombie 1986). Jack Rhaburn (pers. comm.), a master Belizean hunter, knew the dimensions of a Dermatemys egg but could not accurately describe a crocodile nest or egg. After guarding their nests during egg incubation, captive C. moreletii exhibited extended maternal behavior: pods of neonates were guarded and interactions with offspring occurred (Alvarez del Toro 1974). At Zoo Atlanta, females also guarded juveniles (<50 cm in length and <1 year of age) from humans (Hunt 1977). In south and north Cox Lagoon we located two pods of nine young (.4 m etl). Neither of the pods was within 100 m of an adult but it was possible that interactions occurred when humans were not present. Many crocodiles, however, did not seem to be wary of humans. On six occasions in daylight hours of 1990 and 1992 we observed a large crocodile (3.25 m etl) and smaller crocodiles were commonly visible during daylight hours. This visibility of the crocodile population makes the area especially attractive for impatient tourists.

JUSTIFICATION FOR MANAGING COX LAGOON AS A CROCODILE PRESERVE

As a tourist attraction, Cox Lagoon-BFRF is strategically located near Belize City, the Community Baboon Sanctuary and the Belize Zoo. In world conservation strategy, ecotourism can provide income and employment (Munro and Holdgate 1991). It is probable that ecotourism will be increasingly important as a source of revenue in Belize and that BFRF will be a significant contributor if it can be effectively protected.

A diversity of wildlife can be seen on BFRF with minimal investments of time. We observed over 100 species of birds during our observation periods. On three successive days we observed jabiru storks. On four successive days we observed groups of howler monkeys. On two occasions, we observed tapirs. In promoting BFRF as an area for observing wildlife, the crocodiles of Cox Lagoon should be the feature animal. Sighting a large predator in the wild is an exciting experience for visitors and with a large population of crocodiles in Cox Lagoon, such an experience is predictable. With less predictability sightings of jaguars are also something tourists can hope for; on two occasions we found cracks; Pat Shaw (pers. comm.) of BFRF has seen the large cat crossing roads and further reports that jaguars have not preyed on cattle at the farm.

Although subsistence hunters have impacted wildlife in some areas of Belize (Rabinowitz 1986), it is probable that wildlife utilizing BFRF have not been subjected to intense exploitation from either subsistence or commercial hunting. This abundant and visible wildlife is a valuable living resource which can promote tourism.

Land Parcels 47,49,50,53 and 55 contain important wet land corridors (Fig 1). Mussel Creek and its upper branches including Cox Lagoon, Mucklehany Lagoon and Cooks Lagoon have been identified as important freshwater habitat for wildlife and have been proposed as a reserve (Hartshorn et al. 1984). Cox Lagoon is an important link in these wetlands and the opportunity for securing its protection should not be missed.

MANAGEMENT NORTH OF DOUBLE DIKES

1. The 1600 ha contained in this cleared section could be leased for agriculture. Food crops could be grown on 200 ha sections or pasture for cattle could be leased in 400 ha sections which could be leased to farmers.
2. Small parcels of land on the Belize River should be developed for tourist lodging,
3. Lodge and lease operations should include road maintenance.
4. Farm operations should be compatible with the interests of the adjacent preserve: lodge developers must maintain a forest corredor for howler monkeys; farmers can not use pesticides or herbicides in the preserve; no one can engage in hunting inside the preserve; the boundary between preserve and farm must be strictly observed.

MANAGEMENT SOUTH OF DOUBLE DIKES: COX LAGOON CROCODILE PRESERVE (Fig.2)

1. At the intersection of BFRF and Retaliation (LP 49), a guard station should be maintained during daylight hours. After dark the gate should be locked.
2. At the intersection of BFRF road and Cox Creek, a reception center should be established. At the center bicycles and canoes could be rented. With permits issued at the preserve, canoeists would occupy three designated camp sites in Cox Lagoon. Hiking and bicycling trails would provide access to other areas of the preserve.

STAFF

Manager- The Belize Audubon Society could appoint or approve a manager to be steward of the preserve.
Wardens- Two would provide security, prevent poaching and trespassing.
Intern Wardens- Volunteers from North American zoos could assist wardens. For each year of operation, a pool of 24 interns would be selected and trained by a coordinator. In Belize, two interns would work for one month and then would be rotated back to the U.S.

FUNDING

1. Salaries, travel cost and maintenance of interns should be provided by zoos.
2. With a plan to manage BFRF as a crocodile preserve, American zoos of the American Association of Zoological Parks and Aquariums and their associated contributors might be sources of funding for a long-term lease or purchase.
3. Tour groups and individual tourists should be charged a substantial fee for entering the preserve and campers should be charged an additional fee. Profit from facility fees and equipment rentals should go directly into operation of the preserve.

PROPOSAL

We sent a proposal recommending government sanction of BFRP Cox Lagoon as a preserve featuring C. moreletii to the Ministry of Tourism, the Ministry of Natural Resources and the Belize Audubon Society. In July, 1992, however, the property was sold and we are currently hoping to negotiate with the owners on the preservation of Cox Lagoon.

ACKNOWLEDGMENTS

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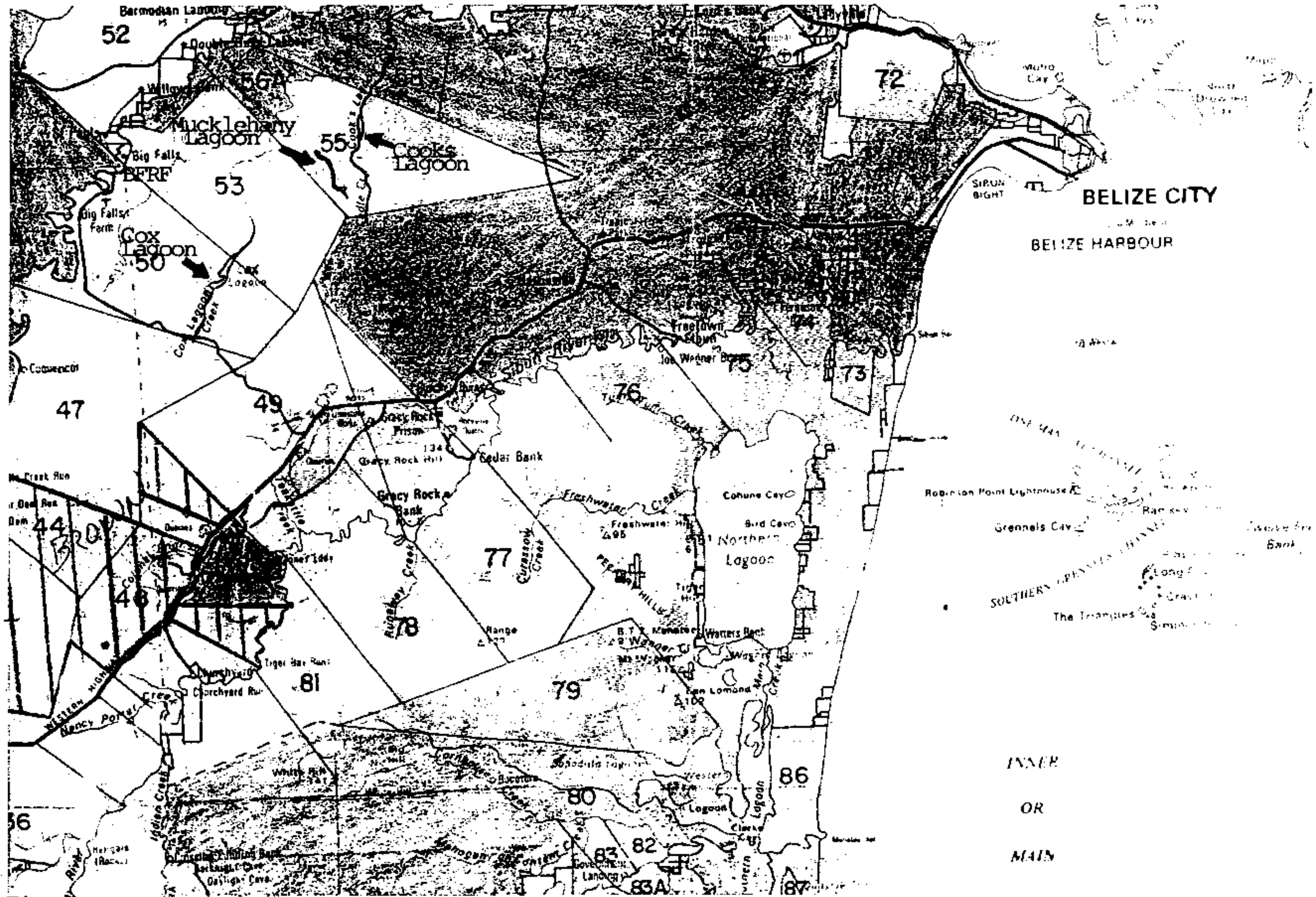

Fig. 1. Land Parcels containing Cox, Cooks and Muclehany Lagoons

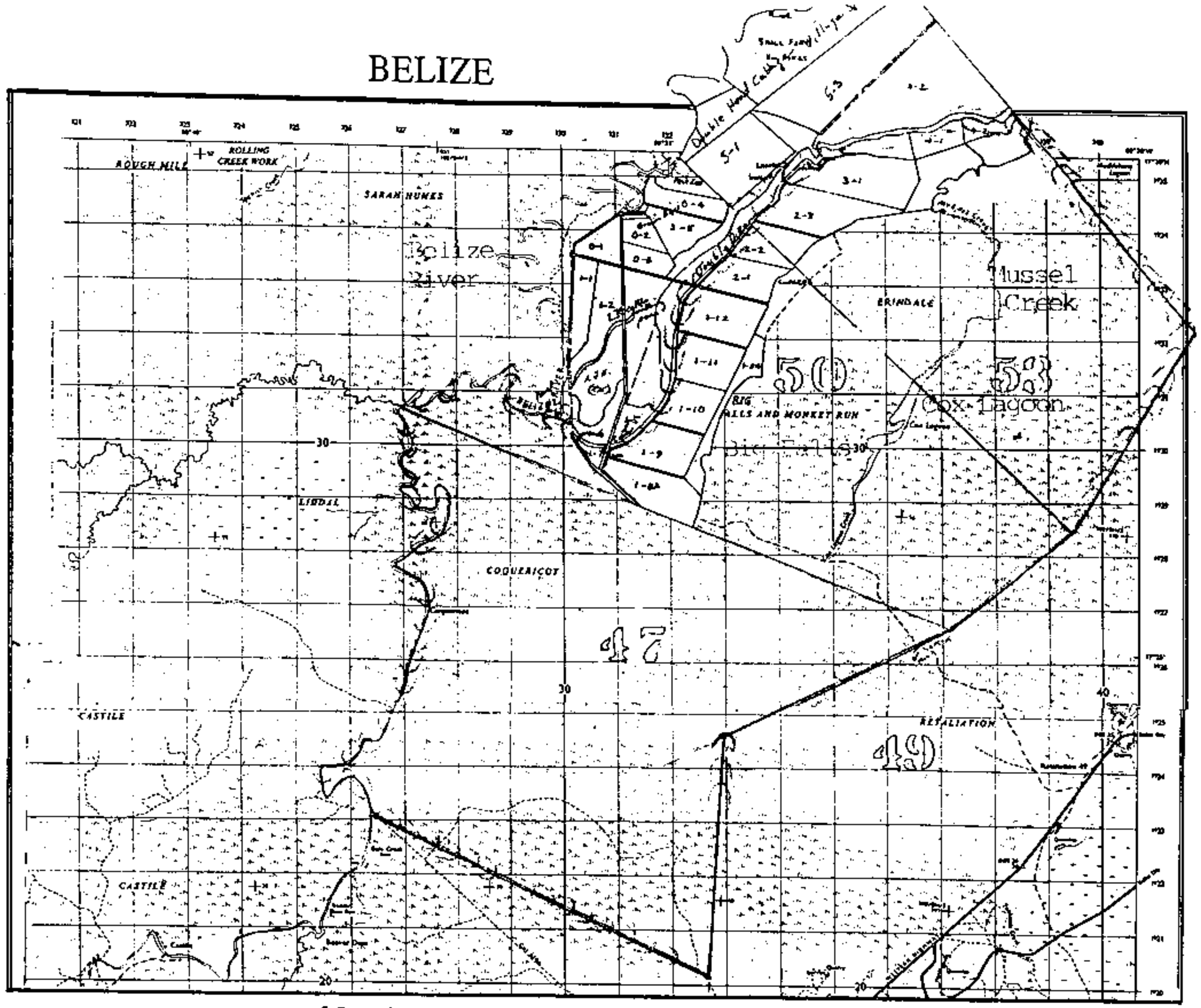

Fig. 1. Proposed Cox Lagoon Crocodile Preserve

HUMANE KILLING OF CROCODILIANS

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Introduction

The ranching and farming of crocodilians for conservation and commercial purposes requires that large numbers of animals are killed every year for their produce: skins and meat.

Traditionally, crocodilians have been killed by direct destruction of the brain, commonly by shooting. Changes in technology have moved a significant portion of rearing stock into indoor enclosures where shooting is impractical. In addition, in some cases the skull of the animal is a valuable product which would be destroyed by shooting. Following these changes in husbandry, the crocodile industry has encountered accusations of inhumane killing, principally from animal rights organizations.

In Germany (Jelden, pers. comm.) animal welfare groups and the press have suggested:

1) That in Florida and Singapore crocodilians are skinned alive because this gives a better quality product.
2) Vertebrae of the crocodilians are broken to prevent the animals injuring handlers.

The claims are, of course, ludicrous, but many crocodile conservation problems now rely on crocodile harvesting and it is of great concern that markets may be affected by extreme animal rights organizations. This brief paper addresses the issue of humane killing and makes a number of interim recommendations.

Killing methods

Shooting

The majority of crocodilians on farms and ranches are still killed by shooting very much in line with a report entitled 'Euthanasia of Amphibians and Reptiles" by the Universities Federation of Animal Welfare (UFAW) which recommended that crocodilians be killed by destruction of the brain with firearms. A small bore rifle, handgun or captive bolt was suggested for immature, farm animals.

However, UFAW also recommended that penetrating instruments be directed from the front of the animal between, but slightly caudal to the eyes. This recommendation is impractical in a farming situation. Under present management systems it would require that a live round is fired in the direction of handlers, which is unsafe.

Spinal cord severance

Many producers have moved to a method of killing known in the USA as the nape-stab in which the spinal cord is severed.

A recent report (Warwick 1990) showed that in one case, in Florida, spinal severance took 5-8 blows (of a hammer on a chisel). After some tests it was concluded that the animals in question were conscious long after their spinal columns had been severed and that the system was inhumane. Although the experimental design was extremely poor, the information presented does strongly support the conclusions made.

Spinal cord severance is commonly used in Zimbabwe, but is concluded by one blow of a heavy hammer on a sharp chisel after which the head is immediately bent forward and a sharpened stainless steel rod used to "pith" and destroy the brain. The time between the hammer blow and brain destruction is less than 2 seconds.

This is clearly an advance on the method described by Warwick from Florida, but the question must still be raised: Is the method humane?

Determination of this hinges on whether the severance of the spinal cord causes sufficient neurogenic shock to result in a loss of consciousness before the brain is destroyed. The workshop of experienced veterinarians at the 11th Working Meeting of the Crocodile Specialist Group discussed this matter and was of the unanimous opinion that method used in Zimbabwe (of spinal severance with a chisel, followed immediately by pithing) does result in immediate unconsciousness and is humane. It was also noted that further detailed investigations on methodology are continuing in several producer countries.

Recommendations on killing methodology and research

The use of firearm/captive bolt systems is clearly preferred for killing crocodilians in a farming situation, but more research on methodology is needed because practically, the trajectory of any firearm should be from the rear of the head, away from handlers. Even though UFAW suggest that substantial layers of bone may interfere with and deflect bullets or bolts when this trajectory is used, it is likely that the animal will be stunned. To avoid critisism it is strongly recommended that even when this method is used the spine is severed and the brain destroyed by pithing.

It is clear that the addition of pithing to the nape stab method constitutes an essential, immediate improvement over the nape stab alone. Where firearms are unavailable this method should be universally adopted until further research suggests otherwise.

Conclusions on the Animal Rights issue

The accusations put forward by animal rights activists seem to have resulted from the report in the Texas Journal of Science, but are so widespread as to suggest an orchestrated campaign against the industry. Similar suggestions have appeared elsewhere in the world (such as the magazine "Common Cause", (April-June 1992; Action Aid, UK)) and have caused concern within the British Royal Society for the Prevention of Cruelty to Animals (Dr. A. Lindley, Wild Life Dept., RSPCA, pers. comm.)

To counter this tendency, the following is suggested:

1. The industry undertake or fund further research on routine humane killing methods for crocodilians.

2. The CSG remain receptive to reports of inappropriate methods of killing from all ranching and farming programmes and take any legitimate measures that are necessary to prevent inhumane slaughter.

3. That ranches and farmers take joint legal action against specific inaccurate accusations. Recently, the German fur industry undertook successful legal proceedings following irresponsible accusations made by an animal rights group. The financial loss effectively closed the offending group.

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CONSERVATION STRATEGY FOR CROCODILIANS IN AFRICA

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Introduction

A keynote address is intended to set the pace for the following sessions and we thank the CSG for providing the opportunity to articulate our African concerns with respect to the conservation of crocodiles. I hope we do indeed set the tone for this session.

It would be easy for us to detail, yet again, how crocodiles were hunted in the 1940s and 1950s, were protected and subsequently recovered. It would be easy laboriously to detail all countries' specific crocodile conservation and management procedures, but this would not constitute much of a keynote address. Instead, we are going to try and avoid specifics in favour of principles and general practices. Fundamental to our thesis will be CITES, a conservation tool which we believe is distorting our conservation priorities.

The Mixed blessing of CITES

The most severely endangered crocodiles in the world have reached this state because of habitat loss. Don't just take my word for it - read the IUCN Action Plan for Crocodile Conservation. There are 23 species of crocodilians. Of these, the CSG has identified that seven are actually endangered. None of these species is from Africa. A few species have virtually vanished from the wild, oue or two are almost extinct. All of these species are on CITES Appendix I. Indeed, they have been on Appendix I since the inception of CITES in the early 1970s, about 20 years ago.

CITES has not helped these species because CITES is only able to address international trade as a factor which is contributing to pressure on species, but these species have declined because of habitat loss. While CITES has not been very effective at conserving these species, it has been singularly effective in deflecting attention from their plight to more commercially important, but less endangered species.

There is a sad trend in the conservation community to view species on CITES Appendix I as saved. CITES is a sort of 20th century magic charm - warding off extinction. This is why in the last 20 years we have spent more time and resources on *Caiman crocodylus*, which is one of the commonest vertebrates of South America, than *Crocodylus intermedius* which is one of the rarest. Within Africa this trend is clearly manifest by the difference in the amount of knowledge we have on the Nile crocodile compared to the other two species, *Osteolaemus tetrapsis* and *Crocodylus cataphractus*.

Crocodylus cataphractus and *Osteolaemus* could be endangered, indeed, they could go extinct and it would be some time before anyone even noticed. We have neglected, and are neglecting species which have no commercial value in international trade and in encouraging this emphasis CITES has become a real liability. Of course, the fault doesn't lie with the Convention, flawed as it is, the problem is that we don't have any equivalent mechanism to address the real cause for species extinction - habitat loss (and I must say that we don't really see the new biodiversity convention as improving the situation). So in a mad rush to help, to contribute, to do some good, we over-emphasise and abuse CITES.

In Africa we have the Nile crocodile, the second most valuable of the crocodilians. The Nile crocodile has never been in danger of extinction, though easily accessible populations were severely reduced in the 1940s, 50s and even 60s. There is no single reason why over exploitation abated, but certainly in southern Africa legal protection was introduced well before CITES. Where human populations allowed, crocodile populations quickly built up. Any long-lived animal which lays up to 80 eggs a year is liable to build up quickly in depleted habitats, but this will only happen where human populations allow it. In some situations (in Uganda for example) human pressures mean that crocodiles will never return. The habitat may still be there, more or less, but it is denied to crocodiles.

It was after this time of severe exploitation that CITES did play a role with the Nile crocodile. As crocodile numbers built up so did pressure to start another round of utilisation, but this was effectively blocked by the Appendix I listing for the species. No doubt this seemed like a good thing in the 1970s, and it has perhaps worked out for the best, but it could have been a disaster for the Nile crocodile and it would have been if CITES had not adapted to new management situations.

This brings us to a most important point. The crocodiles, and especially the Nile crocodile, are at the cutting edge of contemporary conservation. Crocodilians are the only species for which CITES has adapted to fit in with species management, rather than constraining species management to fit in with CITES. And even for crocodiles the changes have been hard won and remain only partial. If we look at the Nile crocodile as our African example, we can now, from a 1990s perspective, see that 4-5 m man-eating predators do not stand much chance of long term survival in modern Africa where water resources are at a premium. The whole issue now seems obvious - crocodiles have to be valuable, very valuable, to survive outside protected areas. This is not just theory. This year, in southern Zimbabwe we are mounting a rescue operation for crocodiles affected by the most severe drought in living memory: animals will be returned once it rains again. Would we have bothered if the animals had no value? In fact, would there still have been any animals to save in this heavily settled area?

As recent as 1980 it looked as if the crocodile's value would be lost. In order to trade in Nile crocodile skin an African country had to obtain a down-listing of the animal to Appendix II under the Berne Criteria, something which was, and remains, virtually impossible, not so much because of the poor wording of the criteria as the way they are interpreted and enacted. It took immense pressure, first of all to have the conservation benefits of controlled trade recognised, then to have the ranching system adopted and then to have the separate country populations down-listed according to these new criteria. Many countries found the process too expensive.

In 1985, by sticking together, African countries managed to introduce more innovations to CITES - the special criteria or quota system was introduced. The idea was to allow utilisation under quotas with the aim of financing the introduction of ranching at a later date. Quotas were meant to he temporary and later, in 1989, this was written into the system when it was reviewed. This period saw a massive investment in Nile crocodile research and management. In fact, by 1989 a few conservationists were heginning to wonder at the emphasis on a species which, it was grudgingly agreed (in a preamble to the resolution on quotas), should never have been on Appendix I in the first place, especially if this effort was at the expense of other species ahout which little was known.

The Nile crocodile is not endangered as a species. Some marginal populations may have a tentative hold, but this is analogous to alligators in the USA's North Carolina. No trade ban will increase a species on the edge of its range, nor will a ban increase a species affected hy habitat loss. This is where we find fault with the ranching system. The ranching criteria are focused on countries rather than species "in essence, they continue the han while allowing some very limited, individual operations to recommence" (Swanson and Barbier 1992). This, essentially, is why there was such pressure to introduce the quota system and why the whole CITES procedure for the Nile crocodile - and other species - is now so complicated.

It is likely to get more complicated too. While the conservation status of the Nile crocodile is secure, in many cases this has been achieved through the use of commercial trade as a conservation tool. We have always been aware that there are dangers in this approach - not least when powerful commercial interests clash with long term conservation aims - but the market place holds other dangers too. How is the present slump in crocodilian leather business going to affect conservation? From our African perspective it seems likely that many ranching schemes will not survive. In addition, the depressed market is distorting the relative advantages of ranching and cropping from the wild. When prices were high, the high investment and operation costs of ranching were economically acceptable and we were able to travel around Africa recommending this harvesting strategy over cropping, which is demographically much more risky. Now that much of east and central Africa has gone ranching and are having problems with it, what do we tell our colleagues in west Africa?

We see a need for new mixed harvesting strategies for Africa so that we can try and reduce the cost of producing hide while keeping the risk to populations low. In this regard we are inspired by the work with Green Iguanas in Central America in which the animals are hatched and maintained for a short period in captivity before release back into the wild where they are ultimately hunted (Werner 1991). If we could treat Nile crocodiles in this way the costs of rearing would be dramatically reduced and dependence on wild ecosystems would be increased thereby increasing our conservation benefits.

Such a scheme is, we believe, workable. One of the main impediments will be CITES.

Assuming that the target population starts on Appendix I, the present complex set of resolutions would allow a mixed strategy to start under the quota system, but because quotas are temporary it would very soon be necessary to move the affected population to Appendix II either under the Berne Criteria or the ranching criteria, neither of which is really appropriate. If the population is already being ranched any change of management also requires attention from CITES and as sometbing new is likely to be viewed with considerable scepticism.

What is needed is a review of CITES as it affects crocodiles and to start we have to try and take a more global view and avoid becoming mired in detail. The system needs simplifying and to become more flexible so that mixed harvesting strategies can be accommodated.

This brings us back to the title of this keynote address, our conservation strategy for the Nile crocodile involves the introduction of a new quota system for Appendix II which would obviate the need for a split listing. In practice, the whole species would be placed on Appendix II, each range state receiving an appropriate quota approved by the C.O.P. in the first instance. Countries harvesting through ranching would very easily obtain quotas, those wishing to crop from the wild would require more biological information and would receive smaller quotas in line with the increased risk to the species. Those with small populations (on the edge of the species range, or with degraded habitat or a history of over-exploitation) could receive a zero quota.

Since we also happen to believe that this system would have wider application, not only to other crocodilians, it would appear likely that, once more, crocodiles will be setting the pace in CITES.

The Difficult Species

This consideration of CITES has once again focused all our attention on the Nile crocodile, which is under no threat whatsoever. What of our other two African species, what strategy is there for them? The answer is that there is none.

Although not as significant as the Nile crocodile, these species have some commercial value, both for hide and meat, but most of this is internal rather than international and the role of CITES, and therefore the international profile of the species, is limited. However, CITES is starting a crocodile project in west Africa and, to the credit of the Secretariat, management issues for *C. cataphractus* and *Osteolaemus* will be important even though they are both on Appendix I and not presently traded.

Conclusion

In conclusion, there seems to be no immediate answer to the conundrum of CITES and its effect on conservation priorities. We hope that sometime in the future the conservation significance of international trade in wild species will finally be recognised as <u>secondary</u> to loss of habitat and even the local use of wild species. Until that time the Nile crocodile will have a disproportionately high profile in our African crocodile conservation strategy.

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EFFECTS OF NEW INTERNATIONAL CONTROLS ON THE CROCODILIAN SKIN INDUSTRY - AN UPOATE OF RECENT CITES RECOMMENDATIONS -

by

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At the 8th Meeting of the Conference of the Parties of CITES at Kyoto, Japan, in March 1992 four resolutions were adopted, which do not only significantly affect the crocodilian farming or ranching industry. Moreover the new resolutions also provide for stricter rules concerning the international trade with crocodilian skins, their parts and derivatives thereof.

The intention behind this paper is to give a very general and easily to understand overview on the content of the new CITES resolutions which are of some significance to the crocodile skin or leather industry.

Universal tagging system for the identification of crocodilian skins (Res. Conf. 8.14)

This resolution demanded by the IUCN Crocodile Specialist Group from the international conservation community for many years, in order to better control the still extensive illegal international trade in crocodilian namely caiman skins, provides for the tagging of all crocodilian skins or parts thereof, irrespective of whether they come from a species listed in Appendix I or II of CITES and irrespective of whether the skins come from farming and ranching projects or have been taken from the wild.

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Other highlights of the resolution in brief:

- Only whole skins, flanks, bellies, tails, throats, legs and feet are to be tagged.
- Standardized tag information should also be given on CITES documents accompanying each shipment
- From June 1993 onwards parties should only accept any shipment if skins are tagged and tag information is quoted on CITES documents.

Use of coded microchip implants for marking live animals in trade
(Res. Conf. 8.13)

The resolution aims at microchip marking for identification of only CITES - Appendix I animals moving for instance between zoos, circuses, with travelling exhibitions or as high value personal pets. In this respect it could also affect the transfer of one or another crocodilian species. Furthermore the resolution acknowledges the need for standardisation of the type of microchip being applied, including the location of implants, as well as the general access of all CITES parties to a central data bank with the retrievable chip information.

Additional criteria for the establishment of captive breeding operations and for the assessment of ranching proposals for crocodilians
(Res. Conf. 8.22)

Initially it was the intention to persue two aims with this resolution:

Firstly the resolution should once more make it very clear that if a crocodilian resource is used commercially, ranching on the basis of egg or hatching collection, as a very robust option, is the preferable management scheme which in contrast to pure farming can contribute significantly to a secure management of wild crocodilian populations.

Secondly, because of some irregularities in the past, where commercial farming and ranching operations had harvested wild subadult and adult animals indiscriminately from the wild, the international conservation

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community consented to the need of establishing some stricter rules to prevent such shortcomings in the future.

Major highlights of this resolution are:

- with regard to farming:
  - Only under certain circumstances should animals caught from the wild be allowed to form the breeding stock.
  - The registration of farms with the CITES-Secretariat should only be accepted if breeding animals have not been acquired by depleting populations in the wild.
- with regard to ranching:
  - The projects should be limited to the way of exploitation of wild populations as initially approved by the Conference of the Parties to CITES and any change of programmes for harvesting wild animals should only be started after consultation of the CITES-Secretariat.
  - Any programme including a wild adult harvest should be examined more stringently before an approval than those based only on egg or hatching collection.
  - Any programme aiming at a long term commercial harvest of wild animals has to satisfy the criteria ("Berne Criteria") for down-listing a population from CITES Appendix I to II as adopted at the 1st Conference of the Parties (COP), i.e. there must be positive scientific evidence, among others by a well documented population survey showing recovery of the population, and that the crocodilian species concerned can withstand the planned exploitation.

Guidelines for a procedure to register and monitor operations breeding Appendix - I animal species for commercial purposes (Res. Conf. 8.15).

This is not a really new resolution. First of all it is a complete revision of different resolutions (Conf. 4.15, 6.21, 7.10) on the same topic, which had been adopted at previous CITES conferences. It there-

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fore contributes to an acknowledgeable simplification of the increasingly difficult to understand CITES regulations.

Major highlights of the resolution are:

- Principal responsibility for approval of a captive breeding operation lies with the Management Authority of the party concerned.
- The CITES-Secretariat will get more involved in the registration process than before, e.g. if the CITES-Secretariat agrees and if no party has any objections, a captive breeding operation can now be registered without putting it to a vote at the next Conference of the Parties (COP).
- For any species known being difficult to breed or difficult to distinguish from wild taken specimens, additional criteria for registration can be established by parties or by the CITES-Secretariat.
- Finally the resolution defines very clearly in its four appendices which of the following institutions has what kind of responsibility in the process of registration:
  - the captive breeding operation
  - the Management Authority of the party concerned
  - the CITES-Secretariat
  - the CITES-parties.

Final comments

Since the 1st COP now more than 150 CITES resolutions have been adopted in order to help improve the effectiveness of the Convention. Many of these resolutions are meanwhile out of date, but the majority does still apply. With each CITES-conference more resolutions are adopted whereas others are repealed. This has created over the years a situation where it has become increasingly difficult to overlook the whole system of recommendations. For instance someone completely unfamiliar with all these CITES regulations but who has the intention to start a crocodile ranch must cope today with at least five basic resolutions (3.15, 5.16, 6.22, 7.11, 8.22) containing various rules to follow.

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This is an unbearable situation and does not help to further the improvement of the application of CITES, the major aim resolutions should actually fulfill.
What is needed now and the sooner it is put into practice the better, is an entire revision of the CITES-resolution system.
The IUCN/SSC - Crocodile Specialist Group should therefore as it has done in the past take its share and contribute as much as possible to the accomplishment of this considerable but rewarding task.

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*) Anyone interested in obtaining the above mentioned resolutions in their original version may contact the

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SEQUENCE OF NESTING, CLUTCH SIZE, AND HATCH RATE FOR ALLIGATORS IN SOUTHWEST LOUISIANA

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Introduction

In 1989, the Louisiana Department of Wildlife and Fisheries initiated a study to investigate the relationship of nesting sequence, clutch size, fertility, and hatching rates for alligator (*Alligator mississippiensis*) eggs collected on its Rockefeller Refuge. The refuge is located in southwest Louisiana and comprises 32,400 ha of coastal marshland. The refuge is bounded on the south by the Gulf of Mexico and on the north by the Grand Chenier-Pecan Island stranded beach ridge complex.

Marsh elevation averages 33.5 cm above mean sea level. Tide water enters the refuge from the Gulf of Mexico through five major channels. Freshwater run off from the north flows through the refuge and dilutes the salty gulf water. As a result of complex water flow patterns, marsh types on the refuge are diverse and consist of fresh, intermediate, brackish, and saline (Joanen and McNease 1989). Eggs were collected in intermediate and brackish marsh.

The primary objective of Rockefeller Refuge egg collections was to supply hatching year young to a fledgling farming industry. For this project, Department personnel collected, incubated, and hatched approximately 41,000 eggs over the three-year period, 1989-1991. As soon as the hatchlings began feeding they were distributed to farms within the state. The secondary objective of this project was to determine sequence of nesting in relation to clutch size, fertility, and hatchability.

The authors are grateful for the assistance of W. G. Perry, R. Elsey, and L. Theriot for the collection of field data and preparation of charts and figures used in this publication.

Methods and Materials

The peak of egg laying varies from year to year depending upon springtime temperatures, as previously described (Joanen and McNease 1989). In order to determine dates eggs were laid, field checks of nests were initiated at the onset of nest construction and continued throughout the egg laying period. Sequence dating of egg deposition according to individual clutch involved 2 methodologies to determine dates eggs were laid during 1989, 1990, and 1991 when large numbers of clutches were collected daily over a 30-day interval. One technique involved opaque banding of the eggshell. From the degree of opaque banding, we were able to accurately age eggs 5 days of age or less (Ferguson 1981) and then plot the sequence of nesting. A more refined method and one probably with the highest degree of accuracy for artificially incubated clutches, was to back date the number of incubation days from the date of first sign of hatching. Again, accuracy depended upon using freshly deposited eggs from wild nests collected no later than five (5) days after being laid.

Clutch size, fertility, and hatchability data from slightly over 1,100 nests monitored between 1989-91 were analyzed according to date eggs were deposited. The 30 day interval during which oviposition occurred were divided into 3 - 10-day periods. The periods were simply designated 1 through 3 chronologically. That is, number 1 was the earliest, 2 the mid, and 3 latest period. The progression of daily nesters is presented graphically as A through U, with A representing first clutches laid and U the last. Data on relationship of sequence of nesting (periods) on number of clutches (percent of clutches), average clutch size, percent fertile, and percent hatch were subjected to ANOV analysis. Alligator eggs were marked so as to preserve their original nest orientation. Each clutch of eggs was set individually in a single layer and completely enclosed with natural nest material and placed inside an environmental chamber as described by Joanen and McNease (1976).

These data involve eggs which were collected within a 20,000 ha area of Rockefeller Refuge. By keeping the study refined to a relatively small area, we were able to negate the effects of geographical variation on time of nesting and clutch size.

Results

Sequence of egg deposition was related to springtime ambient temperatures for alligators in southwest Louisiana. Nesting occurred earliest when March-April-May ambient temperatures were highest (Figure 1). Rainfall had no significant relationship with time of nesting activity although water levels did affect the degree of nesting (Joanen and McNease 1989). Egg deposition at Rockefeller Refuge occurred from 31 May to 2 July during the 3 years of study (Table 1). Most eggs, approximately 60%, were laid during the middle period (Figure 3). When number of clutches by period (percent clutches) was analyzed, a significant difference was noted (P = 0.033). Period 2 was significantly different from Period 3 (P = 0.030).

As described by McIlhenny (1935), alligators lay once in a season and deposit all of their eggs at one time, without any material being placed between the eggs. Our observations also indicate a single female deposits all of her clutch at one time, usually at night (Joanen 1969). The majority of egg laying takes place within a 2-1/2 week period each year. Collectively, all individuals in a population will require at least 3 to 3-1/2 weeks to complete nest construction (Joanen and McNease 1989).

Clutch size as reported by Joanen (1969) averaged 38.9 and ranged from 2 to 58 for Rockefeller Refuge. Figure 2 shows the relationship of clutch size and nesting sequence which indicated that nests containing the largest clutches are laid earliest. Nests which averaged 40 eggs per clutch (range 3-55) were laid during the first period of nesting (Figure 2) and represented 26% of the nesting population (Figure 3). The second sequence of nesting averaged 38 eggs per clutch (range 9-59). This group comprised the bulk of the nesting females and represented approximately 59% of the entire nesting population. The third and smallest nesting group comprised approximately 16% of the nesting population (Figure 3) and produced the smallest clutch size, averaging slightly under 35 eggs (range 4-53) per nest (Figure 2).

Average clutch size by period was significant (P = 0.015) over the three years. Between the individual periods, Period 3 was slightly different from Period 1 (P = 0.024) and Period 2 (P = 0.053).

Fertility rates for the three groups were found to be quite high and almost identical. Fertility averaged 96.5% for eggs laid within the first period of nesting and associated with the largest clutch size (Figure 2). The mid nesting group with the intermediate clutch size averaged 95.6% fertility. The late group of eggs laid were found to have a 96.6% fertility rate. Hatch rates were similar for the early and mid group; with 81.6% and 81.3% hatchability; whereas, hatchability for the late group averaged 73.2% (Figure 2). Neither percent by hatch nor percent fertility were found significant between periods, P = 0.361 and P = 0.503, respectively.

Discussion

Ferguson and Joanen (1983) suggest that social hierarchies favor breeding of larger females before smaller ones. They further suggest if smaller (young) females mate at all, they do so late in the breeding season. Therefore copulation and ovulation are slightly asynchronous for larger males breeding with small females. Also, Joanen and McNease (1989) found older and larger males produced sperm cells earlier than did younger males, thus the chances of older males copulating with small (young) females may be much reduced.

Lance (1989) reported the spermatogenic cycle can begin as early as November if the weather is unusually warm and that alligator testes collected in an exceptionally warm February had enlarged seminiferous tubules with actively dividing spermatogenic and primary and secondary spermatocytes. Normally, seminiferous tubules were greatly enlarged by late March and early April, and contained abundant secondary spermatocytes, but no mature spermatozoa. Mature spermatozoa were visible in the seminiferous tubules by late April and early May, but spermiation was not apparent until late May and June. In mid-June, spermatogenesis ceased abruptly and testicular regression increased.

Field data collected from alligators on Marsh Island in southwest Louisiana over a 3-year period (1980-82) indicated larger males become sexually active earlier (data based on increased weight of testes) than do smaller males. Also, plasma testosterone levels have been found to be higher in larger males as compared to smaller males bled on the same day (Lance and Elsey 1986). Therefore, this data suggests the larger males copulate with the larger females (group 1 and 2) and the smaller females (group 3) mate with the smaller males. This may help explain the low hatch rates by the late nesting group 3 females. Ferguson (1985) suggests young females in their first laying season usually produce a high percentage of infertile eggs, and of those that are fertile a large number may contain malformed embryos which die early in incubation.

<u>Alligator Nesting Sequence by Group</u>

Recent observations on Rockefeller Refuge suggest that nests with larger clutch sizes are laid first, probably by larger size females. The second or middle group comprises the largest number of females (58.9%) and are possibly made up of a relatively high percentage of middle age animals. The late group (group 3) comprises the smallest number of nesting females (15.5%) and probably represents young alligators with just a few years of nesting experience.

The alligator population on Rockefeller Refuge is relatively unharvested because rigid protection has been afforded these animals for the past 25 years. Theoretically, within this relatively undisturbed population, the late nesting group (group 3) should provide us with an indication of the recruitment of young breeders which may be expected to move up into the more productive middle age female group. If this is the case, eggs collected over the entire laying period may provide a means of determining the health of a population by comparing the percentage of animals in group 3 to the percentages for the other 2 groups (Figure 3).

A declining alligator population which may result from over exploitation or habitat loss, could very well be detected by a downward trend in the percent of young nesters in group 3 indicating limited recruitment of young breeding females. It may well be possible to utilize a recruitment standard of young breeders into the large nesting segment, as an indicator of the health of the population under current management strategies. However, careful consideration must be given to environmental parameters that regulate nesting densities. Alligator nesting effort is affected by water level and temporary influxes of salt water on an annual basis which makes it imperative to consider nesting trend data when interpreting recruitment data or group nesting standards. Conversely, a degrading habitat caused by long-term salt water intrusion or permanent flooding or dry-up would result in a declining population which should first be manifested as a decline in recruitment of young nesters.

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TABLE 1. Sequence of nesting on Rockefeller Refuge for 1989-1991; clutches assigned to early (1), mid (2), or late (3) period according to date laid.

Year	Period	Date Laid	No. Clutches	Total No. Eggs	Average Clutch Size	*Percent of Clutches	Percent Fertile
1991	1	May 31-June 12	56	2,381	42.5	13.8	96.5
	2	June 13-June 19	324	12,467	38.5	79.6	95.5
	3	June 20-July 2	27	849	31.4	6.6	95.6
1990	1	June 1-June 9	118	4,709	39.9	26.2	96.3
	2	June 10-June 16	235	9,155	39.0	52.2	96.2
	3	June 17-June 23	97	3,469	35.7	21.6	97.0
1989	1	June 9-June 15	120	4,690	39.1	41.2	96.7
	2	June 16-June 22	117	4,371	37.4	40.2	96.3
	3	June 23-June 29	54	1,920	35.6	18.6	96.2

*Significant ($P<0.05$)

TABLE 1. Continued

1989-1991 Summary

Group	No. Clutches	Percent of Clutches	Average Clutch Size	No. Eggs			Hatchability	
				Fertile	Infertile	Unknown	Number	Percent
1	294	25.6	40.5	11,326	407	47	9,271	81.9
2	676	58.9	38.3	24,882	1,071	40	20,252	81.4
3	178	15.5	34.2	5,998	214	26	4,515	75.3

Figure 1. Average air temperature and peak nesting at Rockefeller Refuge, 1964 - 1968, 1973 - 1992.

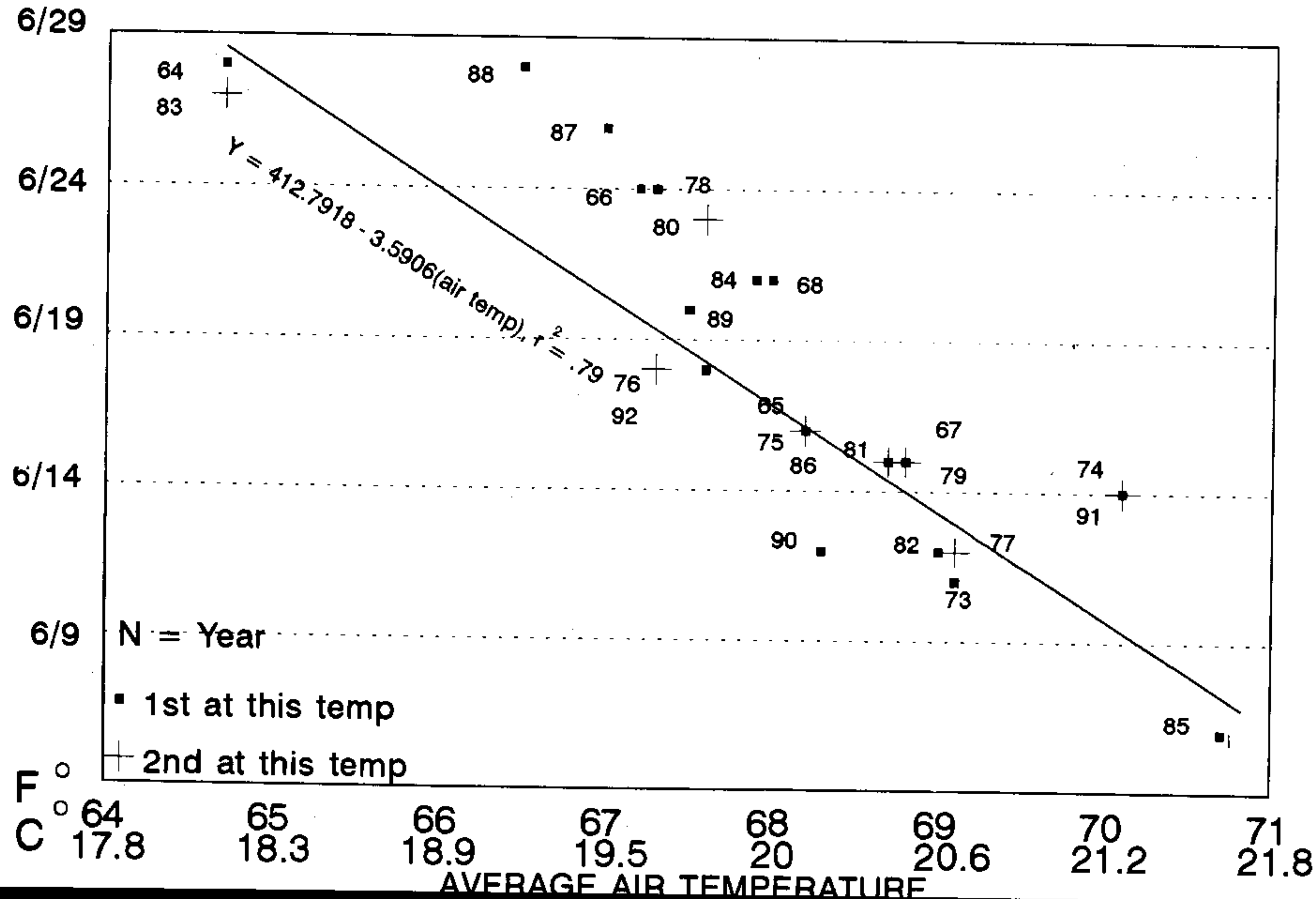


Figure 2. Sequence of alligator nesting and clutch size for Rockefeller Refuge, 1989 - 1991. A - U = progression of daily nesting increments.

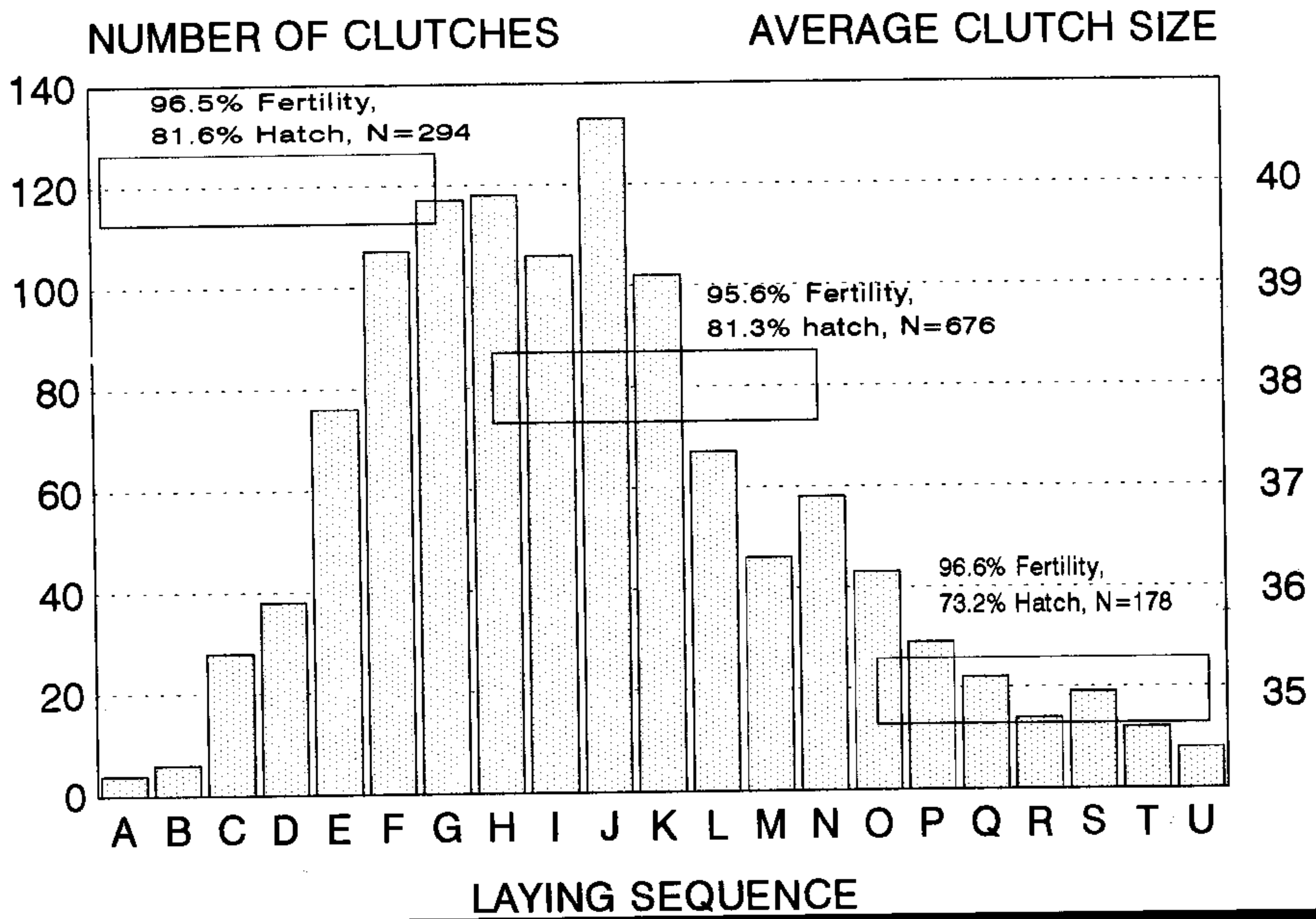
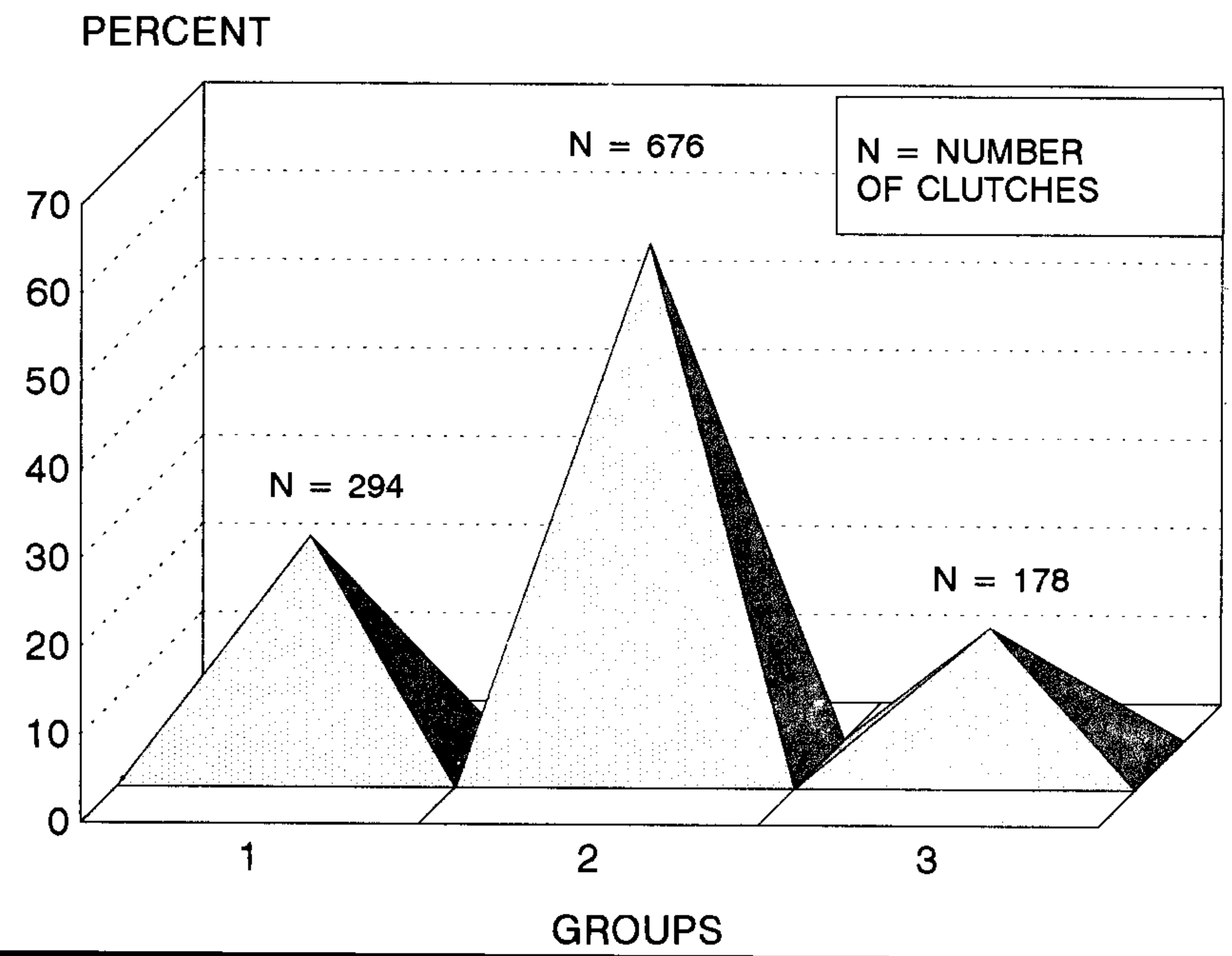


Figure 3. Nesting sequence 1989 - 1991, Rockefeller Refuge.



CONSERVATION:RESEARCH AND MANAGEMENT OF ESTUARINE CROCODILES *CROCODYLUS POROSUS* SCHNEIDER IN BHITARKANIKA WILDLIFE SANCTUARY:ORISSA:INDIA DURING THE LAST 17 - YEARS : AN OVERVIEW

- O -

S.K.KAR*

ABSTRACT

With initiation of the Government of India / FAO / UNDP Project ' Crocodile Breeding and Management ' early in 1975 , a scheme for conservation, reseach and management of Estuarine Crocodiles, *Crocodylus porosus* has been implemented in Bhitarkanika Sanctuary by the Forest Department, Government of Orissa with the purpose of quickly multiplying the population using the ' grow and release ' techniques. This paper deals with the " Conservation success " of the Estuarine Crocodiles in Orissa during the last 17 years through release of 1150 captive reared crocodiles into nature .

Study on the ecology and biology of Estuarine Crocodiles in Orissa emphasises the presence of mangroves to be most important facet of environment for the crocodiles. Loss or depletion of mangrove forest cause either complete extermination of the population or draws the population to the verge of extermination. The Estuarine Crocodiles have been extinct in the southern Indian states of Andhra Pradesh, Tamilnadu and Kerala . Their population is not secure in Andamans and Sundarbans, the latter being the largest *Crocodylus porosus*

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habitat in the country. The climate and the mangrove ecosystem are the key factors for survival of the Estuarine Crocodiles. In Orissa, the adult cohort of the population is on the lower side. The only hope for the survival of the population lies with very rigid protection of the habitat (Mangrove Forests) together with removal of all inimical factors.

INTRODUCTION

The Saltwater (Estuarine) Crocodiles, <u>Crocodylus porosus</u> Schneider in India critically reduced in numbers as a result of over hunting for their skin as well as over exploitation of mangrove habitat (Bustard, 1974 & 1975 ; Daniel and Hussain, 1975; Kar, 1978 & 1981) . The mangrove ecosystem, to which this species is tied in India, is one of the country's most threatened ecosystems . Once cleared and bunded, the fertile alluvium built up by the mangroves provides rich agricultural land . The problem now is that population pressure on good agricultural land combined with the need for fuel wood has resulted in increasing destruction of the mangrove forests .

The Estuarine Crocodile is tied to the mangrove forest which provides its entire habitat-shelter for adults and young food supply, resting and nesting sites for female crocodiles. The Estuarine Crocodile is now extinct in the southern Indian States of Kerala, Tamilnadu and Andhra Pradesh and are very rare in the Sundarbans in West Bengal and Andamans (Bustard and Choudhury, 1981; Kar, 1981 & 1984) . The best future in the entire country would appear to be in Orissa in the Bhitarkanika Wildlife Sanctuary (Kar, 1981 & 1985) .

The Forest Department, Government of Orissa declared the entire habitat of Estuarine Crocodiles as a Sanctuary on 22nd April,1975 and it was named as Bhitarkanika Wildlife Sanctuary . It covers an area of 170 Sq.Kms. and it is the second largest patch (rather compact) of mangrove forest in the country .

With the initiation of the Government of India / FAO / UNDP Project ' Crocodile Breeding and Management ' early in 1975, a scheme for conservation of Saltwater Crocodiles was implemented by the Forest Department, Government of Orissa along with two other crocodilian species Gharial (*Gavialis gangeticus*) and Mugger crocodile (*Crocodylus palustris*) . A Saltwater Crocodile Research and Conservation Centre was established at Dangmal in the heart of the Sanctuary with the purpose of quickly multiplying the population using the ' grow and release ' techniques to save this endangered reptile .

The present paper describes the success of this conservation, research and management programme during last 17 years and emphasiss the need for protection of mangrove forest and its ecosystem for survival of crocodiles and other animal life. It is most urgent to manage viable areas for the Saltwater Crocodiles and these areas should be kept free from human intrusion .

2. OBJECTIVES:

The prime objective of this Project were two fold (Kanungo, 1976) :

1. (a) To conserve this endangered archic reptilian species by providing adeq-uate protection to its threatened habitat (b) quickly build up the

depeleted wild population through large scale ' rear and release ' progra-mme, and (c) to conduct research on the ecology and biology of Estuarine Crocodiles .

2. Later, to exploit the species (surplus population) through large scale captive farming (during the second phase of the Project) .

During the last 17 years, maximum emphasis was given for collection of wildlaid eggs from the Bhitarkanika Sanctuary for safe Project hatchery incubation by simulating the natural conditions, rearing the young ones with sound husbandry conditions and release of the crocodiles (above 1.0 m length) in the river systems of the Sanctuary, monitoring the released crocodiles, collection of relevant data on wild and captive populations, study on the socio-economic aspects of the local inhabitants and'man and crocodile ' conflict etc .

3. THE SANCTUARY:

The Sanctuary, comprising 170 Sq.Km. of protected forests (under Indian Forest Act,1972), is located in the deltaic region of the Brahmani - Baitarani rivers in Cuttack District, Orissa (Fig. 1). The habitat consists of deltaic mangrove swamps growing on rich alluvium . Some areas have been bunded for cultivation purpose and in all unbunded areas, however, mangrove vegetation is dominant (Kar and Bustard,1989).

The Annual rain fall averages 1200 mm / annum (based on the data collected at Dangmal Crocodile Research Centre during last 17 years) with the main rainfall occuring during the monsoon months of August and September. The area is prone to severe cyclonic storms during April - May and October - November every year and there occasional tidal bores. In Winter

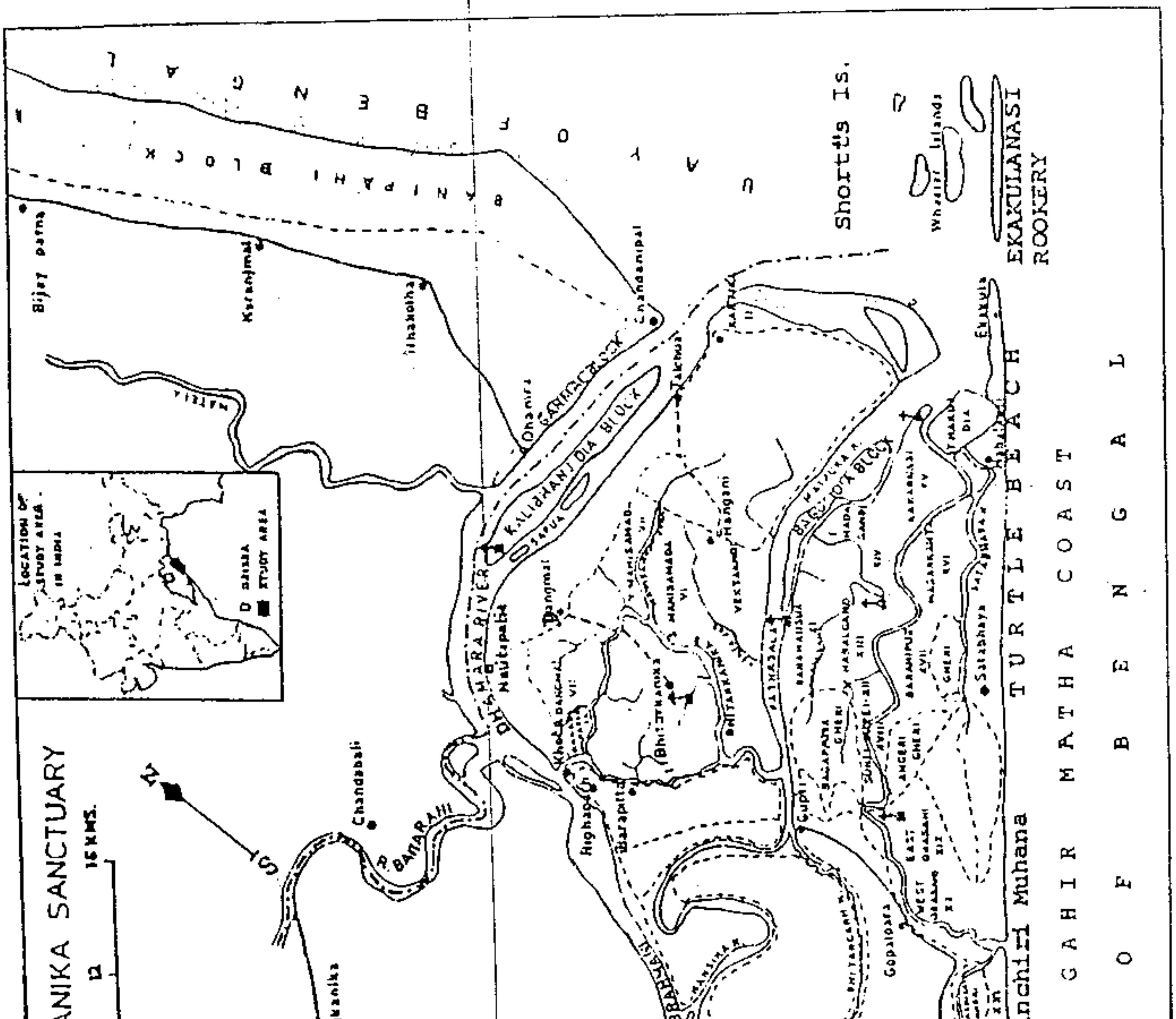

FIG. 1 MAP OF BHITARKANIKA WILDLIFE SANCTUARY.

the temperature comes down to 10.0°C minimum and in Summer the maximum temperature reaches upto 45.0°C. Due to the coastal environment, humidity is also high through out the year, varying between 75 - 95% . The mangrove habitat is intersected by numerous creeks and creeklets, the water flow is influenced twice daily both by high and low tides at approximately six hourly intervals

The main mangrove (Mangals) species are Avicennia officinalis, A. alba, A, marina, Heritiera fomes, H. littoralis Sonneratia apetala, Exoecaria agallocha, Rhizophora mucronata Ceriops roxburghiana, Acanthus illicifolius and Aegiceras majus etc. The palm Phoenix paludosa the aquatic fern Acrostichum aureum and Hibiscus teliaceus are widespread throughout the mangrove forests .

The mammalian fauna includes the leopard (Panthera pardus),Striped hyaena (Hyaena hyaena) and the lesser cats (Felis chaus, F. viverrina); spotted deer (Axis axis),Samber (Cervus unicolor) and wild boar (Sus scrofa) . Large troops of Rhesus macaque (Macaca mulata)also occur in the Sanctuary. The larger reptilies include the Indian python (Python molurus) King Cobra (Ophiophagous hannah) and the monitor lizards (Varanus salvator, Varanus flavescens and Varanus bangalensis) (Biswas & Kar ,1982) . The avifauna is rich and varied (Kanungo,1976) . Kar (1991) prepared a checklist of birds in which 170 species of birds have been identified in the Sanctuary . Mangrove areas support a range of inter-connected food webs whcih directly sustain the varieties of crustaceans, crabs and fishes .

4. DISTRIBUTION:

The present day distributional range of the Estuarine Crocodile is limited to two pockets in Eastern India Sundarbans (West Bengal) and Bhitarkanika (Orissa) . A small remnant population of Saltwater Crocodiles still exists in the Andamans but these are threatened as a result of heavy hunting pressure, particularly on the nest and nest-ruarding females (Bustard and Choudhuary,1980) and as a result of repeated habitat encroachment by settlers. The last remaining ideal habitat of the Saltwater Crocodiles in India is in what is now the Bhitarkanika Wildlife Sanctuary, Orissa. It has also been reported that there was a good population of *C. porosus* in deltaic areas of the river Mahanadi (Kujanga area) in Orissa but at present the Crocodile population has almost exterminated in this area .

5. THE POPULATION:

Prior to survey, it was presumed that there were many more saltwater crocodiles in Bhitarkanika than was latter found to be the case. It was learnt from the local people, more particularly from the old people, that very large number of crocodiles were killed by shikaries coming from outside the State and also a smaller number were killed by the local people .

5.1. Former population:

The saltwater crocodiles formerly occurred abundantly in all favourable habitats from Cochin (Kerala) round the Peninsula and up the east coast of India to Bangal Desh (FAO,1974) . Early writers frequently commented on its abundance. The distinguished Herpetologist Gunther (1864) wrote, " This is a very common species along all the rivers of the East Indian continental Archipelego " .

More recently Deraniyagala (1939) noted: " It flourishes along the shores of Bay of Benal " .

Following a catastrophic decline as a result of indiscriminate hunting in the total absence of controls (Bustard, 1978), the saltwater crocodile is now rare or extinct in most of its former Indian habitat, starting at its Western geographical limits, it is now believed to be extinct in Kerala (where most of the mangrove habitat is lost), extinct in Tamilnadu (the last individual was shot in 1936, Biddulph, 1936), and extinct in Andhra Pradesh (Bustard and Choudhury, 1980). The combination of number of factors have reduced the estuarine crocodile population so much so that, this species has been included in the Schedule-I of the Wildlife (Protection) Act, India, 1972. Status of wild population of C. porosus in the wild (Singh, Kar & Choudhury, 1984) in Bhitarkanika and other geographic ranges of India, prior to ' rear & release ' programme has been shown in Table - 1 .

Location	State	Adult	Juvenile	Total	Source
1.Bhitarkanika (1976-77)	Orissa	34	61	95	(Kar & Bustard, 1989, based on their study during 1976 - 77)
2.Sundarbans (1978)	West Bengal	4	96	100	
3.Andaman and Nicober					
North A		50	150 upto	100-200	Singh, Kar & Shoudhury, 1984)
Middle A		20	80	50-100	
South A		10	20	20-30	
Nicobar		-	-	20.25	

Table-1 : Pre-release population of Estuarine Crocodiles in the Wild in Bhitarkanika, Sundarban (West Bengal) and Andaman Islands .

6. REAR AND RELEASE PROGRAMME:

Due to excellent conservation management programme, being operated at Dangmal within the Bhitarkanika Sanctuary by the Forest Department, Government of Orissa with assistance from Government of India, the deplated population of Saltwater Crocodiles are now gradually built up through large scale egg collection, incubation of eggs in the Project Hatchery, rearing of young ones and release of captive reared crocodile into the wild (Table - 2) .

During the last 17 years, a total 3541 eggs of *C. porosus* have been collected from the forest blocks of the sanctuary, out of which 1950 hatchling hatched (55.07%) and 1740 crocodiles survived (89.23% survival)(Table - 2)at Saltwater Crocodile Research and Conservation Centre, Dangmal .

Egg laying takes place in the 3rd week of May with a variation of only a few days between nests. The mean clutch size is 45 eggs (range 10 to 70 eggs). It has been noticed that larger females laid larger clutches (Kar, 1981). The study indicated that experience is necessary for successful nesting. Losses of eggs are more than ten times greater in smaller (clutch size below 50 eggs) as opposed to larger clutches of eggs (clutch size of 50 eggs) .

Nesting female Crocodiles defend the nest against predators including their most deadly enemy - man . A number of parameters including fertility, damage and maintenance of nest temperature and humidity (but absence of flooding) are critical for hatching of eggs. The mean nest temperature recorded in nests at the project hatchery through out the study period was 31.5°C. Incubation period of eggs at the Hatchery is 75 - 80 days .

The quantity of food consumed by the young captive reared crocodiles varied at different seasons of the year for all year classes. Marked reduction in food consumption occurred during the winter (Kar, 1981) .

At present 590 crocodiles including one White (Sankhua) female crocodile are being reared in the pools including nature simulating rearing / breeding pools with sound husbandry conditions at the Research Centre.

About 200 crocodiles of about 1.0m length are awaiting release into the river systems of the Bhitarkanika Sanctuary . The White Crocodile (1975, August hatchling) has been laying infertile eggs since 1985 in captivity at the centre. Due to want of a suitable male partner (all her batchmates & immediate juniors are females) the breeding programme is not successful .

6.1. Restocking of Crocodiles:

The wild population of Estuarine Crocodiles in Bhitarkanika was depleted to such an extent that the only way to restock was by release of Captive reared young crocodiles (1.0m above size) . The first releases back into the wild of 15 individuals took place in February to May 1977 (Kar & Bustard, 1989) and then 80 crocodile during 1978 (Kar & Bustard, 1991) and this followed by subsequent releases of 1055 crocodiles in phased manner into the river systems of Bhitarkanika Sanctuary (Table - 2) .

The average density of Estuarine Crocodiles (other than hatchlings) in Bhitarkanika was 0.87 individuals / Km (Kar & Bustard, 1989 & 1991) during 1976-77 census (Prior to release) and 1.27, 1.62, 3.33 and 3.84 individuals / Km. during the year 1984, 1985, 1988 & 1991 respectively .

TABLE - II

DETAILS ABOUT EGG COLLECTION HATCHLING SURVIVAL & RELEASE OF C. *POROSUS* IN BHITARKANIKA WILD LIFE SANCTUARY DURING LAST 17 YEARS.

Year	No. of eggs collected	Hatchlings hatched.	Percentage of hatching.	Wild caught hatchling	Crocodile survived	Percentage of survival	Crocodile released.	Present stock position.	REMARKS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1975	48	24	50	4	25	90	19	6	Release programme carried out for the first time during 1977.
1976	230	140	61	-	86	62	81	5	
1977	203	112	56	36	106	72	100	6	Since then release of crocodiles have been taken in phases
1978	220	100	46	21	69	57	63	6	
1979	290	218	76	-	149	69	133	16	
1980	-	-	-	-	-	-	-	-	Very unusual (Eggs were predated prior to egg collection).
1981	236	209	89	4	198	93	195	3	
1982	225	125	56	-	102	82	100	2	
1983	220	135	62	-	126	93	123	3	
1984	288	131	46	-	127	97	125	2	
1985	317	106	35	-	106	100	99	7	
1986	225	130	58	-	130	100	112	18	
1987	199	148	75	-	147	99.4	-	147	
1988	68	54	79	-	51	94.5	-	51	
1989	93	26	28	-	26	100	-	26	
1990	231	82	35.5	-	82	100	-	82	
1991	448	210	46.1	-	210	100	-	210	
TOTAL	3541	1950	55.07%		1740	89.23%	1150	590	

6.2. Census of Crocodile Population :

To ascertain the status of the crocodile population the whole sanctuary has been survyed (Table - III) including a-ll the river and creek systems . Since the inception of Crocodile Conservation Programme at Dangmal (1975-76) during the winter months (Dec. - Jan.) . The annual census of Estuarine Crocodiles indicates most dramatically the close corelation between crocodile numbers (adults, Sub-adults and Juveniles) and the presence of healthy mangrove ecosystem. 75% of the total C. porosus population restricted to 30% of the total sanctuary area (Kar, 1985 & 1989; Kar & Bustard 1991). These forest blocks provide all the requirements for the life of the adult Crocodiles, including protected egg laying sites, where the mother Crocodile can obtain nesting material readily and have easy access to creeklets / creeks / rivers . The undistured mangrove habitat is characterised by numerous Creeks and Creeklets, overhung by mangrove forest, and with exposed mud banks at low tide .

Censusing year	Adults (2.5m to 7m +)	Sub-adults (1.6m to 2.5m)	Juveniles (0.3m to 1.6m)	Total	Percentage of incre--ase.	Remarks.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1976-77	29	6	61	96		Prior to release .
1984-85	34	13	118	165	172	Released plus natural recruits .
1985-86	39	10	162	211	128	-do-
1988-89	58	162	213	433	205	-do-
1991-92	-	-	-	500+	115.5	Data under compailation.

Table-III : Census of Crocodile Population in the River systems of Bhitarkanika Sanctuary .

During the population study, the presence of four white coloured crocodiles (one adult male, one female and two sub-adults) have been noticed in the river and creeks of the Sanctuary . These individuals are well known to the local people who consider that they are distinct species of Crocodiles. They called these animals as " Sankhua " (means white colour like 'conch') to distinguish them from typical C. porosus known as ' BAULA ' in Oriya .

Monitoring of the released crocodiles have been taken up regularly :

- to assess their survival in nature;
- to study the habitat preferences and ;
- to record their movement, home range, seasonal migration and growth rate etc.

7. THE WILD POPULATION:

A close corelation was found to exist between the distribution of the crocodile population in the sanctuary and distribution of good habitat (Kar, 1981; Kar & Bustard, 1989). The adult crocodile population of the sanctuary consisted of a couple of huge males (5m +) with a smaller number of females and some recruiting individuals (sub-adults, juveniles and hatchlings) in addition to the released ones. The largest surviving male saltwater crocodile in the sanctuary (7.0 -7.3m) inhabited in the river systems of the sanctuary. It has been recorded in Guiness Book of World Record (1991) . The maximum number of (immature) crocodiles were sighted nocturnally in the rivers and creeks of the sanctuary during colder months of the year rather than in hot season. Development of territorially in immature crocodiles of around 1.5m length results in spacing out the populations. During the winter months (Dec- Jan), a large number of adult crocodiles are seen basking in the river & creek banks under the fringing mangrove vegetation in comparision to other months of the year .

A couple of released crocodiles (1977 & 1978 batch releases) have already bred and laid eggs in the wild, which is positive indication of the successful conservation and management programme of the Estuarine Crocodiles implemented in the Bhitarkanika Sanctuary since over a decade and half .

8. ATTACK ON HUMAN BEING BY WILD CROCODILES:

The Saltwater Crocodile, is widely stated to be most dangerous species of Crocodilian from a human stand point (Neill, 1971) . However, in our experience, instances of man eating have been greately exaggerated (Kar and Bustard, 1983) There have been 15 instances of attacks on humans in 17 years which include nine males and six females. In 14 cases, large male crocodiles of above 16' were responsible but in only one case, a Crocodile of 9' was involved for killing of a human being . During the year 1988, one Crocodile of about 21' was responsible for killing three persons with a span of few days, who were catching fish illegally, at the night time in one of the creecks of the Sanctuary . Later that crocodile was killed by the poachers .

It is clear that the diet of even largest crocodiles in Bhitarkanika is almost entirely fish. This also seems to hold good for crocodiles in Northern Australia and in Papua New Guinee, there being no indigenous large mammals in these areas (Kar & Bustard, 1983). In the Bhitarkanika Wildlife Sanctuary all the ingredients for human attack exist, particularly, frequent human intrusion into the crocodile's habitat illegally and a crocodile population in the sanctuary containing a good number of very large males (Kar & Bustard, 1989) . But it has been observed that the crocodiles never leave their territory to chase after the human being on land unlike the tigers & other terrestrial predatory animals . Most of the incidences occurred when the victims entered into the crocodile habitat(s) either for illegal fishing or collection of firewood or collection of Nalia grass from the river or creek banks or while setting the traps / noose for trapping the deers / wild boars etc. very close to creek / river banks .

8. ATTACKS ON DOMESTIC LIVESTOCK BY WILD CROCODILES:

Instances of attack on domestic live stock by Estuarine Crocodiles have been recorded from August, 1975 to December, 1987 inclusive. A total of 21 attacks involving buffaloes, bullocks, cows, calves and a goat were recorded. All attacks were reported were by very large males of above 16' length . Hightide is usually essential to bring the crocodiles lying in wait in the water within striking distance of the animals grazing on the river bank . 90% of the attacks occurred during the rainy season when the river banks were flooded by high tide / flood . The attacks all occurred at locations where the natural mangrove cover had been destroyed by the people . Cattle attacks increase the unpopularity of the Saltwater Crocodiles and increase the pressures working against its conservation (Kar and Bustard, 1981) . Ideally crocodiles and cattle should be separated there should be no grazing in Sanctuaries. The solution lies in maintaing a strip of undistrubed mangrove forests, atleast 100m wide along all river / creeks adjacent to cultivated land inside the sanctuary .

9. RESEARCH :

The aspects that are immediately relevant to the ' rear and release ' techniques and the management of the Sanctuary was given priority . Some of the important aspects are :

- interpretations of various types of data collected during survey and census,
- studies on the nesting ecology of crocodiles in the nature,
- determination of parameters for maximum hatching success and survival rate,
- husbandry of young crocodiles including food,

feeding and growth, beheviourial biology including reproduction, thermoregulation , feeding, movement and social behaviour,

- studies on the role of temperature on sex differntiation of *C.porosus*,
- studies on the ' man and crocodile ' conflict,
- studies on the carrying capacity of *C.porosus* in the river systems of the Sanctuary ,
- monitoring of the released crocodiles and,
- habitat features and population structure .

10. INVOLVEMENT OF PUBLIC FOR CONSERVATION PROGRAMME:

This Crocodile Conservation and Research Project not only ensures the conservation of this species but also, provides job oppertunities to a number of local people in various ways such as boatman, crocodile / sanctuary guards, husbandry attendants, fish suppliers for captive reared crocodiles and other such various work from time to time for upkeep and progress of the project .

11. RECOMMENDATIONS:

1. The entire mangrove forest of Orissa be declared as a National Park under the Provision of Wildlife (Protection) Act to afford rigid protection to the unique crocodile population and the ecosystem .
2. Encroachment on the mangrove habitat for rehabili--tation, agriculture and prawn culture etc. should be completely banned .
3. The use of gill nets in the rivers, creeks and creeklets throughout the sanctuary should be strictly prohibited .

4. Degraded mangrove forest should be restored by plantation and rigid protection .

5. Large scale eco-development programme should be implemented in and outskirts of the sanctuary to minimise / reduce the pressure on mangrove forests by local people .

6. Studies on the ecology of Estuarine Crocodiles should be continued, considering the existing gap in the knowledge regarding various aspects of ecology of the species in Bhitarkanika and ; other distributional range in Orissa as well as in India .

CONCLUSION:

Inspite of the best efforts of ' rearing and rehabilitating ' this species, the future can not be bright unless the Sanctuary is adequately protected and untill large number of juvenile Estuarine Crocodiles attain breeding size and commence breeding in the wild .

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THE REPRODUCTIVE PERFORMANCE OF CAPTIVE BRED NILE CROCODILES

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ABSTRACT

The analysis of the reproductive capabilities of captive bred (F1 Generation) Crocodylus niloticus has become an important component in the evaluation of the commercial viability of captive breeding operations in South Africa. The reproductive performance of captive bred crocodiles producing for the first time can now be analysed and evaluated. Of the 34 registered crocodile farms in South Africa, only five have reported breeding from F1 generation captive bred crocodiles and the production of F2 hatchlings. This paper reports the reproductive performance of captive bred crocodiles on two of these farms.

INTRODUCTION

Commercial crocodile farming has expanded tremendously over the last twelve years in South Africa. A relative abundance of food, minimal labour costs, a favourable rand/dollar exchange, positive natural conditions and "crocodilian mystique" have resulted in an estimated investment of sixty million Rand (US$ 20 million) in commercial crocodile farming in South Africa.

Most of the original breeding stock was brought in from Zimbabwe and Bostwana and for farms which have been established more recently stock has been purchased from existing farms. On only five of the original farms has breeding by F1 generation crocodiles been reported. In establishing a commercial crocodile farm the reproductive potential of the breeding stock is one of the principal factors in determining the financial viability of the farm.

The breeding capabilities of both wild or captive Nile crocodiles have been documented, analysed and evaluated in numerous papers to date (Hutton 1989). This paper serves to document, analyse and evaluate the breeding performence of captive bred F1 generation crocodiles held on two farms in South Africa.

Riverbend Crocodile Farm is situated near Southbroom (Est 1981) and Crocworld near Scottburgh (Est 1985) - both coastal resorts on the Natal South Coast. Situated 90km apart, these farms are situated at latitude 30,5 degrees, South. Average minimum winter temperatures of 14,5 degrees C and hot humid summers result in favourable conditions for crocodile reproduction. Records show that natural breeding took place in this area in the early 1900's.

SEXUAL MATURITY

It is generally accepted that Nile crocodiles become sexually mature between ten and twelve years of age. It is accepted that body size at sexual maturity varies with species and also sex. Populations of the same species with different resource bases grow at different rates and consequently mature at different ages. (Lang 1981).

Maturity is size dependant and may be accelerated by rapid growth in captivity (Lance 1981). From studies done at Riverbend Crocodile Farm, it would appear that females mature at smaller sizes and a younger age than male crocodiles. In the study unit A, four females layed eggs in the 1990/91 breeding season but all eggs were infertile, indicating possible male immaturity. Isolated incidences of four year olds laying in rearing houses have been reported in South Africa these animals had attained lengths in excess of 1.80m. It would appear that, given the correct climatic conditions, a suitable feeding regime and good farm management, 57% of captive bred *Crocodylus niloticus* are capable of reproducing in their 7th year.

FARM DATA

Data has been obtained from the two farms mentioned. It should be noted that these farms double up as successful tourist operations and breeding units are exposed to the stress of seasonal tourism.

In addition to substantial adult breeders both Riverbend Crocodile Farm and Crocworld have captive bred (F1 generation crocodiles) which are now breeding.

TABLE I

Riverbend Crocodile Farm - (Study Unit A) - F1 Crocodiles

26 Females born 1983 (February)	average length 2.44m
4 Males born 1983 (February)	average length 2.56m

TABLE II

Crocworld - (Study Unit B) - F1 Generation Crocodiles

45 Females born 1983 (January)	Average Length 2.42m
8 Males born 1983 (January)	Average Length 2.63m

All the crocodiles spent their first year under controlled environment conditions at a temperature of 32 degrees C. These animals have been fed poultry (80%), with the remaining 20% of their food being red meat in the form of horse or beef. Both groups are held in concrete lined breeding pools with maximum depth of 3 m.

BREEDING DATA

Both Riverbend Crocodile Farm and Crocworld have had successful breeding over a period of eight years with hatchability ranging from 54,4% to 87,5%. Mating commences in late July continuing through August with egg laying taking place from the end of September through to the end of December.

While it is important to draw a distinction between fertility and factors mediating hatchability (Marais J 1988), on both farms the same egg removal and hatching techniques have been utilised from year to year and in the case of Riverbend Crocodile Farm performed by the same person. Both farms use incubators kept at a constant temperature of 31.5 degrees C and a humidity range of 85-97% (RH). Eggs are incubated in moistened vermiculite and incubation periods range from 72-86 days. This reproductive data above can be used as a comparison or control when analysing the data obtained from the captive bred crocodiles in this study.

Appendix I information refers to the captive bred crocodiles reproductive performance during the 1991/92 breeding season while Appendix II details the information from Crocworld for the same season.

By making egg index comparisons it is evident that there is a marked difference between the indices of first time breeders and those of mature adults.

Egg indices are calculated as follows $\frac{\text{Egg Length}}{\text{Egg Width}} \times \frac{100}{1}$

An average egg index of 162,5 has been obtained for adult females on Riverbend Crocodile Farm during the 1991/92 breeding season. Tables III and IV detail average indices obtained in this study.

EGGS

TABLE III

RIVERBEND CROCODILE FARM EGG DATA

Average Measurements	Egg Index
Length 64,0mm Width 43,1mm	148,49

TABLE IV

CROCWORLD EGG DATA

Average Measurements	Egg Index
Length 61,0mm Width 39,6mm	154,04

TABLE V

HATCHLINGS

Average hatchling lengths and weights obtained from captive bred females breeding in their 1st year indicate a 21% and 36% reduction respectively in length and weight as against the average length and weight of hatchlings obtained from mature adult females.

TABLE VI

Average hatchling lengths and weights (captive bred females 1991/92 breeding season).

RIVERBEND CROCODILE FARM AND CROCWORLD

Average Length:	274 mm
Average weight:	94 grams

CONCLUSION

Although more data needs to be collected, these preliminary studies on the reproductive capability of captive bred *Crocodylus niloticus* indicate that 57% of females are capable of reproducing in their 7th year provided there are males mature enough to fertilize them. An average of 28 eggs were laid per female in their 1st breeding year, however a very low percentage hatchability of only 21% was attained. The resulting hatchlings are, on average, smaller when compared with hatchlings obtained from adult females.

Data now needs to be collected and analysed as regards the growth rate of these hatchlings and the ecomonics of their propogation to slaughter, as compared to to information we have on growth rates for hatchlings for adult females.

Having now collected data obtained from the 1st breeding season of captive bred females, it would appear that those farmers who were expecting high percentage hatchability in F1 crocodiles in their first breeding season will now have to calculate the profitability of their breeding stock, based on some of the results of this study.

At present product prices, an investment of R 5000.00 (US$ 2000) for adult breeding females can now be sutstantiated with the initial results of studies done on these crocodiles at Riverbend Crocodile Farm and Crocworld. Indications are that adult breeders are almost six times more efficient than young females.

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APPENDIX I

REPRODUCTIVE DATA - RIVERBEND CROCODILE FARM
CAPTIVE BRED FEMALES 1991/92 SEASON

Date Laid	Female I.D	No Eggs	No infert Eggs	No Embryo Failure	Inc'btn Period	Viable Hatch	% Hatch
1.11.91	FN1	38	35	-	83	3	7,89%
2.11.91	FN8	34	34	-	-	0	0,00%
3.11.91	FN16	24	24	-	-	0	0,00%
3.11.91	FN9	45	40	2	82	3	6,66%
3.11.91	FN3	33	26	-	81	7	21,21%
4.11.91	FN11	26	25	-	83	1	3,85%
5.11.91	FN5	42	22	-	80	20	47,62%
17.11.9	F55	30	15	4	74	11	36,66%
20.11.91	FN4	28	26	-	71	2	7,14%
3.12.91	F62	10	7	-	80	3	30,00%
9.12.91	F54	23	9	-	77	14	60,87%
10.12.91	F59	41	4	37	-	0	0,00%
11.12.91	F56	23	23	-	-	0	0,00%
14.12.91	F58	23	11	2	80	10	43,48%
14.12.91	F64	20	12	-	80	8	40,00%
14.12.91	F60	9	7	-	80	2	22,22%
Averages		28,09			79,25	6	20,48%

APPENDIX II

REPRODUCTIVE DATA - CROCODILES
CAPTIVE BRED FEMALES 1991/92 SEASON

Date Laid	Female I.D	No Eggs	No infert Eggs	No Embryo Failure	Incbtn Period	Viable Hatch	%Hatch
23.10.91	C6	20	20	-	-	-	0,00%
6.10.91	C5	13	13	-	-	-	0,00%
26.10.91	C7	35	34	-	80	1	2,86%
1.11.91	C11	36	27	7	78	2	5,55%
3.11.91	C9	33	33	-	-	-	0,00%
10.11.91	C7	35	34	1	-	-	0,00%
10.11.91	C12	33	17	5	76	11	33,33%
7.11.91	C2	32	26	-	78	6	18,75%
12.11.91	C14	17	16	-	80	1	5,88%
Averages		28,22			78,4	2,33	7,37%

THE EXPERIMENTAL BREEDING STATION OF Caiman latirostris AT SANTA FE CITY, ARGENTINA (1991/92)

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INTRODUCTION

As it has been said in my former work (Larriera, in press), the Caiman latirostris Experimental Breeding Station which belongs to the Agriculture Ministry of Santa Fe Province has not commercial aim. At first it tries to get information about reproductive biology and the growth of the specie under controlled conditions in order to apply it on the management of natural populations under Ranching system, for example (Larriera, 1990).

The Breeding Station is located in Santa Fe city and has a stock of 26 adult animals that are separated into two groups in two differents ponds, one with 19 (7/12) animals and the other with 7 (2/5) animals.

With respect to previous years, the incubation conditions and eggs management have been changed in this reproductive season, making completed ovoscopies at 2 and 50 days of the incubation period.

In this paper the results that were obtained from clutch size, incubation period and hatching success are compared to the ones of the former season. Besides there are described twin cases ocurred in the Breeding Station, one egg from the Station itself and two more that were harvested from nature.

REPRODUCTION

In this season the first mates ocurred in the first week of November, and the first laid happened on December 14th. In all cases the eggs were collected from the nest in the same day of being laid, so the disarmed nest was able to be used again by others females for a new oviposition.

In pond #1 four nests were constructed, only two were used through three times each (Total: 6 clutches).

In pond #2 only one nest was constructed and one laid was registered

Dates of laids and clutch sizes are shown in Table 1.

TABLE 1

NEST	LAID DATE	CLUTCH SIZE	HATCHLINGS	INCUBATION PERIOD
1	14/12/91	39	31	83
2	24/12/91	38	34	83
3	25/12/91	34	24	76
4	27/12/91	40	31	78
5	29/12/91	38	27	74
6	31/12/91	28	16	76
7	28/1/92	46	1	85
TOTAL		263	164	79,2($\bar{x}$)

EGGS AND BIRTHS MANAGEMENT

Transportation to incubator:

At the moment of being harvested a mark made by paint was put on the upper face of the eggs and then they were moved to the incubator. In fact, the incubation room that has been used consist in a nylon tent of 1.8 mts. high, 1.8 mts. wide and 4 mts. long, with a heater, a ventilator and a thermostat that keep the temperture at 30o C. (+- 0.2o C.) along the whole period ; the humidity was kept at 95% through periodical sprinkled water.
The eggs were clumped per nest in the incubator and put over wooden trails piled up on shelves.(Figure 1).

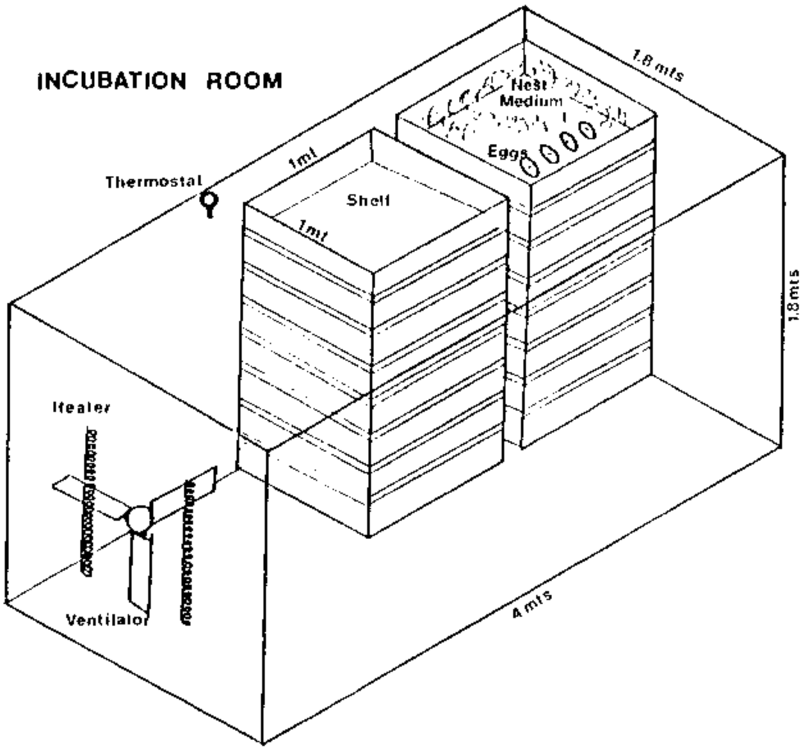

FIGURE 1

Ovoscopies:

Ovoscopies on all eggs were made at 2nd and 50th days of incubation, in order to discard those which were not fertile and viable.
The 2nd day ovoscopy detected presence or absence of opaque band, and at the 50th day ovoscopy eggs partial or totally translucent were discarded.
Discards made per nest at the 2nd and 50th day of incubation and at the moment of birth as well as hatching success registered are shown in Table 2.

TABLE 2

NEST	CLUTCH SIZE	DISCARDED EGGS (Day 2)	DISCARDED EGGS (Day 50)	DISCARDED EGGS (Hatch)	HATCHING SUCCESS
1	39	2	5	1	79%
2	38	3	1	–	89%
3	34	–	3	7	70%
4	40	3	2	4	77%
5	38	–	2	9	71%
6	28	1	5	6	57%
7	46	2	42	1	2%
TOTAL	263	11	60	28	62,3%

Comparison between 91' and 92' incubations:

There have been some differences among incubation variables used this year with respect to the previous year. Results obtained in clutch size, hatching success, and incubation period are displayed in Table 3.

TABLE 3

	CLUTCH SIZE	HATCHING SUCCESS	INCUBATION PERIOD
'91	36,5	49,3%	71
'92	37,5	62,3%	79,2

There has been an improvement in hatching success this year and it can be as a result of using nest medium during incubation, and an enlargement of the incubation period in 8 days, probably because incubation temperature has been reduced about 1o C. this year.

TWINS FINDING

A twin birth among the 263 eggs laid in this breeding station was verified (0.38%). In particular this egg had a size significantly bigger than the average, its longitude and wide were 8.2 cm. and 4 cm. respectively (Figure 2). When the egg was open manually the twins were united by yolk, one was alive and in good condition (18 cm. lenght and 29 grs. of weight), the other was formed completely but dead (17 cm. lenght and 24 grs. of weigth). (Figure 3).

FIGURE 2

FIGURE 3

Two twin births were verified among the 903 eggs collected for the Ranching Program presented in this Meeting (0.22%), but the size of the eggs this time was normal, in one of them a hatchling alive and completely formed was found (17 cm. lenght and 33 grs. of weight) and the other united to him by yolk, was alive but malformed and not viable (Figure 4); in the other case the hatchlings were alive and completely formed but were too small (15 cm. on lenght each and 18 and 20 grs. of weight respectively), and they died after 24 hs.

FIGURE 4

Considering the total amount of eggs (1166), the twins findings average was of 0.25 %, in all the cases the unions occured by yolk, surviving to this date just 2 of the 6 hatchlings.

REARING

After hatch the newborns are located into cement pens, 50 % of its surface is covered by water. The place is warmed with electrics heaters.(Figure 5).

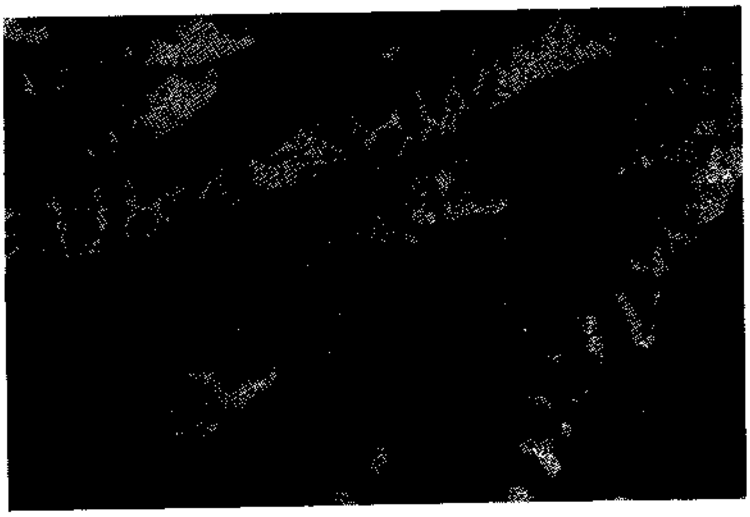

FIGURE 5

The feeding is provided ad libitum three times a week over the basis of the 20% of the body weight per week. The food consist on minced chicken (with bones), bran cereal and a vitaminic mineral mixture.

The rearing density used is 14 hatchlings per square meter.

CONCLUSIONS

The amount of nests (7), the total number of eggs (263), and the hatching success (62.3%), have improved with respect to the last year.

The rearing of the animals from previous year is going good, so probably older animals (5 years old) will start reproducing in one or two years from now, closing the cycle in the Experimental Breeding Station.

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ENVIRONMENTAL VARIABLES AND ITS INCIDENCE ON Caiman latirostris COUNTS

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INTRODUCTION

The Wild Fauna Management Programs are based mainly on a close monitoring of the population trends. Of course in crocodilians this situation occur (Bayliss, 1987.), and we have consistent information to suppose that in most of the species night counts are the most important (and accessible) way to get the knowledge about the status (or trends) of a population.

Despite of this, there are many environmental variables which finnally affects the possibility to watch animals.

Lang (1987) studied the thermal selection in crocodilians, and bis conclusion was that the behavior is the principal mechanism they have for regulation. Because of this the possibilities to watch crocodiles will be related with the temperture.

There is a work about thermal preferences in Caiman crocodilus (Diefenbach, 1975), which is the only study on the behavior related to the temperture in southamerican species.

Woodward and Marion (1978) did an interesting survey on a population of Alligator mississippiensis in Florida (USA), and after considering ten environmental variables they concluded that water temperture was the most important item in cool weather and the water level in warm weather.

This particular study was done on a known population of Caiman latirostris in a place with similar conditions as the wild. In the survey were considered variables easy to record in nature, with the aim to get an usefull mechanism to improve the presicion of the night counts in the wild and in order to know the percentage that conforms the counted caimans from total population

MATERIALS AND METHODS

The study was made on an initial population of 19 individuals, which was reduced to 18 because one animal died during the survey. They are located in a place of 1800 square meters of total surface with a 60% of it covered by water. (Figure 1). Besides, there are an abundant vegetation.

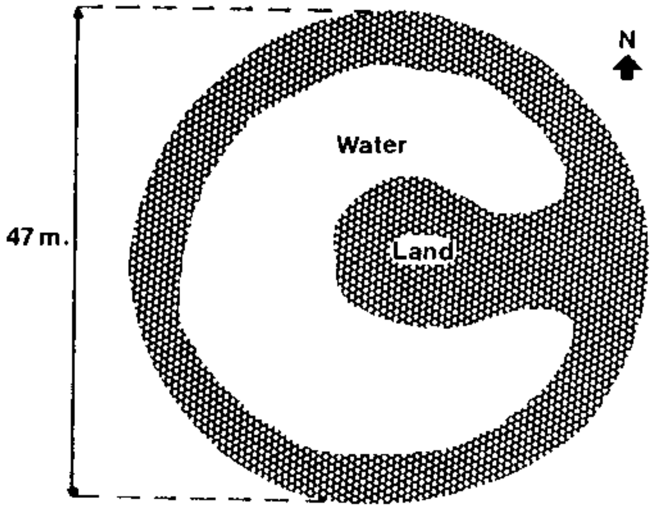

FIGURE 1

The animals have been there for more than six year . We think that an indicator that the place is adecuated for the caimans is the fact they have reproduced there for five years.

Nights counts were made almost daily between one to three hours before dawn during a year. We used an a medium handlight and at the moment of the count. Three environmental variables were considered WATER TEMPERTURE; AIR TEMPERTURE AND MOONLIGHT. It was calculated the correlation of the total amount of caimans watched with those variables, and an analysis of partial correlation for total amount of caimans watched related with moonlight. It was done with the aim to discard variations due to the other items.

It was not made an analysis of regression because the data recorded did not show a linear distribution, due to the population was little and finite, which from certain values of the independent variable has not real possibility to increase the dependent variable.

For each temperture recorded in the air and in the water, was calculated the medium and the standard deviation of caimans counts in the water, out of it and the total. It was defined the confidence limits of the calculated mediums for the total of caimans counted. They were expresed as real values and as a percentage of the total known population.

In order to annalize the effect of the air and water temperture over the total of counted caimans, an analysis of variance of single clasification was done and it was complemented with three comparative tests among mediums.

RESULTS

The analysis of correlation shown that exist a significant association between the total amount of counted caimans and the three environmental variables considered.

The values of the correlation coheficient were:
x= Air Temperture: 0.517.
z= Water Temperture: 0.631.
w= Moonlight: -0.156.
(The critic value of r with 275 d.f. y $P \leq 0.05$ is of 0.119).

When partial correlation for the moonlight was done in order to discard the influence of the other valiables, its association with the total amount of caimans counted lost significance (ryw.xz= 0.066).

The analysis of variance shown that the effect of the Water and Air Tempertures Treatment, on the total amount of caimans counted, was highly significant (Tables 1 and 2).

TABLE 1

Analyisis of Variance

Night Counts: Relation between water temperture and total amount of caimans counted.

Source of variation	d.f.	S.S.	M.S.	F.s
Among tempertures	20	2258.6	112.93	14.52926***
Into tempertures	255	1982.01	7.772588	
TOTAL	275	4240.61		
$F_{0.05(20;\infty)}$= 1.57	$F_{0.001(20;\infty)}$= 2.27			

***: Very significant.

TABLE 2

Analysis of Variance

Night Counts: Relation between the air temperture and the total amount of caimans counted.

Source of variation	d.f.	S.S.	M.S.	F.s
Among tempertures	20	2247.56	112.378	14.17938***
Into tempertures	255	2020.99	7.925450	
TOTAL	275	4268.55		
$F_{0.05(20;\infty)}$= 1.57	$F_{0.001(20;\infty)}$= 2.27			

***: Very significant.

The Comparison of Mediums Test (Table 3), shown that the counts made when the air temperture was higher than 17º C. and the water temperture was more than 20º C. are significantly different than those made under lower tempertures.

TABLE 3

Mediums Comparison

Total amount of caimans counted in relationship to:
x= Air Temperture.
z= Water Temperture.

	x<17o vs x≥17o	x<17o vs x=17o	x>17o vs x=17o	z<20o vs z≥20o	z<20o vs z=20o	z>20o vs z=20o
Fs	183.4**	26.56**	0.725	207.2**	49.42**	0.040
d.f.: 1;255	F0.001(1.120)=11.4		F0.001(1.00)=10.8			F0.05(1.00)=3.84

** Very Significant.

In Tables 4 and 5 are shown the mediums of the total amount of caimans counted by grades of air and water tempertures and its confidence intervals.

TABLE 4

Mediums and confidence intervals

Water Temperture	10	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
y	2.33	2.40	1.43	4.00	4.71	7.38	7.71	8.67	9.36	11.17	11.45	10.24	11.11	11.38	11.80	11.29	11.05	11.79	11.93	11.33	10.00
%	12	13	8	21	25	39	41	46	49	59	60	54	58	60	62	59	58	62	63	60	53
n	3	5	7	9	17	13	7	12	14	18	11	21	18	13	24	21	22	19	15	6	1
SD	2.08	1.95	1.99	3.43	4.45	4.05	4.03	4.01	3.39	3.19	2.46	2.95	1.68	2.10	1.67	2.65	1.99	2.02	1.03	1.97	–
CI	5.167	2.421	1.841	2.637	2.300	2.448	3.727	2.548	1.957	1.586	1.653	1.343	0.836	1.269	0.705	1.206	0.882	0.974	0.570	2.068	–
L1%	0	0	0	7	13	26	21	32	39	50	52	47	54	53	58	53	54	57	60	49	–
L2%	40	25	17	35	37	52	60	59	60	67	69	61	63	67	66	66	63	67	66	71	–

y: Medium of the total amount of caimans counted

%: Medium of the total amount of caimans counted, expresed as a percentage of the whole population.

SD: Standard Deviation.

CI: Confidence Intervals.

L1%/L2%: Lower and higher confidence limit expresed as a percentage of the whole population.

TABLE 5

Mediums and confidence intervals

Air Temperture	6	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
y	3.50	1.67	2.64	4.70	3.67	7.25	9.17	9.00	8.44	10.54	10.63	11.20	10.47	12.13	10.88	11.25	11.71	11.17	11.44	11.83	14.00	11.00	9.00
%	18	9	14	25	19	38	48	47	47	55	56	59	55	64	57	59	62	59	60	62	74	58	47
n	2	6	11	10	9	12	6	11	19	13	19	15	19	16	16	20	21	23	18	6	1	1	1
SD	0.71	2.25	3.04	3.59	4.09	4.27	3.54	4.41	3.29	3.20	3.09	2.88	2.29	2.55	2.00	1.71	1.82	2.39	2.09	1.17	–	–	–
CI	6.379	2.362	2.042	2.568	3.144	2.713	3.716	3.016	1.586	1.934	1.489	1.595	1.104	1.359	1.066	0.800	0.828	1.034	1.039	1.228	–	–	–
L1%	0	0	3	11	3	24	29	31	38	45	48	51	49	57	52	55	57	53	55	56	–	–	–
L2%	52	21	25	38	36	52	68	63	55	66	64	67	61	71	63	63	66	64	66	69	–	–	–

y: Medium of the total amount of caimans counted

%: Medium of the total amount of caimans counted, expresed as a percentage of the whole population.

SD: Standard Deviation.

CI: Confidence Intervals.

L1%/L2%: Lower and higher confidence limit expresed as a percentage of the whole population.

CONCLUSIONS

Moonlight do not incide on Caiman latirostris counts.

Air and water temperture could be useful indicators to improve the precision of C. latirostris night counts in the wild, using for this the confidence intervals expresed as a percentage of the whole population as it is shown in Tables 4 and 5.

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A PROGRAM OF MONITORING AND RECOVERING OF WILD POPULATIONS OF CAIMANS IN ARGENTINA WITH THE AIM OF MANAGEMENT THE SECOND YEAR

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INTRODUCTION

Monitoring and recovering of argentine caiman populations' program with management aim has as an objective to determine if ranching technique is useful as a mechanism of conservacionist exploitation based on sustained yield of broad-snouted caiman (Caiman latirostris) mainly whose population situation is weaker than the other argentine specie (Caiman yacare).

The work is on and it is based on the methodology that was displayed at the 10th Working Meeting of the CSG (Larriera, 1990), and the first progress report was presented at the Primera Reunion Regional del CSG in Colombia (Larriera, in press).

The first animals release in the wild took place last November (Figure 1).

FIGURE 1

This paper is about the second year wild habitat harvest and information on amount of nest found, amount of harvested nests, clutch size, hatching success and night counts in the wild are shown

STUDY AREA

This year the work has been carried out in three different places (Figure 2).

FIGURE 2

Zone #1 is "Estancia El Lucero" which is located in the marshy lands of Salado River in San Cristobal State (29o 55' S; 60o 50' W). Here we already worked last year.
Zone #2 is "Mayoraz" which is in the marshland of Las Conchas Brook (30o 5' S; 60o 55' W).
Zone #3 is "Corralitos", San Javier State (30o 10' S; 59o 55' W) and it is formed by Saladillo Dulce River marshes.
There are some other places in the Province were nest were found but for different reason they couldn't be collected. There spots are: "Campo Fisco" (30o 15' S; 60o 50' W) by Las Vizcacheras Brook (Zone #4); and "Islas de La Paz" (30o 50' S; 59o 55' W) by the Parana River coast (Zone #5).

EGGS' HARVEST

In Zone #1 (Estancia El Lucero), an area of 27,000 has. 17 nest were marked and 15 of them were harvested (11 on February 19th 1992, and 4 on March 18th 1992). (Figure 3).

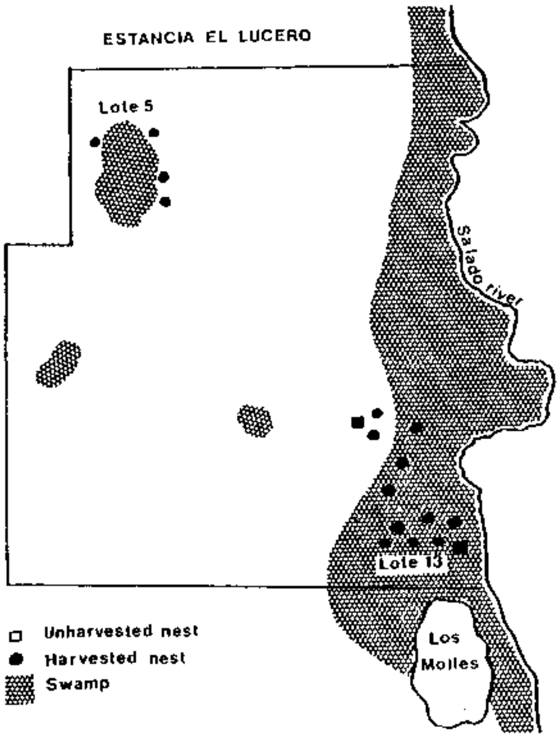

FIGURE 3

In Zone #2 (Mayoraz), an area of 2,000 has, 5 nest were marked, 4 of them were harvested on February 19th 1992. (Figure 4).

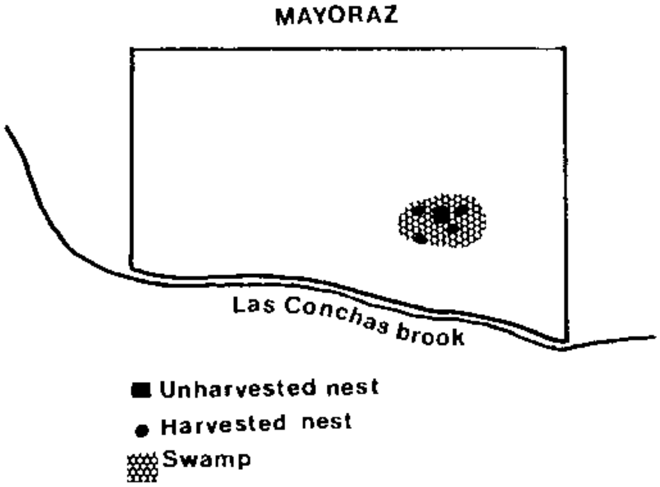

FIGURE 4

In Zone #3 (Corralitos), an area of 3,500 has, 9 nest were marked, 6 of them were harvested on February 22th 1992. (Figure 5).

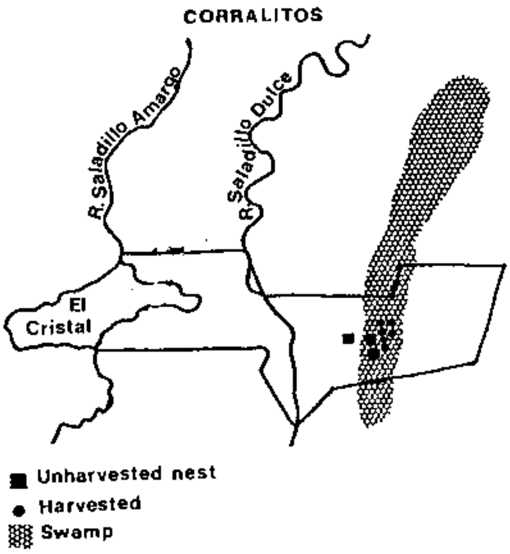

FIGURE 5

In Zone #4 (Campo Fisco), an area of 1,500 has, 2 nest were marked but they were not harvested.

In Zone #5 (Islas de La Paz), an area of 2,500 has, 2 nest were marked but any of them were harvested.

Due to the difficulties the land offered, eggs' harvests were carried out in the same way as it was done last year, first on horseback and them by truck. Plastic containers were used for transportation.

This year the eggs were painted by an aerosol bomb in order to mark its position into the nest so as to keep it into the incubator (Figure 6).

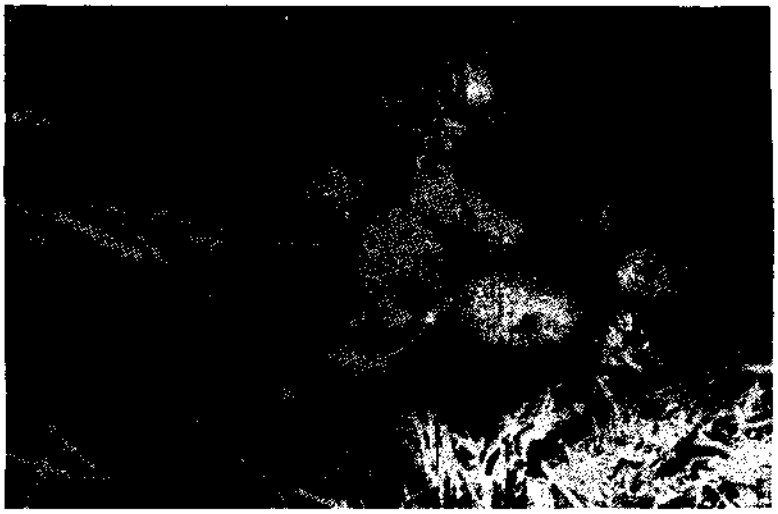

FIGURE 6

In Table 1 amount of nest marked and harvested, amount of eggs and births per sample areas are displayed. The average of clutch size recorded was **36.12.**

TABLE 1

	NESTS RECORDED	NESTS COLLECTED	EGGS HARVESTED	HATCHLINGS
ZONE 1	17	15	561	398
ZONE 2	5	4	160	146
ZONE 3	9	6	182	157
ZONE 4	2	–	–	–
ZONE 5	2	–	–	–
TOTAL	35	25	903	701

CHARACTERISTICS OF THE NESTS

Some comments must be made about the characteristics of the nests found in nature because there are many differences of height and material between nests and therefore two types of Caiman latirostris nests can be clearly distinguished.

Savanna nests: (Figure 7) They are built up near lagoons, swamplands and marshlands. They are only made of grass cut in the surroundigns and they do not have any shadows nearby. In general this type of nests are very big (about 65 cm. of height and about 120 cm. of diameter. The area of grass cut near the nests is very big as well. Nineteen nests were like this.

SAVANNA NEST

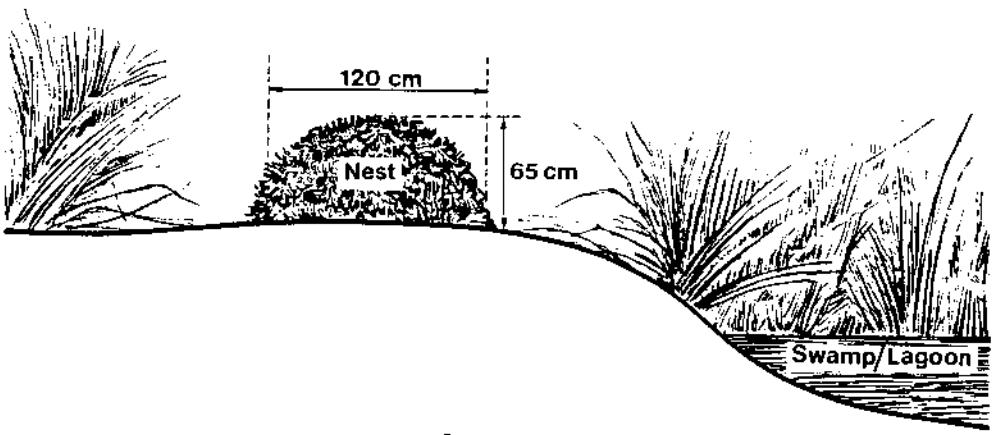

FIGURE 7

Forest nests: (Figure 8) They are built up in the forest far from important mirror-like surfaces of water but close to clearings of semipermanent water. They are made of some herbs, copious quantities of soil and a lot of branches and wood. As a consecence of this, it is quite common to find cracked eggs in this kind of nests. In general the forest nests are smaller than the savanna nests. They can be found in the shadows under the trees and sometimes part of the trunk of a tree is a part of the nest. Six nests were like this.

FOREST NEST

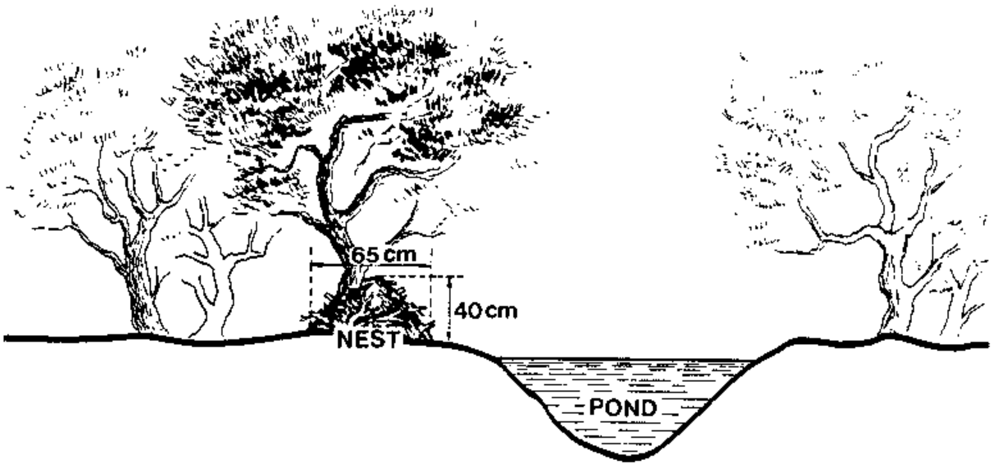

FIGURE 8

Despite the clear differences between the two types of nests, there are not significant differences neither in clutch size nor in the hatching success of one and another.

ARTIFICIAL INCUBATION AND HATCHINGS

At present the incubator is working at a temperture of 30o C. (+- 0.2o C.) and humidity is kept at 95%.

With the aim of lessering humidity variations, nest material is being additionated to the incubator. (Figure 9).

The time that eggs remained into the incubator until hatching, varied between 0 to 42 days, no significant differences on hatching success between them were observed.

In Table 2 the clutch size, artificial incubation period, amount of hatchlings and hatching success per each nest and total are shown.

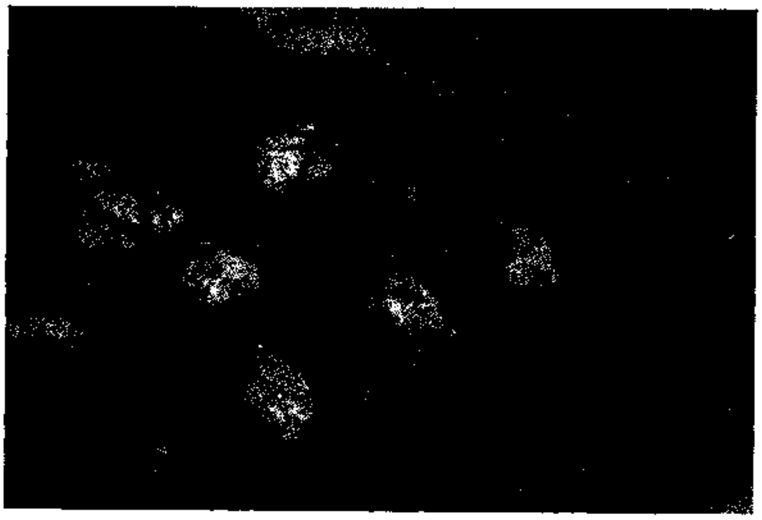

FIGURE 9

TABLE 2

NEST	EGGS/NEST	ARTIFICIAL INCUBATION	HATCHLINGS	HATCHING SUCCESS(%)
1	44	34	42	95
2*	28	—	—	0
3	43	22	38	88
4	29	31	23	79
5	42	21	40	95
6	41	15	24	58
7	41	31	12	29
8	44	30	13	29
9	44	36	37	84
10	39	40	37	94
11	36	0	35	97
12**	49	12/30	39	79
13	42	28	39	93
14	33	12	33	100
15	40	42	27	67
16	30	24	30	100
17	33	26	23	69
18	27	27	25	92
19	35	11	31	94
20	30	24	29	93
21	27	24	19	70
22	37	0	25	67
23	37	0	31	84
24	37	8	34	91
25	15	0	15	100
Total	903		701	77,6

*The nest was found open at the moment of the collect.

**Probably due a multiple nesting.

HATCH AND REARING CONDITIONS

The nests in the incubator were examined twice a day, and when the first call of hatchling was registered, the nest was put in the birth box, where it was kept in dry conditions for three days to make possible natural births. When this period was over, the birth of the remnant eggs was provoked and the animals were moved to cement rearing pens . The rearing took place in pools warmed with electric heaters (Figure 10).

FIGURE 10

The rearing density was of 14 animals per square meter aproximately and the feed (milled chicken with bones, bran cereal and vitaminic-mineral mixture) was supplied three times a week and ad libitum (20% of the corporal weight per week aproximately).

NIGHT COUNTS

In the counts it was registered the number of animals, height, moonlight, water temperture and air temperture.

The results obtained from night counts done between November 1991 and April 1992 are shown in Table 3 and they are compared with those registered between November 1990 and October 1991.

TABLE 3

	Dec.90 to Oct.91	Nov.91 to Apr. 92
Los Molles Lagoon (20 ha)	0.4 caimans/ha	0.6 caimans/ha
Lot Nº5 (40 ha)	1.1 caimans/ha	0.9 caimans/ha
Lot Nº13 (30 ha)	0.9 caimans/ha	1.2 caimans/ha
Lot Nº16 b (1.5 ha)	1.3 caimans/ha	12 caimans/ha

In general the differences are not important despite the releasing of animals that took place in November 1991, with the exception of Lot 16 b where the increase in the number of animals is very significant. This can be easily explained since the Lot 16 b is the only place where the nest was in the same place of the count; consequently the liberated animals remained there during the following counts. The other nesting places are relatively far away from the count places, because of which it is probable that the animals released there will start appearing in places of deeper waters (count places) during this winter (May of 1992).

CONCLUSIONS AND PROSPECTS

The number of collected eggs (903) has been increased considerably and the number of births that took place (701) this year produced a hatching success of 77.6 %.

If the rates of mortality in rearing are kept on the same level as those of last year, we will release in the wild on November 1992, more than 600 animals with a medium weight of 400 gms. aproximately.

This year we will attach telemetric equipment to some animals before liberation in order to follow them.

Now sampling points have been chosen and will be included to the work so that quantity of collected eggs will be increased again.

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Broad-nosed Caiman [*Caiman latirostris*] Semen Collection, Evaluation, and Maintenance in Diluents

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Abstract

Spermatozoa were collected from 8 live male *Caiman latirostris* during December in Piracicaba, Sao Paulo, Brazil. Sperm cells were collected by aspiration from the penile urethra or "groove". In one animal spermatozoa were not found. Two animals produced over one billion sperm cells. To study maintenance of spermatozoa in semen extenders and assess the toxicity of glycerol, six diluents were prepared. These were: 1) BEST - BES (n,n - bis - (2 hydroxyethyl)-2-aminoethane sulfonic acid), TRIS (hydroxymethyl aminomethane), NaCl, glucose, and egg yolk; 2) NaCl with egg yolk; 3) Glucose with egg yolk; 4) BEST with 2% glycerol; 5) BEST with 6% glycerol; 6) BEST with 10% glycerol. All extenders were titrated to pH 7.0 and 327 milliosmoles (before addition of glycerol in diluents 4,5, and 6). Glycerol at 10% caused immediate loss of motility. Glycerol at 6% caused more rapid loss of motility than did 2%. BEST maintained motility at a higher level than did NaCl or Glucose for five days of storage at 5C.

Introduction

The broad-nosed caiman (*Caiman latirostris*) is an endangered species, uncommon in zoos in Europe and North America (Honegger and Hunt, 1990). The native range of this species is the tributaries of the Parana and Sao Francisco Rivers in southern Brazil. A number of *C. latirostris* have been born in captivity in Brazil (Verdade and Lavorenti, 1990) and some observations on reproduction in the species have been made at zoos in North America (Widholzer et al, 1986; Honegger and Hunt, 1990). A colony of *C. latirostris* is maintained at the University of Sao Paulo, Piracicaba, Brazil, for investigations in captive management (Verdade and Lavorenti, 1990).

The purpose of this study was to attempt semen collection in *Caiman latirostris*, assess the numbers of spermatozoa available for artificial insemination and sperm cell preservation efforts, and compare the efficacy of different diluents in maintaining motility of spermatozoa.

Materials and Methods

The *Caiman latirostris* colony maintained at Piracicaba, Sao Paulo, Brazil was utilized for male subjects. Eight males, in apparent good health, were captured by noose from drained concrete ponds where they were maintained either alone or with other animals. Animals #1 and #2 were kept in individual pens. Animals #3 #4, #5, and #6 were housed together in one pond. Animals #7 and #8 were each maintained as the lone male in a pond with three females. Animals were captured without tranquilization by neck snare, the jaws taped shut, and weighed and measured. They were held in dorsal recumbency for exposure of the cloaca.

Semen Collection: The highly concentrated spermatozoa present in the penile urethra and penile groove of males were collected by aspiration and scraping of the groove. The penis was manually exteriorized and held in place by one operator. A second operator passed a soft plastic catheter (size: 04) into the groove and moved it proximally to the fully enclosed urethra. Gently aspiration was applied with a 3 cc syringe. Before placement the catheter was filled with BEST diluent to prevent loss of cells from wetting the interior of the catheter. Spermatozoa in the more distal open groove of the penis were scraped from the inner surface of the groove using the smooth end of a scalpel handle as a spatula. The spermatozoa and mucus were mixed with a drop of BEST diluent.

After collecting all retrievable spermatozoa the cells were diluted in different extenders at approximately 10×10^6/cc. Pooled samples of the remaining cells from all animals evaluated in a single day were reconstituted in BEST at 200×10^6/cc.

Semen Diluents: Stock solutions of BES (n, n-bis-(2 hydroxyethyl)-2-aminoethane sulfonic acid), TRIS (hydroxymethyl aminomethane), NaCl, and glucose were prepared at 350 mOsM. 1) BEST solution contained approximately 50% NaCl, 25% glucose, and 25% BES and TRIS to titrate the mixture to pH 7.0. Table 1 lists the relative concentrations of components required to produce a final solution with pH 7.0 and osmolality of 327 mOsM after 20% egg yolk v/v is added. The concentrations listed are for the clear solution prior to addition of the yolk. A freeze-point osmometer was used to assess osmolality so all solutions could be adjusted to 327 mOsM after yolk was added. The concentrations listed in Table 1 include the addition of BES, TRIS, and water to titrate the solutions to pH 7.0 and 327 mOsM. 2) NaCl solution was primarily NaCl with 20% egg yolk v/v and sufficient BES and TRIS to titrate pH to 7.0. 3) Glucose solution contained primarily glucose with 20% egg yolk v/v with TRIS titration to pH 7.0. 4) BEST with 2% GLYCEROL was BEST with 2% glycerol added v/v. 5) BEST with 6% GLYCEROL and 6) BEST with 10% GLYCEROL were prepared similarly.

TABLE 1

Composition of semen extenders used for dilution of Caiman latirostris spermatozoa. Concentrations of BES, TRIS, NaCl and Glucose are calculated for solution before addition of yolk

Constituent	BEST	NaCl	Glucose
BES	1.192 g %	0.143 g %	
TRIS	0.430 g %	0.091 g %	0.120 g %
NaCl	0.515 g %	0.980 g %	
Glucose	1.590 g %		5.507 g %
Na Pen	1000 u/cc	1000 u/cc	1000 u/cc
Yolk	20% v/v	20% v/v	20% v/v
mOsM	327	327	327
pH	7.0	7.0	7.0

Motility evaluation: Diluted spermatozoa were maintained at 5C in capped airtight plastic tubes. Once daily, a drop of diluent with spermatozoa was placed on a glass slide, coverslipped, and examined at room temperature by two observers. Motility was estimated to the nearest 5 percent. Because no more than three males were handled on each day, some samples were evaluated for longer periods than others.

Results

Two of eight males stored sufficient semen in the penile groove that over one billion cells were collected. One male was not apparently producing spermatozoa. Of six attempts to collect the maximum number of cells from the penile urethra, mean yield was 576 $\pm$ 384 cells. This included a second attempt on a male subjected to collection two days earlier. For all collection attempts in which sperm cells were obtained, motile spermatozoa were present in the material evaluated (Table 1).

Spermatozoa obtained by aspiration were highly concentrated in a volume less than 0.1 cc. These cells were sometimes in clumps when viewed by microscopy, but dispersed into solution as motility was acquired, evidently from the dilution effect. Semen obtained by scraping of the penile groove contained mucus.

In some cases, the catheterization of the penile groove lumen caused bleeding and most of the samples had a slight pink tinge due to contamination with blood. The tissues lining the groove are fragile with a highly vascular tissue, possibly erectile, lining the lumen.

Table 3 summarizes the motility of sperm cells diluted in BEST, NaCl, and Glucose over a five day period. Animals 1, 2 and 3 are included in every observation as spermatozoa were obtained from them on the first day of collection efforts. Other considerations made it impossible to treat subsequent samples from other animals in exactly the same way, but means for all samples available for the specific time period are calculated. BEST maintained a slight advantage over NaCl and Glucose for 3 days. At 4 and 5 days the ability of BEST to maintain motility of spermatozoa was markedly superior to NaCl or glucose.

TABLE 2

Weight and length of animal, total sperm cells recovered, and initial motility and 24-hour motility of sperm cells recovered from the penile groove of *Caiman latirostris*.

Animal	Weight (Kg)	Length (meters)	Total Cells	Initial Motility	24-Hr Motility
1 (238)	44.9	1.96	$1,025 \times 10^6$	90	85
2 (2568)	41.3	1.97	360×10^6	90	90
3 (3478)	32.2	1.80	220×10^6	90	90
4 (378)	31.3	1.89	No sperm cells	--	--
5 (28)	29.8	1.79	$1,100 \times 10^6$	70	80
6 (267)	20.3	1.59	430×10^6	60	80
7 (57)	30.0	1.76	NA	70%	40%
8 (3467)	38.8	1.95	NA	80%	40%
1 (2nd collection)	--	--	320×10^6	40%	70%

NA: No attempt made to collect maximum number of cells

TABLE 3

Mean motility (± s.d) of spermatozoa recovered from 7 *Caiman latirostris* (one animal was used twice) over time in semen extenders BEST, NaCl, and Glucose (n = number of samples available at each time period)

TIME	BEST	NaCl	GLUCOSE
Initial	75.0 ± 17.5 (8)	71.4 ± 15.7 (7)	52.8 ± 29.3 (7)
24 h	73.0 ± 24.6 (8)	66.6 ± 28.5 (7)	65.7 ± 25.9 (7)
2 d	57.5 ± 22.5 (8)	58.0 ± 27.7 (5)	36.0 ± 33.6 (5)
3 d	49.1 ± 30.7 (8)	56.0 ± 23.0 (5)	39.0 ± 30.5 (5)
4 d	63.3 ± 5.8 (3)	20.0 ± 17.3 (3)	20.0 ± 10.0 (3)
5 d	66.7 ± 5.8 (3)	13.3 ± 11.5 (3)	0.67 ± 1.2 (3)

TABLE 4

Motility of *Caiman latirostris* spermatozoa diluted in BEST semen extender with glycerol added at concentrations of 2,6, and 10%

		Glycerol concentration		
Time	Animal	2%	6%	10%
24 h	1	90	70	0
	2	80	10	0
	3	80	5	0
2 d	1	70	20	0
	2	70	10	0
	3	70	0	0
3 d	1	70	0	0
	2	50	5	0
	3	60	0	0
4 d	1	30	20	0
	2	20	2	0
	3	40	0	0

Table 4 presents the results of incubation of spermatozoa from animals 1, 2 and 3 in BEST with 2, 6 or 10% glycerol. Glycerol at 10% eliminated sperm cell motility. Glycerol at 6% was detrimental but allowed some motility. Glycerol at 2% did not cause a diminution in motility over that seen in the same diluent without glycerol until the fourth day.

Discussion

Results from this pilot study in short-term maintenance of liquid cooled semen in *Caiman latirostris* are similar to those obtained in work with *Alligator mississippiensis* (Larsen et al., 1984). The method of collection used is not completely atraumatic in either insult to the tissues involved or in stress to the animal. A semen sample obtained two days after the first collection from one male was decidedly inferior in both quality and quantity to the first.

Motility of cells was maintained better in a solution with a mixture of NaCl and glucose and strong buffering capacity than in a solution with only yolk constituents providing buffering elements. Glycerol was toxic at 6% and 10%, though at 2% it did not markedly inhibit motility for the first three days of liquid cooled storage.

The optimum number of cells for oviductal artificial insemination is unknown in this and other crocodilian species. Work with *Alligator mississippiensis* suggests that artificial insemination can be successful with 300 to 1000 x 10^6 spermatozoa deposited in each oviduct (Cardeilhac et al., 1982; Larsen et al., 1982). The number required for artificial insemination in *Caiman latirostris* may well be smaller but no successes have been recorded.

Freeze preservation of spermatozoa would be helpful in building up the numbers of stored sperm cells for an effort to inseminate multiple females. The studies in cryopreservation could be carried out with spermatozoa collected in the manner described here. Even younger, smaller males would serve to provide 200-300 x 10^6 spermatozoa for investigations of this sort. For studies in artificial insemination with fresh semen, it would appear that larger males providing in excess of one billion cells per collection attempt are necessary to build a pooled sample of spermatozoa adequate for ventures utilizing multiple females.

Acknowledgements

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ESTABLISHMENT, CROCODILE FARMING METHODS, HATCHLING PRODUCTION AND HIDE PRODUCTION OF *Crocodylus niloticus*, AT CROCWORLD, SOUTH AFRICA 1984 TO 1992.

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ABSTRACT:

1) ESTABLISHMENT: HOLDING COMPANY AND FEASIBILITY STUDY, SITUATION, CLIMATE, ORIGIN OF BREEDING STOCK AND RUN AS FARMING AND TOURIST OPERATION.

2) FARMING METHODS

   a) BREEDING PONDS. DESIGN, RATIO OF MALE TO FEMALE, AND REPRODUCTION PERIODS.

   b) INCUBATION. TEMPERATURE, INCUBATION ROOM DESIGN, MATERIALS AND EQUIPMENT USED.

   c) REARING HOUSE (CONTROLLED ENVIRONMENT). DESIGN, POND DESIGN, HEATING BY L.P. GAS BROILER HEATERS, STOCKING RATE AND AGE AND SIZE WHEN REMOVED.

   D) FEEDING SCHEDULES. TYPES OF MEAT FED, ADDITIVES TO MEAT DIET, MONTHLY INTAKE PER CROCODILE IN EACH AGE GROUP AND AN ESTIMATE OF FEED INTAKE OF A CROCODILE AT SLAUGHTER SIZE.

3) HATCHLING PRODUCTION: TABLE SHOWING EGGS LAID, HEALTHY HATCHLINGS AND BREAKDOWN OF DIFFERENCE.

4) HIDE PRODUCTION: TABLE SHOWING NUMBER OF HIDES, AVERAGE BELLY WIDTH AND TOTAL DRY cms.

ESTABLISHMENT

CROCWORLD IS OWNED BY CROOKES BROTHERS LTD (CBL) WHICH IS AN AGRICULTURE COMPANY AND IS LISTED ON THE JOHANNESBURG STOCK EXCHANGE. THE COMPANY HAS ITS ROOTS IN SUGAR CANE FARMING BUT HAS A WIDE VARIETY OF FARMING ACTIVITIES THROUGHOUT SOUTH AFRICA TODAY. AT THIS TIME THE COMPANY HAD BEEN INVESTIGATING VARIOUS FORMS OF AQUACULTURE BUT NONE WERE VIABLE IN 1983 MR DOUG COOKE WAS EMPLOYED TO CO-ORDINATE AND WRITE-UP A FEASIBILITY STUDY AND NATAL PARKS BOARD MADE THE SERVICES AVAILABLE OF MR TONY POOLEY, A LEADING CROCODILE EXPERT.

RENISHAW IS SITUATED 30 DEGREES AND 15 MIN. SOUTH AND 30 DEGREES AND 45 MIN. EAST. THE FARM IS SITUATED ON THE HILLSIDE ABOVE THE AMAHLONGWA RIVER AND 200 METRES INLAND FROM THE SHORELINE OF THE WARM INDIAN OCEAN. THE TOTAL AREA OF THE COMPLEX IS 20 HECTARES. THE DEVELOPED AREA COMPRISES COASTAL DUNE FOREST AND OLD SUGAR CANEFIELD. INDIGENOUS TREES WERE REPLANTED WHEN LANDSCAPING WAS DONE.

THE SITE WAS CHOSEN BECAUSE IT HAD THE POTENTIAL TO SUPPORT A LARGE TOURIST INDUSTRY, HAD MOST OF THE INFRASTRUCTURE REQUIRED, AND A SUITABLE CLIMATE. (TABLE 1).

<u>TABLE 1:</u> FIGURES OF WEATHER DATA TAKEN AT CROCWORLD, MONTHLY SUMMARIES FOR 1991.

	ABS MAX. TEMP. (C)	ABS MIN. TEMP. (C)	MEAN TEMP. (C)	mm RAIN	HOURS SUN TOT	km WIND	ABS MAX. HUM%	ABS MIN. HUM%
JANUARY	30.7	15.5	23.7	99.7	179	6563	96	52
FEBRUARY	29.4	17.1	24.1	99.6	195	5334	96	49
MARCH	31.0	15.1	22.6	104.3	203	5439	96	42
APRIL	27.4	13.2	21.3	8.0	210	4746	95	19
MAY	27.5	11.1	19.3	97.8	201	5283	94	17
JUNE	25.5	8.4	16.5	18.3	213	3427	93	19
JULY	24.2	6.8	16.6	47.5	218	5210	90	11
AUGUST	24.0	8.0	16.8	11.2	175	6696	92	18
SEPTEMBER	29.6	13.4	19.0	119.7	164	5568	96	27
OCTOBER	24.9	12.5	20.0	164.9	119	6167	95	41
NOVEMBER	29.6	13.9	21.7	96.6	148	6317	96	26
DECEMBER	27.6	13.9	22.6	38.1	183	7089	96	32

THE GENERAL TEMPERATURE RANGE FELL WITHIN THE REQUIRED NORMS FOR EGG LAYING AND GROWTH IN SUMMER MONTHS. WINTER TEMPERATURES ARE LOW BUT THE WATER TEMPERATURE WILL NOT DROP BELOW 12 DEGREES CELSIUS IF THE DEPTH OF PONDS IS 1.2 TO 1.5 METRES.

DURING SEPTEMBER 1983 THE FIRST CROCODILES ARRIVED AT CROCWORLD. TONY POOLEY WAS AT CROCWORLD AND DID MUCH OF THE PIONEER WORK. DURING 1984 NINE ADULT MALE CROCODILES AND THIRTEEN ADULT FEMALES WERE ACQUIRED. DURING 1985 A FURTHER FOUR MALES AND FORTY FEMALE ADULT CROCODILES WERE ACQUIRED FROM BOTSWANA AND ONE THOUSAND HATCHLINGS FROM ZIMBABWE. THE FIRST EGGS WERE LAID IN 1985.

CROCWORLD IS DIVIDED AND RUN AS TWO SEPARATE OPERATIONS. FIRSTLY A TOURIST OPERATION (60 TO 120 THOUSAND VISITORS PER ANNUM) WHICH INCORPORATES THE BREEDING PENS, A FEW CROCODILIAN SPECIES, BIRDS, TRADITIONAL TRIBAL HUTS AND DISPLAYS OF OTHER REPTILES AND NATURAL HERITAGE. THE SECOND OPERATION IS THE FARMING OPERATION WHICH IS CLOSED TO THE PUBLIC AND CONCENTRATES ON THE HATCHING AND REARING OF CROCODILES FOR HIDE PRODUCTION.

FARMING METHODS

BREEDING PENS

AN AREA OF 3000 TO 4500 SQUARE METRES HAS BEEN ALLOCATED FOR EACH BREEDING PEN. THE POND SURFACE AREA IS APPROXIMATELY 1000 SQUARE METRES (35% OF TOTAL AREA). EACH PEN HAS TWO PONDS, SO THAT WHEN WATER IS DRAINED THERE IS ALWAYS A POND WITH WATER, DECREASING THE STRESS ON CROCODILES. PONDS ARE CONSTRUCTED OF GUNNITE AND HAVE AN IRREGULAR SHAPE. THE BOTTOMS OF THE PONDS ARE CONTOURED TO ALLOW SHALLOW AREAS OF 0.6 m FOR MATING ACTIVITIES, DROPPING TO A DEPTH OF 2 m AT THE OUTLET. THIS DEPTH ENSURES A MORE CONSTANT WATER TEMPERATURE.

ISLANDS HAVE BEEN INCORPORATED IN THE POND AND ARE VERY USEFUL AS BASKING AREAS AND , IN PARTICULAR, AS OBSTRUCTIONS WHEN MALES ARE FIGHTING. MALES SWIM AROUND AND AROUND THE ISLAND FLEEING OR CHASING OTHER MALES.

THE TWO PONDS IN EACH PEN ARE NOT AT THE SAME LEVEL AND HAVE A BANK WHICH IS WEST FACING BETWEEN THEM. NEST SITES ON THESE BANKS ARE THE MOST UTILIZED SITES IN THE PEN. FEMALES WHICH LAY ON THESE SITES OFTEN ESCAPE UPHILL TO THE TOP POND AND ONLY USE THIS TOP POND. THIS IS CONTRARY TO THE BELIEF THAT NEST SITES HAVE TO BE ABOVE THE LEVEL OF THE WATER. NEST SITES ARE SAND PITS OF 1 m IN DEPTH. THESE SAND PITS OFFER GOOD NESTING MATERIAL AND LIMIT EGG DAMAGE. MANY FEMALES USE THE SAME NEST SITE EVERY YEAR. SOME NEST SITES HAVE BEEN USED BY FOUR DIFFERENT FEMALES IN THE SAME YEAR.

SHADE HAS BEEN PROVIDED IN THE FORM OF TREES, SHRUBS AND REED FENCES (20 TO 30% OF TOTAL AREA). THESE AREAS ARE WELL UTILIZED DURING HOT SUMMER MONTHS. THE GROUND AREA HAS BEEN PLANTED WITH GRASS LAWNS.

A RATIO OF 5 TO 7 FEMALES : 1 MALE IS APPLIED WITH GOOD BREEDING RESULTS - CERTAIN PENS HAVING 100% OF FEMALES LAYING FERTILE EGGS. MOST PENS HAVE 20 FEMALES AND 3 TO 4 MALES. COURTING AND MATING ARE FIRST OBSERVED IN EARLY MAY AND CONTINUE UNTIL LATE IN AUGUST. THIS ACTIVITY IS MOSTLY SEEN IN THE MORNING JUST BEFORE AND AFTER SUNRISE. THE FIRST LAYER STARTS LAYING IN THE THIRD WEEK OF SEPTEMBER AND THE LAST LAYER IN THE SECOND WEEK OF DECEMBER, WITH A PEAK PERIOD DURING OCTOBER (UP TO SEVEN FEMALES LAYING ON ONE DAY). LAYING TAKES PLACE FROM 1500H TO 2000H.

INCUBATION

PATROLS OF BREEDING PENS ARE CARRIED OUT IN THE AFTERNOONS AND EVENINGS. THE SAME AFTERNOON OR NEXT MORNING FEMALES ARE CHASED FROM THE NEST SITE USING A LONG BAMBOO POLE. THIS TASK HAS BECOME EASIER EVERY YEAR AS FEMALES BECOME ACCUSTOMED TO FARMING ACTIVITIES (STOCK COMES FROM THE WILD). STYROFOAM COOLER BOXES ARE USED TO PACK THE EGGS INTO AND VERMICULITE IS USED AS PACKING MATERIAL. DATA COLLECTED AT THE NEST SITE ARE :- DEPTH OF NEST, NUMBER OF EGGS AND ANY DAMAGES, FEMALE NUMBER, SOIL TEMPERATURE AND MOISTURE ACCORDING TO TOUCH.

THE EGGS ARE TAKEN TO AN INCUBATION ROOM, OF WHICH FIVE OF THE CLUTCH ARE MEASURED, AND THEN PACKED INTO SLATED WOOD CRATES. THE WOOD CRATES ENSURE GOOD EXCHANGE OF GASES AND ALLOW DRAINAGE OF EXCESS WATER, ARE CHEAP AND HAVE NO HARMFUL ELEMENT).

SHADE CLOTH IS USED TO LINE THE BOX AND A LAYER OF MOIST VERMICULITE, 5 cm THICK, IS PLACED ON THE BOTTOM. THE EGGS ARE LAID DOWN HORIZONTALLY IN ROWS AND PACKED IN LAYERS. IF A CLUTCH IS LARGER THAN 60, IT IS PACKED INTO TWO BOXES. VERMICULITE IS PLACED OVER AND AROUND THE EGGS ENSURING A COVERING OF AT LEAST 6 cm. A LABEL IS PLACED ON THE BOX WITH THE FOLLOWING INFORMATION : NUMBER OF EGGS, FEMALE NUMBER, CLUTCH SIZE, DATE LAID AND EXPECTED HATCHING DATE.

THE INCUBATOR IS INDOORS AND DOES NOT NEED HEAVY INSULATION. THERE IS A CENTRE WALKWAY WITH RACKS ON EITHER SIDE. TWO FAN HEATERS ARE MOUNTED ON THE WALLS ON EITHER SIDE OF THE PASSAGE AND CONTROLLED BY A THERMOSTAT SWITCH. A CEILING FAN ENSURES EVEN HEAT DISTRIBUTION AND TWO EXHAUST FANS SUCK IN FRESH AIR AND BLOW OUT STALE AIR (THE EXHAUST FANS ARE CONNECTED TO TIME SWITCHES AND ONLY RUN FOR SHORT PERIODS). HUMIDITY IS MAINTAINED BY SPLASHING WATER ON THE FLOOR AND KEEPING THE VERMICULITE MOIST IN THE EGG BOXES.

INCUBATION IS CONTROLLED AT A TEMPERATURE OF 32.5 DEGREES CELSIUS AND A HUMIDITY OF OVER 85% RESULTING IN 80% FEMALES. AIR TEMPERATURE IS NORMALLY 1 DEG. C HIGHER. AT HATCHING TIME WE LISTEN FOR THE SOUND OF THE HATCHLINGS AND REMOVE THEM TO OUR HATCHERY WHICH IS NEXT DOOR. THIS TASK MUST BE DONE AS SOON AS POSSIBLE OR ELSE PRELIMINARY HATCHING OCCURS IN OTHER CLUTCHES.

HATCHLINGS ARE LEFT TO HATCH BY THEMSELVES AND UNHATCHED EGGS ARE BROKEN OPEN 24 HOURS LATER. THE CAUSE OF AN EGG NOT HATCHING IS RECORDED. HATCHLINGS ARE RINSED IN A SALINE BATH TO REMOVE ALBUMIN AND IT ACTS AS A SAFE WEAK DISINFECTANT. THE CROCODILES ARE LEFT TO DRY FOR A NUMBER OF HOURS. THE TAIL SCUTES ARE CUT IN A CODED SYSTEM AND ARE THE SAME NUMBER AS THE MOTHER. THE YOUNG ARE THEN TAKEN TO CONTROLLED ENVIRONMENT HOUSE. THIS IS NORMALLY WITHIN A 24 HOUR PERIOD.

<u>REARING HOUSE (CONTROLLED ENVIRONMENT. CE)</u>

THIS HOUSE IS A LARGE BUILDING (38 X 35 m) WITH A HIGH ROOF WHICH HAS A ZIG-ZAG SHAPE AND DIFFERS TO WHAT IS CONSIDERED THE IDEAL CONTROLLED ENVIRONMENT. BUT DESPITE THESE DIFFERENCES THE GROWTH RATE OF THESE HATCHLINGS IS ON A PAR WITH ANY OF THE TOP FARMS IN SOUTH AFRICA. THERE ARE FOUR ROWS OF PENS, EACH ROW CONSISTING OF FOUR PENS (SIXTEEN ROWS IN TOTAL). THIS DESIGN WAS USED TO FIT IN WITH THE ORIGINAL HEATING SYSTEM - AIR CONDITIONING. WARM AIR WAS TO CONVECT IN EACH ROW. THIS DID NOT WORK. THE TEMPERATURE AT GROUND LEVEL WAS LOW AND RESULTED IN HIGH A MORTALITY RATE. A NUMBER OF HEATING SYSTEMS WERE EXAMINED AND THE MOST PRACTICAL, AND COST EFFECTIVE CHANGE AT THE TIME, WAS GAS BROILER HEATERS. WE FEEL THAT THIS IS AN ADVANTAGE AS THE WHOLE PEN DOES NOT HAVE A CONSTANT TEMPERATURE. THERE IS A VARIATION OF 5-DEGREES C IN EACH PEN. THE CE ALSO HAS WINDOWS ALONG ONE WALL ALLOWING DAYLIGHT TO ENTER THE BUILDING. THE HATCHLINGS SHOW NO STRESS AND AN ADVANTAGE IS THAT WE CAN MAKE PROPER VISUAL OBSERVATIONS AT ALL TIMES.

EACH PEN SIZE IS 8 m x 8 m. THERE ARE TWO PONDS IN EACH PEN WHICH HAVE GENTLY SLOPING SIDES WITH A DEEPER BOX AREA IN THE MIDDLE WITH A LIP ON THE PARAMETER. A FLOOR AREA OF 60 cm WIDE SEPARATES THE TWO PONDS AND IS USED AS A FEEDING AREA.

GAS BROILER HEATERS ARE HUNG 1.5 m ABOVE THE GROUND A QUARTER OF THE WAY INTO THE PEN ABOVE THE FLOOR MENTIONED ABOVE. THERE IS A ALSO DRY FLOOR AREA AROUND THE PARAMETER OF THE PONDS.

THE STOCKING RATE IS 200 PER PEN. THE FLOOR AND POND AREA CAN ALLOW MORE, BUT DURING TIMES OF STRESS HATCHLINGS FORM HEAPS WHICH RESULTS IN DEATHS. A GROUP OF 200 IS MANAGEABLE. A HIGH LEVEL OF HYGIENE IS MAINTAINED. FLOOR AREA AND FEEDING PLATES ARE WASHED DOWN DAILY AND ONE OF THE TWO PONDS IS CLEANED ON ALTERNATE DAYS. CLEAN WATER WHICH FLOWS INTO THE EMPTY POND IS AT ROOM TEMPERATURE AND IS HEATED BY THE RADIATION FROM GAS HEATERS. IT TAKES 6 TO 8 HOURS TO HEAT UP TO 27 - 28 DEGREES C. BY ENSURING THAT ONE POND ALWAYS HAS WATER IN, THE HATCHLINGS ALWAYS HAVE A SAFE REFUGE TO ESCAPE TO. FLOORS ARE SPRAYED TWICE A WEEK WITH A DISINFECTANT (PRESEPT). WHEN HATCHLINGS ARE TRANSFERRED OUT, THE BUILDING IS SPRAYED DOWN WITH A HIGH PRESSURE STEAM PUMP AND FUMIGATED TWICE BEFORE A NEW LOT OF HATCHLINGS IS BROUGHT IN. MAINTENANCE WORK IS ALSO DONE DURING THIS PERIOD.

HATCHLINGS ARE HOUSED IN THE CONTROLLED ENVIRONMENT UNTIL AN AGE OF 9 TO 10 MONTHS. THEY ARE THEN GRADED INTO SIZE CATEGORIES, USING A STRING MARKED AT DIFFERENT LENGTHS, AND PLACED IN PENS IN THE OPEN AIR ON THE REARING UNIT. AT HATCHING THE SIZE IS APPROXIMATELY 30 cm AND WHEN TRANSFERRED THERE IS AN AVERAGE SIZE OF 85 cm - WITH THE LARGEST BEING OVER 1 m AND THE RUNTS 40 TO 45 cm.

OPEN AIR REARING UNIT (RU)

THE RU IS THE AREA AT THE LOWEST ELEVATION OF THE FARM AND HAS THE MOST PROTECTION FROM THE WIND, RESULTING IN WARM CONSTANT TEMPERATURES THROUGHOUT THE YEAR AND GIVING IDEAL CONDITIONS FOR GROWTH. THERE ARE 36 PENS DIVIDED INTO SIX ROWS OF SIX PENS. THREE ROADS RUN THROUGH THESE PENS MAKING FOR EASY ACCESS. EACH PEN HAS A SIZE OF 20 X 20 cm. EACH PEN HAS A SINGLE ROUND POND (GUNNITE, WITH A SURFACE AREA OF 78.5 SQUARE METRES) WHICH HAS A CONE SHAPE WITH A GENTLE SLOPE ON THE PARAMETER AND STEEP SIDES IN THE CENTRE WITH A FLAT BOTTOM 2.5 m IN DIAMETER. GRASS LAWNS HAVE BEEN PLANTED, AS WELL AS TREES, TO PROVIDE SHADE (20% OF THE AREA). EACH PEN HAS A CONCRETE FEEDING PLATFORM THE LENGTH OF THE FENCE ALONG THE ROADWAY, WHICH IS 50 cm WIDE.

STOCKING RATE FOR CROCODILES 10 TO 20 MONTHS IS 300 PER PEN AND 150 FOR CROCODILES FROM 20 MONTHS UNTIL SLAUGHTER (30 - 54 MONTHS). THE GROUND AREA CLOSE TO PONDS IS WELL UTILIZED, WHILE OTHER AREAS ARE UNDER UTILIZED. SHADE AREA UNDER TREES IS WELL UTILIZED DURING THE WARM SUMMER MONTHS. PEN SIZE COULD BE MADE SMALLER AND MORE PENS BUILT ON THE TOTAL AREA OF RU. SMALLER PENS WILL HAVE A LOWER STOCK PER PEN WHICH WILL BE EASIER TO MANAGE AND RESULT IN A HIGHER STOCKING RATE FOR THE TOTAL AREA OF THE PRESENT RU.

EVERY WEEK PONDS ARE DROPPED BY 20%, FILLED, AND ALLOWED TO OVERFLOW FOR 1 HOUR WITH A TOTAL DRAINAGE ONCE A MONTH DURING SUMMER, WHEN FOOD INTAKE IS AT A PEAK. DURING WINTER MONTHS THIS IS NOT DONE AS OFTEN.

PROS AND CONS OF SUCH A REARING PROGRAMME ARE :-

PROS - NO COST OF HEATING, LESS CAPITAL SPENT, LARGE NUMBERS OF STOCK (8000 ON RU), LESS LABOUR AND MANAGEMENT INTENSIVE.

CONS - A LONGER GROWTH PERIOD (NO OR LITTLE GROWTH DURING WINTER), MORE OBSERVATION SKILLS NECESSARY TO DETECT SICK OR PROBLEM CROCODILES.

FEEDING SCHEDULES

HATCHLINGS ARE FED EQUINE MINCE MEAT, IF AVAILABLE, OR BEEF. CHICKEN IS AVOIDED. THIS MEAT HAS A LOW FAT CONTENT AND HIGH QUALITY. ANIMALS COME FROM VETERINARY SURGEONS WHO HAVE PUT THE ANIMALS DOWN FOR MEDICAL REASONS. ADDED TO THE MEAT RATION, BEFORE MINCING, ARE BONE MEAL (5% OF TOTAL MASS FED), AND A 50\50 MIXTURE OF CARCASS MEAL AND FISH MEAL (5% OF TOTAL MASS FED). ON TUESDAY AND THURSDAY CROCODILE VITAMIN PREMIX (0.8% OF TOTAL MASS FED) IS ADDED AND ON WEDNESDAY AND FRIDAY A CROCODILE MINERAL AND TRACE ELEMENTS PREMIX (0.4% OF TOTAL MASS FED). HATCHLINGS ARE FED SIX DAYS A WEEK, MONDAY TO SATURDAY, WITH SUNDAY A REST DAY.

CROCODILES IN THE RU ARE FED ON MEAT WHICH HAS BEEN CUT INTO CUBES. MEAT WHICH IS SELECTED FOR THESE CROCODILES IS GOOD QUALITY CHICKEN, PORK AND BEEF. ON WEDNESDAYS CROCODILE VITAMIN PREMIX IS ADDED TO RATIONS (0.8% OF TOTAL MASS FED). CROCODILES ARE FED FIVE DAYS A WEEK WITH SATURDAY AND SUNDAY REST DAYS.

ADULT BREEDING CROCODILES ARE PART OF THE TOURIST OPERATION AND EACH OF THE FIVE PENS IS FED ON A ROTATIONAL BASIS, RESULTING IN A FEEDING ONCE EVERY FIVE DAYS, WITH A MORNING (1100H) AND AFTERNOON (1500H) FEED. DURING MATING AND EGG PRODUCTION SEASON VITAMINS AND BONEMEAL ARE SPRINKLED OVER THE MEAL. MEATS FED ARE WHOLE CHICKEN, LIVERS AND MEAT WITH BONE (RIBS AND NECK OF BEEF AND HORSES).

AMOUNT OF FOOD TO BE FED IS DETERMINED ON A WEEKLY BASIS FROM DAILY RECORDS OF FOOD WASTAGE. IF THERE IS NO WASTAGE, FEED IS INCREASED; 10% WASTAGE OR LESS, FEED REMAINS THE SAME, AND IF MORE THAN 10%, FEED IS DECREASED.

FROM RECORDS IT IS NOW POSSIBLE TO ESTIMATE FOOD REQUIREMENTS FOR BUDGET PLANNING, STOCK PILING IN FREEZER AND ORDERING MEAT. BELOW IS A TABLE (TABLE 2) SHOWING THESE MONTHLY ESTIMATES FOR EACH CROCODILE AGE GROUP.

TABLE 2: FEEDING ESTIMATES IN kg PER CROCODILE PER MONTH, CROCWORLD.

	ADULTS	SUB-ADULTS	HATCH-LINGS	1 YEAR LD	2 YEAR OLD	3 YEAR OLD
JANUARY	17.0	5.6	0.20	1.9	3.6	4.1
FEBRUARY	14.7	5.3	0.28	2.2	3.6	3.8
MARCH	14.5	3.5	0.41	1.9	2.8	3.0
APRIL	10.0	3.3	0.64	1.7	2.1	2.6
MAY	4.3	1.6	0.72	0.8	0.9	0.9
JUNE	3.7	1.6	0.72	0.6	0.8	0.8
JULY	5.0	2.0	0.77	0.6	0.7	0.7
AUGUST	5.2	2.5	0.8	0.8	0.8	0.8
SEPTEMBER	7.6	3.2	0.85	1.1	1.1	1.1
OCTOBER	12.5	4.5	0.9	1.7	1.7	1.7
NOVEMBER	13.5	4.6	0.7	2.0	2.2	2.3
DECEMBER	14.7	4.7	1.0	2.7	2.9	3.1
	123.1	42.4	7.99	18.0	23.2	24.9

AN ESTIMATE CAN NOW BE MADE ON FOOD INTAKE OF A CROCODILE UNTIL SLAUGHTER AGE. WITH THE CURRENT DEMAND FOR SKINS OF THE SIZE 35 TO 40 cm IN BELLY WIDTH, THE AVERAGE AGE OF CULLING IS 42 MONTHS AT CROCWORLD. FOOD INTAKE UNTIL THIS AGE IS ABOUT 60 kgs.

HATCHLING PRODUCTION

TABLE 3: SUMMARY OF EGG PRODUCTION AND BREAKDOWN OF BREEDING RESULTS AT CROCWORLD.

	1985	1986	1987	1988	1989	1990	1991
No. FEMALES			66	68	71	77	132
No. FEMALES LAID	5	20	37	41	55	69	80
TOT. OF EGGS LAID	233	881	1767	2027	2855	3417	4107
INFERTILE		35	361	423	393	315	414
ROTTEN		172	60	66	100	211	442
EMBRYO FAILURE		80	42	8	313	125	93
DEFORMED		23	8	15	54	46	110
HEALTHY HATCH		318	1231	1455	1975	2700	3015
% HEALTHY HATCH		36%	69.6%	71.8%	69.1%	79%	73.4%
FIRST DATE LAID		12/9	18/9	24/9	27/9	28/9	23/9
LAST DATE LAID		3/11	28/11	7/12	6/12	7/12	6/12
MORTALITIES					172	88	

IN TABLE 3, IN 1986 AN INCUBATION METHOD OF LAYING EGGS OUT FLAT AND OPEN WITH HIGHER TEMPERATURES FOR MALES WAS ATTEMPTED WITH POOR RESULTS.

TABLE 3 SHOWS, IN 1989 A TRIAL ON STYROFOAM BOXES WAS DONE. ALL THE BOXES WERE PLACED ON THE TOP SHELF IN THE INCUBATOR. THIS RESULTED IN A HIGHER PERCENTAGE OF EMBRYO FAILURES. THIS HAS RESULTED IN A CEILING FAN BEING INSTALLED TO ENSURE AN EVEN DISTRIBUTION OF HOT AIR, AND CROCWORLD WILL CONTINUE TO USE WOODEN BOXES FOR INCUBATION.

1990 AND 1991 INCLUDE THE EGG PRODUCTION OF FIRST TIME LAYERS, OF WHICH MANY EGGS WERE INFERTILE.

MORTALITIES INDICATED ARE DEATHS DURING THE FIRST YEAR (UNTIL FIRST BIRTHDAY). MANY OF THESE DEATHS OCCUR IN THE FIRST MONTH AFTER HATCHING. POSTMORTEMS SHOW THAT MORE THAN 90% OF DEATHS IS CAUSED BY YOLK SAC INFECTION. SINCE HATCHLINGS TAIL SCUTES HAVE BEEN CUT, IT HAS BEEN SHOWN THAT MOST OF THE DEATHS CAN BE TRACED BACK TO THE OFFSPRING OF A FEW FEMALES.

HIDE PRODUCTION:

TABLE 4: SUMMARY OF HIDE PRODUCTION AT CROCWORLD

	1987	1988	1989	1990	1991	1992
NO. OF HIDES	500	700	800	475	900	1586
TOTAL cm OF SKIN (DRY)		19460		15441	32350	
AVE. SIZE OF HIDE IN cm		27.8		32.5	36.0	

IN TABLE 4, NO OTHER DATA FOR 1987 WAS KEPT ON RECORD. DATA FOR 1989 WAS LOST BY COMPUTER AND WILL HAVE TO BE EVALUATED AGAIN. DATA FOR 1992 IS NOT COMPLETE AS NOT ALL THE HIDES HAVE BEEN EXPORTED. THE AVERAGE SIZE OF THE HIDE HAS INCREASED AS THE MARKET DEMAND HAS SHIFTED. THIS HAS RESULTED IN A LONGER GROWOUT PERIOD AND LARGER ANIMALS. THE PERCENTAGE OF DOWNGRADE HIDES HAS INCREASED. AT PRESENT THIS IS A PROBLEM AS THE MARKET IS OVER SUPPLIED AND TANNERS ARE SELECTIVE AND TAKE FIRST GRADE HIDES ONLY.

CLOSING STATEMENTS

CROCWORLD HAS BEEN ONE OF THE PIONEERS AND LEADERS IN THE CROCODILE INDUSTRY IN SOUTH AFRICA. THIS IS DUE TO THE SOUND AND THOROUGH BACKING OF CROOKES BROTHERS LTD. THE FARM WAS SET UP BY A WORLD EXPERT IN CROCODILES, TONY POOLEY, WHO STILL SHOWS AN INTEREST IN CROCWORLD AND PAYS REGULAR VISITS TO THE STAFF.

CROCODILE FARMING IS STILL GOING THROUGH GROWTH PAINS AS COMPARED TO OTHER LIVESTOCK FARMING eg BEEF OR DAIRY, WHERE MANY EXPERTS IN EACH FIELD HAVE ALL THE ANSWERS. THIS IS WHAT MAKES CROCODILE FARMING SO INTERESTING AND CHALLENGING. EVERYDAY NEW KNOWLEDGE AND EXPERIENCES MAKE ONE RETURN TO THE DRAWING BOARD. MANY CHANGES IN FARMING METHODS HAVE BEEN MADE AT CROCWORLD, AND WILL CONTINUE TO BE MADE.

CROCWORLD IS EXPANDING PRODUCTION AT ABOUT 20% PER ANNUM. WE ARE ALWAYS LOOKING FOR NEW MARKETS, IMPROVEMENTS AND TO SHARE KNOWLEDGE.

PREDICTING BELLY WIDTH OF *Crocodylus niloticus* FROM TOTAL LENGTH AND/OR TOTAL MASS

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Data collected during annual culling operation, Crocworld, South Africa, from 1988 to 1992. This shows a very high correlation, r=0.9 of belly width to total length and/or total mass.

Data collected on a personal computer using a spreadsheet (Lotus 1-2-3), data sorted and summarized. Summary plotted on a graph.

Using these graphs, belly width can be predicted and used as a management tool during culling operation, e.g. cut off total length, for minimum belly width wanted.

Trends in Nest Numbers and Clutch Sizes of *Crocodylus niloticus* at Four Localities on Lake Kariba, Zimbabwe

by

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ABSTRACT

Analysis of crocodile egg collection returns completed by Zimbabwean crocodile ranchers from 1967 to 1991 has been made for four localities on Lake Kariba. These localities are representative of different present land use patterns on the lakeshore, although they would have all been wilderness at the time of the formation of Lake Kariba in 1958. The Deka river runs through communal land before entering the Zambezi at the upper end of the lake. The Gwaai river is bounded by communal land on its western bank and by forest land on part of its eastern bank. Similarly, the Mwenda river's eastern bank is (unsettled) communal land, while its western bank is safari area. The nest collection area of the Ruziruhuru river runs through the Chete safari area. Although there have been marked changes in egg collection pressures over the years, with only one crocodile rancher collecting from these areas in 1967 with a permit for 2 000 eggs to an unlimited quota in 1987 and subsequent years, a notable trend has been a decrease in the numbers of crocodile nests on the Deka and the Gwaai from 1981 onwards and 1984 onwards respectively. No such trends are obvious for the Mwenda or Ruziruhuru. It is suggested that pressures of human settlement are responsible for the changes to the nesting areas and crocodile populations of the Deka and Gwaai, with livestock farming and gill-net fishing being particularly inimicable to successful nesting.

INTRODUCTION

The reproductive cycle and nesting biology of *C. niloticus* has been described by Kofron (1989; 1990) based on research on the Runde river in the south-east of the country. In essential details there is no difference between the timing of reproduction in the Lake Kariba populations of crocodiles and those in the south-east lowveld.

Zimbabwe's crocodile ranching industry was started in 1965 with the Department of National Parks and Wild Life Management issuing permits for the collection of eggs and juvenile crocodiles from the wild to private individuals and companies. The crocodiles were to be reared to cropping size and the skins marketed (Blake, 1974; Child, 1987). As all the early crocodile ranches were situated along the Zambezi river, including Lake Kariba, it was the nesting crocodiles of the Lake, its inflowing rivers and the Zambezi river that bore the brunt of egg collection. Collection of juveniles was soon phased out as being non cost-effective (Child, 1987). From a small start of 101 eggs collected in 1966 (Blake, 1970), wild collected eggs numbered 13 319 in 1983 (Child, 1987), and 58 210 in 1991.

As part of the justification for allowing an unlimited collection quota of crocodile eggs in Zimbabwe, Craig, Gibson and Hutton (undated) pointed out (p.23, p.57) that nest numbers and mean clutch sizes would be useful in monitoring population trends. Both Cott (1961) and Graham (1968) provide data suggesting a correlation between clutch size and total length in *C. niloticus*. If this is true for all populations mean clutch size could be converted using the appropriate regression equation to mean size of females breeding at that locality and season; size could also be converted to age (Craig, Gibson and Hutton, undated), allowing estimates of the age structure of breeding females.

In January 1969 the senior author, in consultation with Angus and Kevin van Jaarsveldt, two of the pioneer crocodile ranchers, devised a "crocodile egg record" card to collect data for each collected nest on various aspects of nest biology in the wild along with details of incubation and hatching success (Loveridge and Blake, 1976). Two of the recorded details are the locality of the nest and the clutch size. Analysis of these data forms the basis of this paper.

METHODS

Originally the crocodile farmers recorded the data on a voluntary basis, but in 1976 it was made a condition of the permit. The first cards had a space on which "locality" was recorded. The accuracy of this was found to vary greatly and in 1985 a new card was introduced which requested the use of six-figure map references, thus greatly reducing ambiguities that had previously arisen. Both cards specify "number of eggs in clutch" which is the variable considered in this paper, as well as "number of eggs removed", the difference between them being the number of eggs rejected.

For each of the four selected localities - Mwenda, Ruziruhuru, Gwaai and Deka (Figure 1), the number of clutches and the mean clutch size $\pm$ 2 x standard errors (S.E.) was calculated and plotted. Lake level data were obtained from the records of Central African Power Corporation (now the Zambezi River Authority). 1967 and 1968 nest numbers and clutch sizes were made available to the senior author by Angus and Kevin van Jaarsveldt.

RESULTS

Crocodile egg records for the Mwenda river close to the University of Zimbabwe research station at Sinamwenda are the most continuous, starting in 1967 and continuing to the present (Figure 2). The numbers of nests collected at this site varied between 10 and 13 over the years 1967-1979. In 1980 the number of nests removed rose to 38 and remained above 30 for the succeeding two years. This is attributed to additional collecting pressure being placed on this locality by several crocodile ranches where only one had previously been collecting there. The number of nests collected declined in 1983-1987 but rose again once unlimited egg collection was permitted in 1987. Mean clutch sizes at Mwenda remained steady each year, being mostly above 40 and below 48. The three years when the mean clutch size fell below 40 were 1968, 1969 and 1973 (Figure 2).

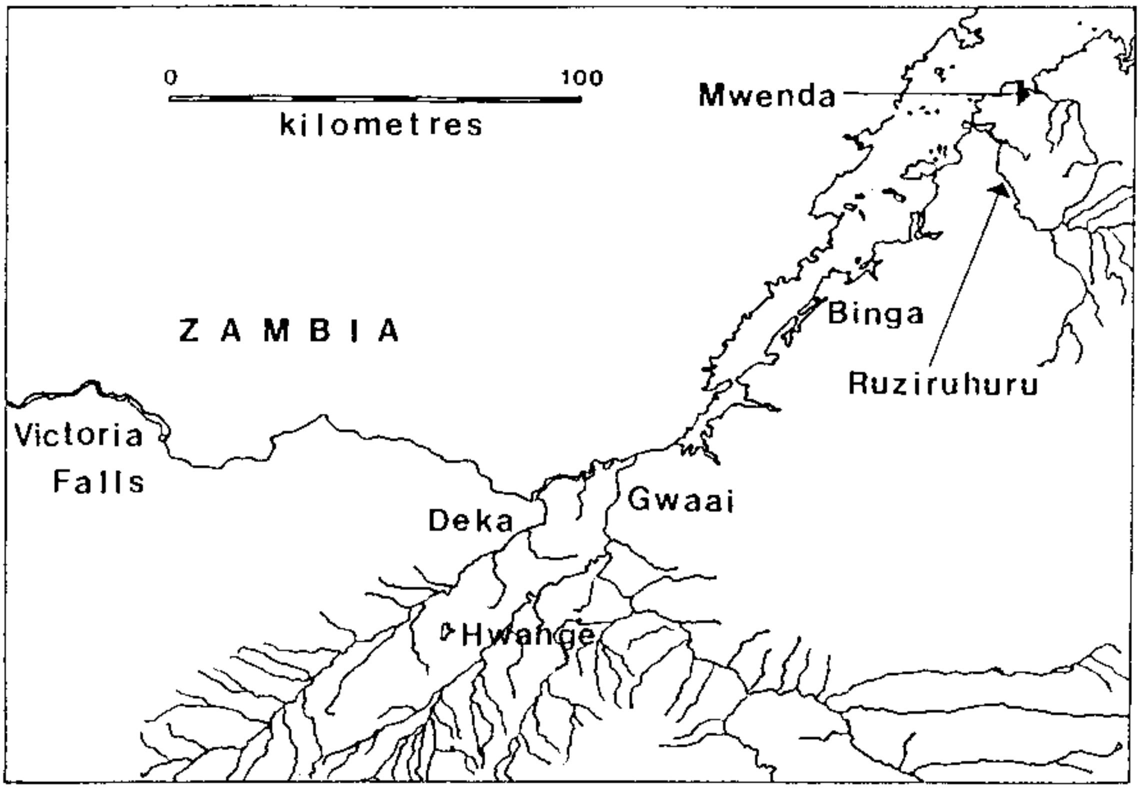


Figure 1. Map of western Zimbabwe showing Mwenda, Ruziruhuru, Gwaai and Deka in relation to the centres Victoria Falls, Hwange and Binga.

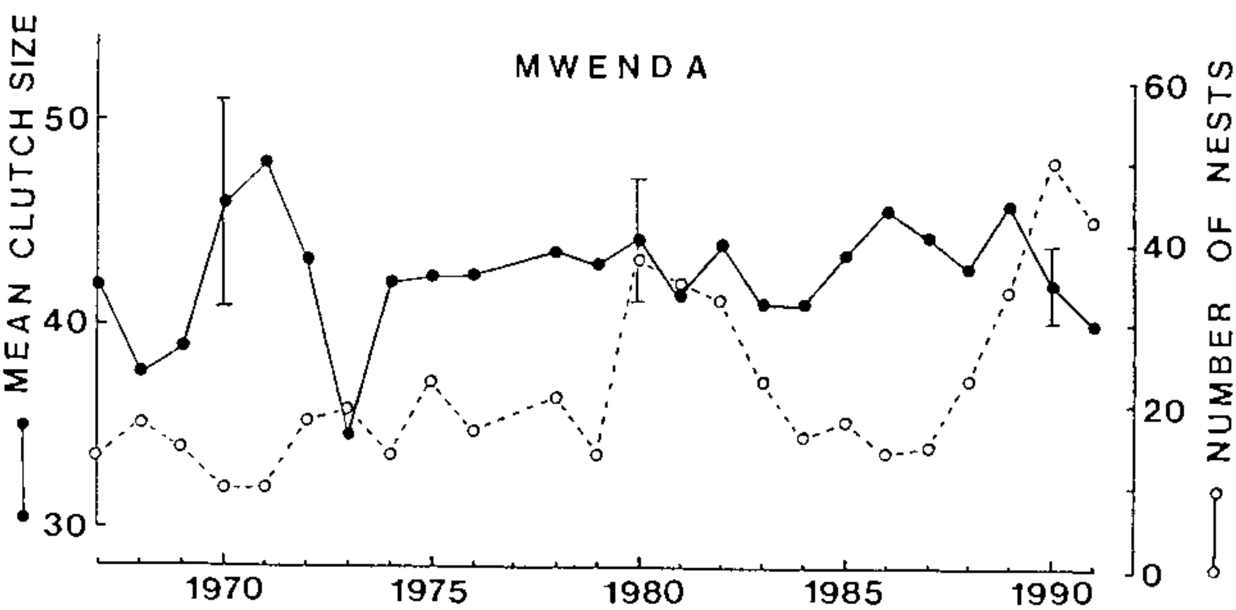


Figure 2. Changes in the number of nests collected and mean clutch size at Mwenda from 1967 to 1991. Error bars $\pm$ 2 x S.E.

At Ruziruhuru in 1967 egg collection yielded 31 nests with a mean clutch size of 42.0 $\pm$ 1.6. As this area was, at that time, a game reserve, no collection was subsequently allowed until 1976, so no data are available for 1968-1975. In 1975, Chete was declared a safari area and crocodile egg collection in the Ruziruhuru was once again permitted. Being generally a rather inaccessible site, the number of nests removed between 1976 and 1986 varied between eight and 42 (Figure 3), with this being not a good indication of nest availability but perhaps more of collection effort. In latter years, and particularly since unlimited quotas were allowed in 1987, many more nests have been collected, with the maximum of 90 being removed in 1991, representing 3 960 eggs. The mean clutch size at Ruziruhuru has remained fairly steady from 1976-1991, although the trend has been mostly downwards (Figure 3) from 48.8 $\pm$ 4.4 in 1976 to 43.7 $\pm$ 3.0 in 1990.

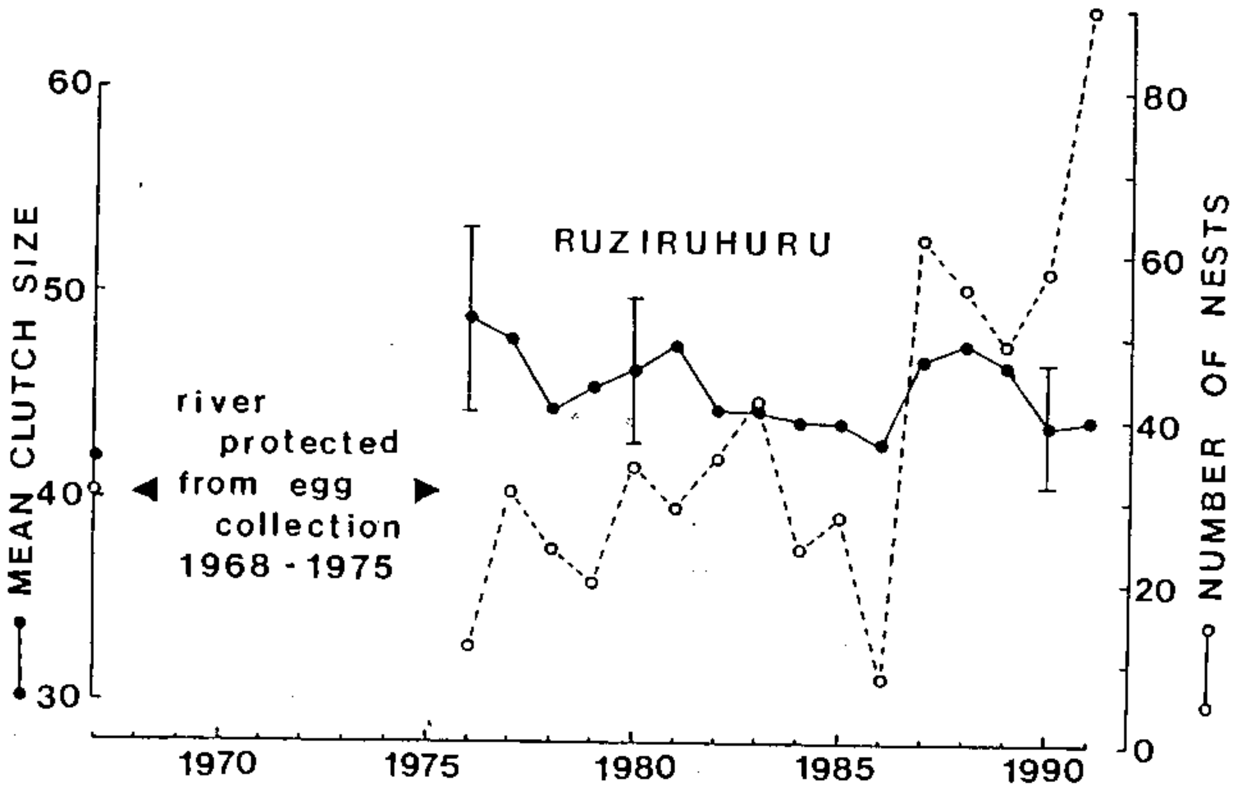


Figure 3. Changes in the number of nests collected and mean clutch size at Ruziruhuru in 1967 and 1976-1991. Error bars $\pm$ 2 x S.E.

At Gwaai river, no nests were collected in 1967 and 1968; in fact the Gwaai and its tributary, the Shangani, were searched in 1967, but no nests were found (A.B. van Jaarsveldt, pers. comm.). In 1969, however, five nests were collected on the Gwaai and this rose over the years to a steady 15-20 from 1977-1983 (Figure 4). In 1984 the number of nests collected dropped to five again and the average number of nests in the years 1984-1991 was 7.0, never again exceeding 12. Mean clutch sizes fluctuated widely at Gwaai, with large error estimates (Figure 4). This is partly attributable to an unusually high incidence of large clutches at this locality. Clutches larger than 70 eggs were recorded there for five of the 21 collecting years, and in 1978 a clutch of 72 and one of 85 were collected.

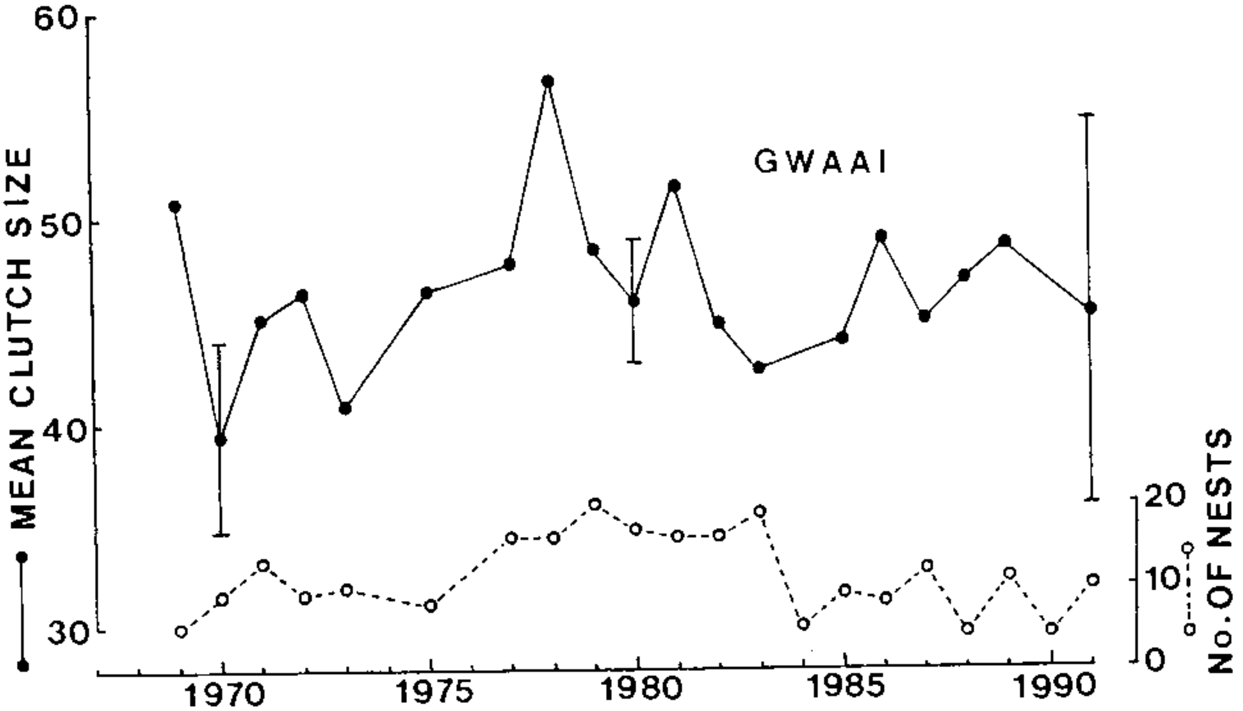


Figure 4. Changes in the number of nests collected and mean clutch size at Gwaai from 1969-1991. Error bars $\pm$ 2 x S.E.

At the westernmost egg collection locality, the Deka river, the most obvious changes have occurred in the number of nests removed (Figure 5). In the years 1969-1979 large numbers of nests were found annually, ranging between 12 and 39. Fairly large annual variations did occur, however, with fewer nests being collected in 1974, 1976 and 1978. The 39 nests removed in 1975 represent 1509 eggs. This should be compared with 1986-1991 when only four to nine nests were found each year and the maximum number of eggs being 358 in 1990. No marked trends are apparent in the Deka mean clutch sizes 1969-1981 where they have a running mean of 40.4 $\pm$ 1.2 (Figure 5). The mean clutch sizes 1986-1991 are somewhat higher, though not statistically so.

DISCUSSION

Trends in Nest Numbers

Provided an accurate estimate of all nests at a locality can be made, this information can provide the basis of estimating the size of the breeding female population. It is doubtful that egg collection alone can provide reliable estimates of nest numbers since some nests are invariably missed by even the most experienced collectors. For example, in 1990 on the Ruziruhuru 59 nests were collected initially and a further five were subsequently found by a second team of egg collectors. On the Mwenda in the same year, 35 were found initially and one was missed. To get even more reliable data it is necessary to visit the area at the time of hatching to enumerate nests that have hatched, and even this will not allow for abandoned nests in which all the hatchlings failed to reach the surface.

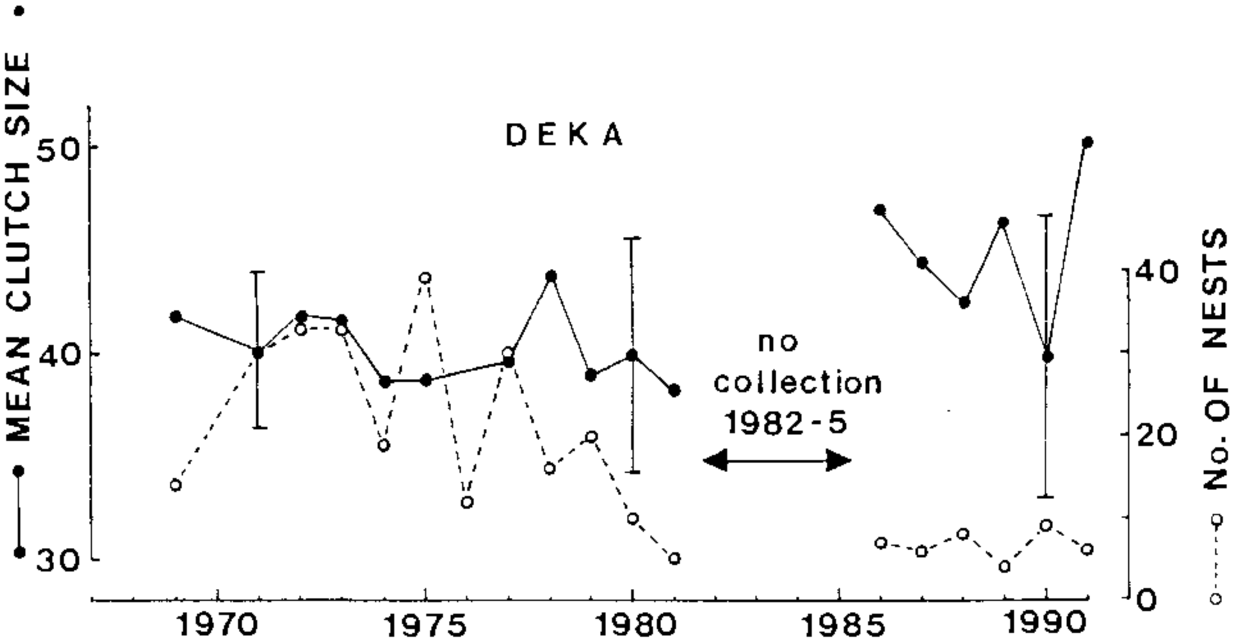


Figure 5. Changes in the number of nests collected and mean clutch size at Deka from 1969-1981 and 1986-1991. Error bars ± 2 x S.E.

For the two sites least subject to human disturbance, Mwenda river (Figure 2) and Ruziruhuru river (Figure 3), trends in nests collected are explicable in terms of collection effort. At both localities, collection pressure up to the mid 1980's was consistently low, with one or two rearing stations searching the area to collect their quota of eggs (initially 2 000, later 2 500 per station). After the introduction of unlimited quotas for the 1987 season based on the recommendations of Craig, Gibson and Hutton (undated), the nests collected at Mwenda and Ruziruhuru increased markedly (Figures 2 and 3). At Gwaai and Deka, however, nests collected declined in the 1980's. At Gwaai this decline occurred in 1985 with a drop from 19 in 1984 to 5 nests (Figure 3). At the Deka river this decline occurred more gradually between 1979 and 1981, though the data are confounded by no collection taking place at this locality in 1982-1985 (Figure 5). The conclusion of decline in the nests is probably justified since collection from 1986-1991 yielded no more than nine nests in any year, as compared with the peak of 39 in 1975. What is more important, perhaps, is that unlimited egg collection from 1987 onwards did not result in more nests from either Gwaai or Deka (Figures 4,5). The reasons for nesting decline at Gwaai and Deka are not certain, but probably are attributable to an increase in human settlement at both these localities. With human settlement came increasing numbers of domestic stock (including cattle) whose grazing and trampling activities are known to make crocodile nesting sites unsuitable (Bruton, 1979). There is a large amount of gill-net fishing activity in the Zambezi and at the mouths of both the Deka and Gwaai rivers which is a further disturbance to the crocodile populations, as well as making crocodiles unpopular with the fishermen (Chimbuya and Hutton, 1987).

Broodstock Production

Captive breeding, to date, has been limited and the first breeding took place in 1989 when eleven females laid 353 eggs, averaging 32 eggs per female. Only 58 eggs hatched and very few of the young survived.

Incubator

An incubator measuring 5 m x 5 m x 2 m was constructed in 1988 and was equipped with underfloor heating and electronic temperature and humidity controls. The cost of the incubator was R15,000. The heating system was improved in 1991 at a cost of approx. R3,000.00.

In 1990 1,250 eggs were produced by 34 females, averaging 37 eggs per female. 600 eggs hatched and many of the young had swollen bellies. Several problems were encountered with diseases and by September 1991, less than 16% of the 1990 production still survived.

During the 1991 season a total of 1,632 eggs were produced by 44 females, averaging 37 eggs per females (minimum 8 eggs; maximum 66). A total of 1,029 eggs were fertile (63%) and 805 eggs hatched (78%). 21% of the fertile eggs that failed to hatched showed evidence of embryonic death.

Analyzing the 1991 results more carefully, the following came to the fore: There were 17 deformities and 36 hatchlings had massive bellies at hatch. Four eggs contained twins and some young hatched with abnormally swollen eyes. Abnormalities of this kind may have a detrimental effect on the performance of the unit.

Rearing Facilities

Two hothouses, each measuring 40 x 12 m, were constructed of bricks, steel and fibreglass. The cost of the buildings, in 1985, was R50,000.00. Both buildings proved to be unsuitable as they were not insulated. One building was properly insulated in 1988 and provided with a diesel heating system. This was done at a cost of R150,000.00.

In addition to the cost of these facilities there are the cost of rearing the hatchlings.

Discussion

Capital expenditure on broodstock enclosures amounted to R30,000 in 1985 and R36,000 in 1988. The investment in broodstock was

R100,000 in 1985 and, up to 1991, R51,000 was invested to raise and care for these crocodiles. R15,000 was spent on an incubator in 1988 and another R3,000 on improving the heating system of the incubator in 1991.

A certain amount of the money invested in 1985 was borrowed at an interest rate of 26%. The prime rate of interest in the Republic of South Africa is, at present, in the region of 19% whereas the official rate of inflation is close on 17%. Investments in government stock, on the other hand, currently earn 16% tax free. Bearing these factors in mind it is essential to add finance costs to the amount invested, in this case a value of 21,5%. This results in a total investment amounting to R692,571.

A value has to be attached to each hatchling irrespective of whether it is to be sold or moved to a rearing unit. If the investment of R692,571 is to be recovered by selling the 800 hatchlings, they should be sold for R865,71 each! (R692,571/800). This is obviously not realistic and it was decided that the investment should be recovered over a five year period, resulting in a cost of R115 per hatching (R692,571/6,000).

The rearing facilities cost R50,000 in 1985 and a further R150,000 was invested in 1988. Again, finance costs were calculated at 21,5%, adding another R72 per hatchling (R429,894/6,000). The total cost, per hatchling, prior to rasing, thus amounts to R187 (R115 + R72).

The fixed costs to raise the hatchlings consists of heating, wages, transport and maintenance. These costs will not very even if double the number of hatchlings are raised. Heating, by means of a diesel burner, costs R24,000 per year. Over the two year period heating costs amount to R60 per hatchling raised (R48,000/800). Wages, transport and maintenance, on this particular farm, amounts to R36,000 per year, thus R90 per hatchling reared (R72,000/800). It is thus evident that the unit costs can only be reduced if the number of hatchlings reared per year is increased.

Variable costs in the form of food amounts to R18 per crocodile. Food is costed out at .45 c per kg and 40kg of food is required per crocodile over the two year period.

If the facility costs, fixed costs and variable costs are summarised, the total cost to raise each crocodile over a two year period amounts to R355. With 800 crocodiles being reared, this indicates that R134.400 in disposable cash will be required over the two year period ((R60 + R90 + R18) x 800).

With regards to income, and for the purpose of this paper, it is assumed that after 24 months 30 cm belly width skins are produced and that these skins, on average, will generate $4 (USD) per cm. With a rand/dollar exchange rate of R2.71 to the dollar the income per skin will amount to R325.20 (30 x 4 x 2.71). A further R50 per crocodile could be generated from meat sold to the restaurant trade.

The internal rate of return on investment therefore amounts to 5,67% on this particular farm. Compared with an internal rate of return of 38% before tax, as proposed by Brummer (1992), this particular unit is nowhere near an acceptable rate of return which could ensure the long-term profitability of this enterprise.

The question arises whether a similar situation prevails on other crocodile farms.

REFERENCE

Brummer, L. M. 1992 A financial model for crocodile farming as an investment. In: Conservation and Utilization of the Nile crocodile in Southern Africa - Handbook on crocodile farming. Ed. G.A. Smith and J. Marais 1992. pp 45 - 50.

ACKNOWLEDGEMENTS

The authors wish to thank Jof Joubert, Bennitt Joubert and Mr B. van Vollenhoven for their assistance in preparation of this paper.

EVALUATION OF BROODSTOCK PERFORMANCE

YEAR	1989	1990	1991
AGE OF BROODSTOCK (YEARS)	8	9	10
TOTAL NO. ADULT FEMALES	135	135	135
NUMBER OF LAYING FEMALES	11	34	44
% OF FEMALES LAYING	8,15%	25,19%	32,59%
TOTAL NUMBER OF EGGS	353	1250	1632
AVERAGE NO. OF EGGS PER FEMALE	32	37	37
FEMALE PRODUCTIVITY (EGGS)	2,61	9,26	12,09
NUMBER OF HATCHLINGS	58	600	805
FEMALE PRODUCTIVITY (HATCHLINGS)	0,43	4,44	5,96

CASHFLOW ANALYSIS
CROCODILE FARMING

YEAR	85	86	87	88	89	90	91	TOTAL	
COSTS INCURRED :									
BROODSTOCK ENCLOSURE	30 000							30 000	
NEST AREAS				36 000				36 000	
BROODSTOCK	100 000							100 000	
BROODSTOCK CARE	4 000	5 000	6 000	7 000	8 000	10 000	11 500	51 500	
INCUBATOR COST				15 000			3 000	18 000	
S/T	134 000	5 000	6 000	58 000	8 000	10 000	14 500	235 500	
Opening balance		162 810	202 814	252 419	364 689	451 098	558 083		
FINANCE COST @ 21.50%	28 810	35 004	43 605	54 270	78 408	96 986	119 988	457 071	
Closing balance	162 810	202 814	252 419	364 689	451 098	558 083	692 571	692 571	6 000
21.50%									115

COST OF REARING FACILITIES :									
REARING HOUSE	50 000			150 000				200 000	
Opening balance		50 000	60 750	73 811	239 681	291 212	353 823		
FINANCE COST @ 21.50%	0	10 750	13 061	15 869	51 531	62 611	76 072	229 894	
Closing balance	50 000	60 750	73 811	239 681	291 212	353 823	429 894	429 894	6 000
									72

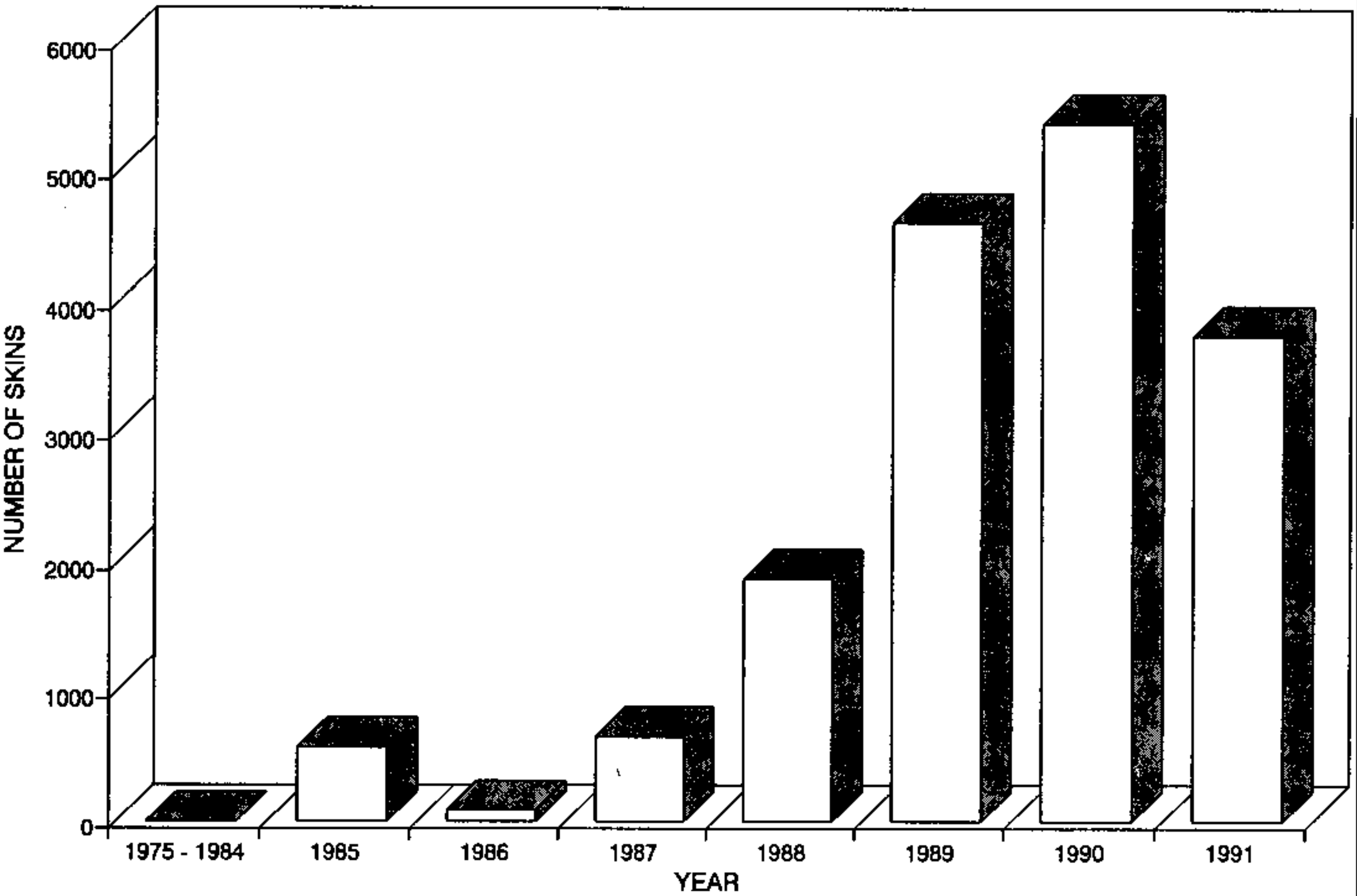
COST PER HATCHLING :			
BROODSTOCK & FACILITIES		115	
REARING FACILITIES		72	
		187	
FIXED COSTS (24 MONTHS) :			
HEATING		60	
WAGES, TRANSPORT & MAINTENANCE		90	
VARIABLE COSTS (24 MONTHS) :			
FOOD		18	
	800	355	134 400

INCOME PER HATCHLING –

	cm	$/cm	$ vs R	R	Total
SKIN	30	4.00	2.71	325.20	260 160
MEAT				50	40 000
TOTAL INCOME				375	300 160

5.67%

SOUTH AFRICAN *Crocodylus niloticus* SKIN EXPORTS



SURVEY OF THE CROCODILE POPULATIONS OF THE REPUBLIC OF PALAU, CAROLINE ISLANDS, PACIFIC OCEAN, 8-24 JUNE 1991:

A Report to the

Government of the Republic of Palau

Koror, Palau.

By

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and

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25 June 1991

INTRODUCTION. The Crocodile Specialist Group (CSG) of the Species Survival Commission (SSC) of the World Conservation Union (IUCN) has prepared an Action Plan for conserving the crocodilians of the world. This plan provides the most up-to-date assessment of the conservation status of the various species and it highlights the critical problems which must be addressed to ensure their conservation and to maintain biological diversity.

One of the highest priorities of the CSG Action Plan is to determine the status, size class and distribution of crocodilians in areas that have not been systematically surveyed in recent times. The Republic of Palau, in the western Pacific Ocean, is one such area.

During 1989, Messel and King (1990) carried out a systematic survey of the crocodile populations of the Solomon Islands, which once were known to have substantial crocodile populations and to have supported an important crocodile skin industry. However, in the 30 years prior to the survey, the crocodile populations had been decimated by both expatriate and local hunters thus precluding the establishment of a viable local sustainable utilization program.

The above issue is of some importance. Firstly, there is the important matter of the conservation of a keystone species and the maintenance of biodiversity. The removal of a crocodilian from the top of the food chain is likely to have damaging, unforeseen, and far-reaching consequences. Secondly, there is the issue of the severe degradation of a valuable economic resource, usually in developing economies, struggling to increase or even maintain a standard of living.

There is now much evidence that one of the most powerful tools for conserving certain species of crocodilians is the sustained yield utilization (SYU) of the wild populations based on the biological requirements of the species. Presently, countries such as Australia, Papua New Guinea, Venezuela, the U.S.A., and Zimbabwe, have been operating successful SYU conservation programs for their crocodilians for some time. Economic incentive has been turned into a valuable conservation tool to the benefit of botb wildlife and the local people. IUCN-The World Conservation Union has embraced SYU of wildlife as one of its cornerstones for helping to preserve biodiversity. Our task, for the present survey was to determine the conservation status of the crocodilians of Palau and the potential for developing a SYU program for this resource.

SPECIES IDENTIFICATION OF THE PALAU CROCODILES. Unwarranted confusion has surrounded what species of crocodile occurs on tbe Palau islands; all the Palau crocodiles are the saltwater or estuarine crocodile, *Crocodylus porosus*. No other species occurs in Palau.

Motoda (1937 and 1938) stated that the Palau crocodiles were the same species as occurs in India, *Crocodylus porosus*, or possibly *Crocodylus palustris*. All other early published records of the crocodiles of Palau referred to *Crocodylus porosus* until Wataru Kimura (1968) reported finding three species of crocodile in Palau during his trip to the islands in 1967, the Philippine crocodile, *Crocodylus mindorensis*, and the New Guinea crocodile, *Crocodylus novaeguineae*, in addition to *Crocodylus porosus*. Without questioning the accuracy of Kimura's identification, most subsequent authors simply repeated his declaration that the three species occur in Palau.

Kimura (1968) reported that prior to World War II, a Mr. Saeki, of the Kimi Marine Products Company, operated a crocodile farm on Arakabesang Island, in the Koror area of Palau. In 1938, Mr. Saeki stocked the farm with 900 crocodiles from Davao in the Philippines; 1,000 crocodiles were purchased but 100 died in transit. These imported crocodiles could have included *C. porosus* and/or *C. mindorensis*. In addition, 10 native crocodiles from Palau were captured for the farm and 10 American alligators also were obtained from a Mr. Tahasaki in Tokyo. A second 1,000 crocodiles were later imported from the Philippines to replenish the farm stock, and 10 crocodiles also were imported from New Guinea. The crocodiles from New Guinea could have been *C. porosus* and/or *Crocodylus novaeguineae*. One of the crocodiles from New Guinea, a 12-foot long specimen, was sent to the Atami crocodile farm in Japan, the rest stayed in the Palau farm. Prior to the start of World War II, the farm stock had been reduced to approximately 200 animals. During the war, soldiers ate many of the crocodiles, and few if any remained by the end of the war. Some may have escaped, though Mr. Saeki, who was interviewed by a third person in 1948, did not believe that the wild crocodiles of Palau were derived from escaped or released farm stock. Kimura (1968) agreed.

Kimura (1968) did not explain how he distinguished between *C. porosus*, *C. mindorensis* and *C. novaeguineae*, but apparently it did not involve the morphological characters used by most crocodile biologists, the presence in *mindorensis* and *novaeguineae* of four enlarged, bilaterally symmetrical (i.e., two on each side of the midline) postoccipital scutes on the nape between the skull and the enlarged nuchal cluster, and their absence in *porosus*. Possibly Kimura recognized different forms based on skin color as in February 1969, he wrote to Robert Owen, a biologist for the U.S. Department of the Interior, Office of Territorial and International Affairs, Trust Territories Administration, seeking replacements for

"New Guinea black skin crocodiles" from Palau that had died. Possibly he mistakenly believed that the occasional *C. porosus* with one slightly enlarged postoccipital scale on one side of the neck was *C. novaeguineae* or *C. mindorensis*.

Kimura (1968) reported that *Crocodylus novaeguineae* was found in the east coast rivers of Babeldaob, while *Crocodylus porosus* and *Crocodylus mindorensis*, and a few *Crocodylus novaeguineae*, occurred in the west coast rivers. We found only *C. porosus* in Palau's rivers, estuaries, and in the freshwater Ngerdok Lake. We also examined every captive crocodile that we could in Palau (see list below) and 2 specimens in the Belau National Museum; without exception they are all *C. porosus*.

More recently several popular publications (e.g., Thyssen 1988) have suggested that two species of crocodiles, *Crocodylus porosus* and *C. novaeguineae*, are found in Palau and that a third form, a hybrid between the two, now is widespread throughout the islands. There is no evidence that *C. novaeguineae* ever occurred in Palau and there is no evidence of any hybrid on the islands. Until evidence to the contrary is produced we will continue to believe that *Crocodylus porosus* is the only species of crocodile that occurs in Palau.

HISTORY. While in Palau, we managed to research the early history of crocodiles and crocodile management in the country. Using a number of reliable sources we documented the fascinating but sad story of the decimation of the crocodiles of the Republic. The responsibility for the decimation must be attributed largely to the recommendations and actions (or lack of action) of the U.S. Department of the Interior, Office of Territorial and International Affairs, Trust Territories Administration (hereinafter U.S. Administration), during the 1960's and 1970's and of the Chief Conservationist and Entomologist in Palau, Mr. Robert P. Owen.

We located two important scientific papers by Sigeru Motoda (1937, 1938) of the Tropical Life Sciences Research Center, Koror, Palau. These were published in Japanese, but fortunately English translations were available to us. Motoda states that a survey was conducted by the Ministry of Education, Special Education Bureau, immediately after the Japanese took possession of the islands in 1914. According to Motoda, the results of the surveys by Messrs. Narabayashi, Ishibashi, and Horii appeared in 1916 and 1917 and were reprinted in the 1928 'Report on the Survey of the Mandate Islands of the Pacific.' Each of them declared that crocodiles were found in Palau, and that a few crocodile attacks had occurred. Mr. Risabura Kyota who had been living in Ngeremlengui since 1910 also gave information on crocodiles in Palau and his observations on nesting and behavior appeared in the 25 February 1937 South Pacific News Magazine. The first crocodile reported to be caught in Ngatbang (= Ngeremeduu Bay) was between 1898 and 1905 when the islands were administered by the Germans. Most of the crocodiles were between 2 and 3 feet in length. Interestingly, the German administration prohibited the capture of crocodiles in Ngatbang Bay in order to conserve them.

Motoda reported a number of crocodile attacks, some of which were fatal, for the period 1915 to 1920. He also enumerated the 54 crocodiles captured during the period 1915 to 1936 and reported that crocodiles were observed 20 times in four years in Galmiskan. While individual nuisance crocodiles were trapped, both the German and Japanese administrations apparently were determined to coexist with the crocodiles of Palau and there is no record of trying to exterminate them.

In 1947, Palau became a trust territory of the United Nations administered by the U.S. government. We were unable to discover much information about crocodiles for the period 1947 to 1958 by which time Mr. Robert P. Owens was the

U.S. Administration's Staff Entomologist in Koror and apparently was responsible for overseeing many wildlife matters, including the crocodiles of Palau.

Then on 28 December 1965, while spearfishing at night, Mr. Ngiramulei Yoroi of Koror was attacked and killed hy a 12 foot 7 inch crocodile weighing 427 pounds. This crocodile was trapped on 8 January 1966, was put on public display, and the public charged a fee to view this man-eater. Yoroi's widow eventually received $70.00 from the viewing fees. The public display of this crocodile so enraged the public that several people attempted to kill it. It died several days later, allegedly after being poisoned. Its remains eventually were shipped to the U.S. National Museum of Natural History, Smithsonian Institution, in Washington, D.C. The U.S. Administration in Palau had hoped to sell the crocodile to a zoo or private collector for a large sum of money, part of which was to be paid to the deceased's family and the remainder to be used to purcbase materials for constructing traps for eliminating the crocodiles. In response to the exceedingly unfortunate death of this one fisherman, the Administration launched not a program to control individual crocodiles that threaten humans but a campaign to eradicate all crocodiles in Palau, no matter where they occurred. It was little more than a war against the species.

It should be noted here that prior to the death of Yoroi, hatred of crocodiles by local Palauans was not as pervasive as it was after the publicity given his death by the U.S. Administration. In fact, local villages regarded crocodiles as special collaborators if not friends -- see 'Local Beliefs' below.

The unfortunate death of Yoroi thus appears to have determined the fate of the crocodiles of Palau under the U.S. Administration for alarm bells immediately were set ringing and calls were made for the destruction of all crocodiles. No attempt was made to calm the citizens of Palau or to discourage eradication. The October 1966 session of the Palau Legislature passed Resolution No. 7-10-66 which requested the District Administrator of the Palau District to provide for construction of crocodile traps to be distributed to all municipalities. In July 1968, a Bill was introduced in the Congress of Micronesia providing for a bounty for killing of crocodiles and alligators for the purpose of encouraging the destruction of these animals which "...have increasingly posed a menace to the health, life and limb, safety and welfare of the people of the Palau District." Interestingly, we were unable to find any record of dissent.

During the period 4 December 1967 to 8 January 1968, a crocodile survey of Palau was carried out by a group under the direction of David Imes and Jack Hardy (Australians?). They made 21 crocodile counting sorties, spent $1,000, and only sighted 23 crocodiles. The surveys were initiated by the U.S. Administration officials in an attempt to determine whether or not the crocodiles of Palau could be harvested profitably for the benefit of locals. Apparently the results of these surveys did not confirm the belief of the U.S. Administrators who were convinced that Palau was infested with thousands of crocodiles. As a result, nothing much appears to have come from this effort to establish a crocodile fishery even though an allocation of $16,200 was proposed by the Fisheries Division of the U.S. Administration.

However, in November 1967, a Mr. Rene Henri of various addresses in Melbourne, Australia, (after a previous meeting) contacted Robert Owen, then Staff Entomologist in Palau, with a proposal to have Australians from "crocodile shooting clubs" come to Palau to shoot crocodiles for sport and for their skins. [Interestingly, after 40 years in Australia and working there for 21 years on crocodiles one of the authors of this report (HM) has never heard of such clubs.] Robert Owen wrote to

Mr. Henri on 23 January 1969 (only 12 months after the Imes and Hardy surveys had found only 23 crocodiles) stating that he thought there were approximately 5,000 crocodiles of all ages in the Palau Islands.

After a very lengthy organizational and bargaining period, on 24 June 1969, the government of Palau, under U.S. Administration, entered into a contractual agreement with the "Australian Crocodile and Big Game Association" of which Mr. Rene Henri was President. Apparently no check was made on the credentials of the Association. This agreement granted the Association exclusive rights for three years to hunt, kill and skin crocodiles in the District of Palau and to sell the hides and remains. In return, the Association contracted to train local Palauans in the killing and skinning of crocodiles and the marketing of hides. Importantly, the contract drawn up by the U.S. Administration required the Association "...to kill all crocodiles which it had the opportunity to exterminate regardless of size." As Peter T. Wilson, the Fisheries Management Biologist in Palau, stated in May 1969, "We find the people of Palau have one unanimous desire and that is to get rid of all crocodiles." The U.S. Administration apparently was doing its best to see to it that this desire was met.

However, the Australian Crocodile and Big Game Association quickly tired and disappointed the government. After only two months (11 August 1969) they broke their 3-year contract and left in their ship the 'Mia-Mia' for further shores. The Association had found that contrary to what the government reported to them earlier there were at best only several hundred crocodiles of a size suitable for commercial hunting and that these were best left to their local trainee, Rik-Rik Spis. They had shot a total of 85 and reported that only 6 remained in areas where they could threaten humans and these would be eliminated within a month or two.

Amazingly, Mr. Henri was congratulated for his efforts by Robert Owen and the High Commissioner of the Trust Territories. Fortunately, this strange episode did not wipe out the crocodiles of Palau.

Rik-Rik Spis continued hunting crocodiles and it is recorded that by 1972 he had shot almost 200, but thereafter the enterprise appears to have come to a halt.

By 1975, the crocodile population of Palau was gaining the attention of a number of overseas scientists and naturalists. James H. Powell, Jr., of Plainview, Texas, U.S.A., contacted Robert Owen, by now the Chief Conservationist of Palau. Powell visited Palau during the period October-November 1975 using an Explorers Club of New York grant to study crocodilians in the field. His objective was to "Determine from first-hand field observations the distribution and status of *Crocodylus porosus* populations throughout the Palau Islands, from Kayangel in the north to Angaur in the south." He also wished to do the same for *Crocodylus novaeguineae* which Owen had stated was present in Palau. Such a project would be a major undertaking requiring considerable logistic support.

Powell reported on his visit in an unpublished document dated 2 February 1976 which was circulated by him privately. From his report, it appears that he was singularly unsuccessful in his mission and only sighted one crocodile in Palau and this animal was swimming in open but shallow sea.

During 1976, Professor W.A. Dunson, Pennsylvania State University, expressed an interest in studying the crocodiles of Palau (with the aid of a National Science Foundation grant) and specially the issue of which species of crocodilians were present in the islands. He was scheduled to arrive in Palau on 9 March 1977, but we have been unable to locate any report on the results of his visit.

In July 1978, Dr. Ian R. Swingland, Oxford University, U.K., and currently of the SSC Tortoise and Freshwater Chelonian Specialist Group, also showed interest in studying the crocodiles of Palau. However, it appears that his visit did not eventuate. If it did, we have not located a report on it.

During the late 1960's, Inoue Tanning Company of Tokyo showed considerable interest in starting a crocodile farm and hide production industry in Palau, but nothing came of this. Strangely, though Owen had received extensive information from Max Downes on the important SYU crocodile program in Papua New Guinea (PNG) as early as 1968, he was not interested. Owen was aware that in 1965-1966, the export of hides was worth $1,000,000 to PNG. While the Papua New Guinea program protected adult crocodiles greater then 9-feet in length so they would continue to breed and produce eggs and hatchlings that could be reared on farms, Owen stated in a letter to Downes dated 18 October 1968 that he was doing just the opposite, he was exterminating the adult breeders in Palau. Owen negotiated the contract with the Australian Crocodile and Big Game Association following this exchange with Downes.

In December 1977, in a letter to John Lever, PNG Crocodile Project, Owen stated, "I will continue to gather what information I can and possibly initiate a small farming project in hopes that some economic benefit can be derived for the people of Palau from crocodile farming without endangering the existence of the species here." Apparently, the decision to exterminate the crocodiles in Palau had been dropped, but by then many people in Palau hated the crocodiles and economic incentives for their conservation were minimal.

The final major assault on the crocodiles of Palau came in the period 1979-1981. It is difficult to find the actual reports documenting this; however, in late 1978 or early 1979, a joint enterprise between two Palauans, Kikuo and Hashida, and two Japanese, Hasegawa and Oshima was established for shooting crocodiles in Palau and selling their skins. This enterprise used three hunting boats and apparently was under the supervision of Joshua Eberdon, who is the local member of the present crocodile survey team. He states that between 500 and 1,000 crocodiles of all size classes were shot, from all parts of Palau, before the enterprise folded in 1981. Toshio Yamanaka, President of Yamatoshi Hikaku Co. Ltd. which purchased the skins, reports that Hasegawa and Oshima "sent approximately 200 skins and the number of skins for one shipment was in the region of 30/50 skins...The size of the skins was mostly 30 to 40 cm of belly width and about 10% of the lot were 50 cm." The money from the sale of the skins was to be used in part to establish a crocodile farm in Palau. A few pens were built and about 50 animals captured, but one night all the animals were stolen so Yamatoshi Hikaku Co. Ltd. abandoned the project.

At the present time, Eberdon has 41 *Crocodylus porosus* on a farm in Koror. Because *Crocodylus porosus* is listed on the U.S. Endangered Species List and Eberdon lacks permits from the Office of Management Authority, U.S. Fish and Wildlife Service (FWS), the crocodiles on his farm are illegal. They range from 3 to 11 feet in length and are in excellent condition. Eberdon states the crocodiles were all caught during the past 2 to 3 years (1989-1991), that this pretty well cleaned out the wild population, and that only remnant crocodiles remain here and there. While the government of Palau does not operate a program to remove nuisance crocodiles that might threaten humans, Eberdon has operated one privately. Whenever he hears by word of mouth that some village is trying to kill a crocodile, he has tried to discourage this. When the village or individuals involved are unrelenting in their determination to kill the crocodile, Eberdon has volunteered to catch it alive and place it in his farm.

We also inspected two (7-8') and two (9-10') *Crocodylus porosus* belonging to ex-Senator Baules in concrete pens behind the 'Crocodile Lounge' in Airai, Babeldaob. In addition, we examined the single (6-7') *C. porosus* in a small enclosure in front of the Hotel Nikko Palau, and a single (7-8') *C. porosus* in a small enclosure on Belilou Island. Mark Vereen, Angaur Island, came to see us in Koror and discussed his desire to establish a crocodile farm on Angaur. He currently has 4 (6-7') *C. porosus* which he is raising in captivity on Angaur. Senator Lucius Malsol has a (4-5') *C. porosus* in a pen at his house, and Baste Terulii has a (9-10') *C. porosus* in excellent condition in a concrete pen, both in Koror. FWS permits have not been issued for any of these captive crocodiles in Palau, bence all of them are held illegally.

LOCAL BELIEFS. Prior to the anti-crocodile hysteria of the U.S. Administration, some Palauan communities did not always try to kill crocodiles but instead tried to live with them even though the reptiles were dangerous. An example of this is the following story involving a village on the Ngerdorch River in eastern Babeldaob:

'Ksau ma Ius'
(Ksau and the Crocodile)

A man named Ksau lived with his family in the small village of Ngersuul on the bank of the Ngerdorch River. All the people living in Ngersuul knew that a crocodile lived in the river and Ksau constantly reminded his family to be careful because of the crocodile.

Every time his children wanted to go near the river, when they wanted to swim in the river, Ksau would protect them by using magic to determine if the crocodile was near. If so, they did not go near the river.

The crocodile also used magic before hunting in the river. The crocodile tried many times to overcome Ksau's magic but was unsuccessful; the crocodile's magic was not strong enough to overpower Ksau's magic.

Eventually, the crocodile approached Ksau in the middle of the night when no one would see them together. Ksau was asked to share his magic so the crocodile could tell if prey was near, magic which the crocodile promised to use for hunting elsewhere. They debated the issues but initially Ksau could not agree to the crocodile's requests. After lengthy discussions, the crocodile told Ksau, "If your children want to swim in the river, you should rub them with a new coconut leaf and then tie it around their necks. If you do that, I will not hother them."

Ksau finally agreed, making a strong binding promise that his children would swim in the river only after being rubhed with new coconut leaves and had the leaves tied around their necks.

The story spread all around the village and soon every child that went swimming would wear a coconut leaf around his or her neck and they were not hurt by the crocodile.

The people of the village named Ksau's family, Keblil ra Ius (= crocodile family). Today, all Palauans know this family name.

This story clearly illustrates that the current hatred of crocodiles is not traditional in Palauan culture. The story first was told to us by Joshua Eberdon and his brother and later verified from a storyboard in the Belau National Museum (though the museum storyboard records the man's name as Sechemlong).

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The present survey would not have heen possible without the active participation of Chuck Cook, head of The Nature Conservancy Office in Palau. We have offered to hire him to organize all of our future surveys -- need we say more.

We also wish to thank David Idip, Director of the Bureau of Resources and Development, Noah Idechong, Chief, Division of Marine Resources, and Demei Otobed, mentioned above. They spent many hours helping us plan the surveys and the important logistic support needed.

Diderot Gicca provided a halfway house for storing gear and bolstering spirits in Guam and helped arrange reservations for us. Greg Gordon, Duty Free Imports, Koror, kindly loaned us the lightweight plastic canoe that was dragged into Jellyfish Lake. We wish to thank them and the many people of Palau who made our brief stay both productive and enjoyable.

Finally, we owe special thanks to Joshua Eberdon who provided us with information on the 1979-1981 hunting period and so ably served as a member of the survey team. His intimate knowledge of the waterways, coral reefs, mudflats, seagrass beds, and narrow channels allowed us to work at night in areas that otherwise would have been difficult or impossible. His unfailing knowledge enabled us to survey at speed, and in the middle of the night when the night's work was done, it allowed us to race back to Koror, even through some horrendous rain storms. On those occasions when the boat ran out of water, his able assistant, Swingly Ngirakiang, got into action and poled and poled until the boat was back in deep water.

METHODS. The survey methods for repeatable night spotlight censusing of crocodile populations are given in detail in Messel *et al* 1981, Monograph 1 of 'Survey of Tidal River Systems in the Northern Territory of Australia and Their Crocodile Populations.' This publication is one of 20 monographs on crocodile surveys by Professor Harry Messel and co-workers and published by Pergamon Press. Since the Palau Islands crocodile survey is only concerned with the species of crocodile, their number, size class, and distribution, it was not essential to measure and record a number of parameters usually recorded in a survey. State of the tide, amount of bank exposed, water salinity and temperature were monitored. Salinity measurements indicate whether the aquatic habitat is a freshwater system or not. This is of importance as salinity generally determines the suitability of the particular waterway as a potential breeding area -- see Monograph 1, page 100.

Normally, on long hazard-free tidal waterways, with a team of three (i.e., spotter, recorder-navigator, and driver), surveys are made at a speed of 20 to 30 km per hour and cover from 40 to 100 km per night before the tide rises and the amount of exposed bank decreases to less than 60 cm making it harder to see the crocodiles. Such ideal conditions do not exist in Palau. The waterways are short, narrow and often quite shallow. Each waterway was surveyed from the zero point at its mouth to the upstream terminal point that was determined by shallow water, rocks, log jams, or mangrove roots that prevented navigation further upstream. The waterways have extensive mudflats and/or coral reefs fronting their mouths making it difficult and often impossible to gain entrance near low water. This is especially true on the east coast of Babeldaob. Once in a waterway, it often is impossible to gain entrance to the next one near low water, especially at night. This ensures minimal night-time survey distances.

The tidal variation between high and low water was often in excess of 2 meters during June 1991 and hence required careful planning both for daytime reconnaissance of the survey routes and for the nighttime surveys. Along the northeast coast of Babeldaob, surveys can only be effectively conducted for 2 hours on either side of high water. Extensive reefs and mudflats surround Palau and expert local knowledge of their location is a prerequisite to navigate these waters at night. We were fortunate to be able to engage the services of Mr. Joshua Eberdon, proprietor of the 'Crocodile Farm' in Koror, mentioned above. His knowledge of the reef strewn seas and the tidal waterways of Palau made it possible for us to work safely and efficiently. His knowledge of where the remaining crocodiles of Palau were most likely to be found proved accurate and saved us much valuable time. In addition, Mr. Swingly Ngirakiang acted as poler for the survey boat and helper to Eberdon. While working with us, we hope that Eberdon was able to pick up the rudiments of rigorous crocodile surveying techniques.

Optimum months for surveying are April and May (see Fig. 1). February and March have less rain, but they also have higher winds which can whip up rough seas. Surveying in June or July in the rainy season is miserable and sometimes impossible.

Prior to commencing our surveys a Cessna 207 aircraft was used for making a broad aerial survey of the coast of the main island, Babeldaob, Belilou, and the Rock Islands. Boats of 5 to 7 meters in length with either twin 75 hp or single 55 hp outboard motors were used for the surveys, although frequently the tides combined with extensive mudflats, grassflats, and coral made the motors useless and poling necessary. For the surveys of Ngerdok Lake, a 3-meter inflatable craft was used, and for Jellyfish Lake, a 4-meter canoe.

Quick response probes for temperature measurement, a temperature compensated refractometer for rapid salinity measurements, a digital compass, a Magellan GPS NAV 1000 PRO for fast and accurate determination of latitude and longitude, spotlights and recording lights operated off a 12-volt automobile battery, 5-cell Magnalites, marking tapes and special reflective tabs were all required and used. In addition, survey sheets and books, large scale maps, cameras, photographic film of various speeds, cassette tape recorder, and a laptop computer and portable printer were used and are requisites for systematic and repeatable day and nighttime surveys and rapid data analysis.

RESULTS. Our findings are presented and discussed separately for each of the general areas surveyed.

1. Belilou Island.

During the nights of 10 and 11 June 1991, the following waterways were surveyed (to locate the latitude and longitude zero starting points see U.S. Geological Survey Map, Republic of Palau, Caroline Islands, 1/25,000 series, Belilou sheet):

	Longitude	Latitude
North Estuary - West Channel	134°16'E	7°02.1'N
North Estuary - East Channel	134°15.5'E	7°00.7'N
South Estuary	134°14.2'E	6°59.3'N
Milk Fish Pond	134°15.9'E	7°02.3'N

Midstream distance surveyed and the numbers of crocodiles sighted were:

	km	number sighted
North Estuary - West Channel	3.4	13
North Estuary - East Channel	2.9	2
South Estuary	1.8	0
Milk Fish Pond	0.5	2
Total	8.6	17

There are three main areas of mangrove on Belilou Island and each of them is difficult or impossible to survey near low water because of the shallow nature of the mangrove channels and the extensive mud flats between the many small mangrove islands in the estuaries. For optimum spotlighting of crocodiles there should be at least 60 cm of exposed bank. On Belilou Island it is best to spotlight on a rising half tide.

There is one important swamp draining into the North Estuary and this could provide good breeding habitat. Measured salinities showed that there was a large freshwater inflow to the estuaries at this time of year, the beginning of the wet season. The South Estuary was more saline than the northern one.

The size classes of the 17 crocodiles sighted were: 1 (2-3'), 5 (3-4'), 2 (4-5'), 1 (5-6'), 2 (6-7'), 1 (9-10'), 3 (EO<6'), 2 (EO>6'). 'EO' stands for 'eyes only,' those animals for which size estimate could not be obtained.

We also examined a captive (7-8') *C. porosus* which had been captured in

Milk Fish Pond. This animal was penned up in a very small area and its condition was not optimum.

Considering the limited crocodile breeding habitat and the smallness of Belilou Island, the sightings of a small population of crocodiles there covering a wide range of size classes, provides hope for a slow recovery of the population if it can be protected. In due course, this could become the basis for a Sustained-Yield Utilization (SYU) program through wildlife tourism which would provide real economic incentive for the local people to conserve their crocodiles and their habitat.

2. Ngeremeduu Bay Area.

During the nights of 13 and 14 June 1991, the following waterways were surveyed (the zero starting points can be located on U.S. Geological Survey Map, Republic of Palau, Caroline Islands, 1/25,000 series, Oreor and Ngermetengel sheets):

	Longitude	Latitude
Ngermeskang River	134°31'E	7°30'N
Nkebeduul River	same	same
Ngetpang River	134°31.1'E	7°29.1'N
Tebecheding River	134°30.7'E	7°28.7'N

Midstream distances surveyed and the number of crocodiles sighted were:

	km	number sighted
Ngermeskang River	7.8	1
Nkebeduul River		
Mainstream at km 2.0	4.7	0
Creek at km 3.8	0.2	0
Creek at km 4.5	0.3	0
Ngetpang River		
Mainstream	3.4	0
Creek and km 0.4	0.3	0
Tabecheding River	4.1	1
Ngeremeduu Bay Shoreline	4.9	1
Total	25.7	3

Ngeremeduu Bay and its four small tidal waterways provide an excellent crocodile breeding and rearing system. Both the Ngermeskang and Nkebeduul Rivers are excellent Type 1 breeding systems (salinities decrease to freshwater upstream) and the Ngetpang and Tabecheding Rivers are slightly less so, but still provide good rearing habitat. The mouth sections of each of the rivers are heavily vegetated with *Rhizophora stylosa* which gradually give way to freshwater complex vegetation on the upstream sections, specially on the Ngermeskang and Nkebeduul rivers. Enclosed Ngeremeduu Bay with its extensive mud flats also provides good crocodile feeding habitat. There are numerous signs of increasing development along the upstream sections of the four waterways which could impinge severely on the crocodile breeding habitat.

Only 3 crocodiles, 1 (5-6'), 2 (6-7') were sighted in the whole system, remnants of a once far greater population, numbering in hundreds. Records indicate that over 200 crocodiles were taken for their skins from the Ngeremeduu Bay area alone.

Surveying near low water is very difficult due to the problem of gaining entrance to the river mouths. It is preferable to survey on a rising tide, for near low water it is impossible to pass from one river to the next, especially at night.

3. Airai Area.

During the night of 15 June 1991, the following waterways were surveyed (zero starting points can be located on U.S. Geological Survey Map, Republic of Palau, Caroline Islands, 1/25,000 series, Oreor sheet):

	Longitude	Latitude
Kadebel River	134°31.3'E	7°21.3'N
Ngrikill River	134°34'E	7°22.1'N
River 'A'	134°34.6'E	7°22.1'N
River 'B'	134°34.7'E	7°21.9'N
Klai (Oikull or Airai) Channel	134°35.7'E	7°22'N

Midstream distances surveyed and the number of crocodiles sighted were:

	km	number sighted
Kadebel River		
Mainstream	1.4	0
Creek at km 0.9	1.6	1
Ngrikill River		
Mainstream	2.2	0
Creek at km 0.5	0.5	0
River 'A'	0.4	0
River 'B'	0.7	0
Klai (Oikull or Airai) Channel		
Main channel	2.1	0
Oikull tributary	0.3	0
New short channel	0.2	0
Bay shoreline	13.6	0
Total	23.0	1

The Airai area with its bays, inlets, channels, and rivers provided some good habitat for *Crocodylus porosus* but that is changing rapidly as the area is developing and fishing, farming, and residential activities are infringing everywhere. Crocodiles have no future in this area and nuisance crocodiles would have to be removed. The area was known to have a large crocodile population even 15 years ago.

Only one crocodile was sighted during a long nighttime survey. This animal was very wary and submerged the minute the light beam hit it.

The Ngrikill River has some good crocodile breeding habitat and is a small

Type 1 freshwater system. All the streams are heavily vegetated with the stilt rooted *Rhizophora stylosa* on the downstream sections. River 'A' is a hypersaline system.

Surveying near low water is practically impossible due to the extensive mud flats throughout the area and the shallow nature of many of the streams. It is better to survey on a rising tide.

4. Babeldaob Island, East Coast Area.

During the stormy nights of 18 and 19 June 1991, the following waterways were surveyed (zero starting points can be located on U.S. Geological Survey Maps, Republic of Palau, Caroline Islands, 1/25,000 series, Ngermetengel and Oreor sheets):

	Longitude	Latitude
Ngiit Creek 'F'	134°38.2'E	7°34.9'N
Ngiit Creek 'E'	134°38'E	7°34.8'N
Ngeredekuu River	134°37.2'E	7°32.5'N
Imolch North Creek	134°37'E	7°32'N
Imolch South Creek	134°36.9'E	7°31'N
Ngerdorch River	134°35.6'E	7°25.9'N
Ngermerecheraki Creek 'H'	134°35.1'E	7°23.7'N
Ngermerecheraki Creek 'I'	134°35.2'E	7°23.5'N
Plus 19.5 km of coast between Ulimang and Badibei.		

Midstream distances surveyed and the number of crocodiles sighted were:

	km	number sighted
Ngiit Creek 'F'	0.6	0
Ngiit Creek 'E'	0.4	0
Ngeredekuu River		
Mainstream	2.5	0
West arm at km 0	1.3	0
East arm at km 0	1.0	0
Tributary 'G' off East Arm at km 0.5	0.4	0
Imolch North Creek	0.5	0
Imolch South Creek	0.7	0
Coastal fringe from Ulimang to Ngeruling	14.0	0
Ngerdorch River		
Mainstream	4.4	0
Estuary at km 0.2	0.2	0
West arm at km 3.6	0.3	0
Ngermerecheraki Creek 'H'		
Mainstream	1.2	0
West Arm at km 0	0.4	0
NW Arm at km 0.1	0.3	0
Ngermerecheraki Creek 'I'	0.8	0
Coastal fringe from Ngerdorch River to west of Badibei	5.5	0
Totals	34.5	0

The northeast coast of Babeldaob Island is a singularly difficult area to survey with its coral reefs and mudflats. The area can only be worked comfortably 2 hours before and after high water and even then the shallow water requires that the motors be abandoned and the boat be poled over long distances. The area is such that local knowledge of the waters is a prerequisite for night survey work. From the Ngerdorch River southward, the area is more amenable to surveys and work can be conducted closer to low water. Generally, surveying on a rising tide is to be preferred.

There are two Type 1 crocodile freshwater breeding systems in the area, Ngeredekuu and Ngerdorch Rivers and numerous hypersaline coastal creeks; only a few of which are navigable. Ngerdorch River with its many small upstream tributaries and freshwater swamps downstream undoubtedly provides the best crocodile habitat in Palau. In addition, it is a scenic river with typical lush Type 1 river vegetation. Unfortunately, it is not possible to navigate upstream beyond km 4.4 because of blockage by fallen timber.

We surveyed 34.5 km of this east coast habitat both during the day and night and did not sight a single crocodile, nor did we sight any signs such as tracks or slides of crocodiles on the banks. We were told proudly by the locals that they killed any crocodile they saw. The locals also told us that there were many crocodiles left in the area, and the reason that neither we nor they saw any crocodiles was because they were hidden. It is difficult to convince the locals that they have been singularly successful in bringing *C. porosus* to the verge of extinction.

It is well known that there was a substantial population of crocodiles in the area in the past. Joshua Eberdon, who guided and worked with us on this survey was born and raised in a village on the Ngerdorch River, some of his family still live there and his Mother is the traditional owner of the downstream freshwater swamps mentioned above. He reports that there was a major population of crocodiles in his area and that these were eradicated during the 1969-1972 and 1979-1981 shoot-outs. In addition, the locals have deliberately killed every crocodile they could since those periods.

During our daytime reconnaissance of the Ngerdorch River we noted very heavy red lateritic soil run-off following the heavy rains the previous evening. Apparently, this silt originates from highway construction upstream. If not remedied quickly, it will undoubtedly kill the reef around the mouth of the Ngerdorch where the silt is deposited.

5. Babeldaob Island, Mid-West Coast Area.

During the day and night of 21 June 1991, the following waterways were surveyed (zero starting points can be located on U.S. Geological Survey Map, Republic of Palau, Caroline Islands, 1/25,000 series, Ngermetengel sheet):

	Longitude	Latitude
Imeong and Ngerutecher Rivers	134°31'E	7°32.2'N
Ngeremasech River	134°32.3'E	7°33.9'N
Irur River	134°33.7'E	7°36'N
Iwekei River	134°34'E	7°36.3'N

Plus 10.3 km of coast between Imeong and Iwekei Rivers.

Midstream distances and number of crocodiles sighted were:

	km	number sighted
Imeong River	1.8	0
Ngerutecher River at km 0.4 on Imeong	1.6	0
Ngeremasech River	0.9	0
Irur River	1.0	2
Iwekei River	2.2	0
Coastal fringe from Imeong to Iwekei Rivers	10.3	1
Total	17.8	3

The four rivers and coastal mangrove fringe surveyed are known to have contained some of the major crocodile populations of the west coast of Babeldaob Island. These are just to the north of the Ngeremeduu Bay area discussed above and the crocodiles were cleared from this are as they were in the Ngeremeduu Bay area. We sighted three crocodiles, 1 (2-3') and 1 (4-5') in the Irur River and 1 (7-8') along the coastal fringe. Crocodiles sighted along the coastal mangrove fringe would be animals from one of the four Type 1 freshwater river systems. These animals do not inhabit the coastal fringe but use it for feeding and for passing from one waterway to another.

The Imeong, Ngerutecher, and Iwekei rivers all contain some good crocodile breeding habitat but these rivers are used heavily by local people and the Imeong and Iwekei each have a village on their upstream sections. Again the villagers told us that they kill any crocodile they see. Local people trim back sections of mangrove along these rivers and crocodiles have no future along them even though there is some excellent breeding habitat upstream of the villages. The downstream sections of these two waterways are heavily vegetated with mangroves and provide good feeding areas for crocodiles.

The Irur and Ngeremasech rivers are again Type 1 freshwater tidal waterways much like the Iwekei and Imeong systems; however, there are no major villages on their banks. They both have freshwater swamps on their upstream sections which usually signifies a good breeding area. Their freshwater sections are clear water streams.

The waterways of the mid-west coast area are easy to survey once entrance is gained into the rivers, but the shallow reefs and mud and grass flats requires a lot of poling near low water. It is preferable to survey on a rising tide.

6. Ngerdok Lake.

During the day and night of 20 June 1991, we surveyed inland freshwater Ngerdok Lake. Its position is 134°36.3'E, 7°30.7'N (see the U.S. Geological Survey Map, Republic of Palau, Caroline Islands, 1/25,000 series, Ngermetengel sheet) and a 4-wheel drive track from Melekeok extends to within 0.5 km of the lake's perimeter (Melekeok is reached by boat from Koror).

The lake is surrounded by a river swamp type forest and its shore has a heavy fringe of dense lily-like vegetation, much of which extends out from the bank as a floating mat. The open water of the lake is easily navigable in a small boat, and has thin floating mats of submerged aquatic vegetation. To gain entrance to the lake requires clearing a 5 m long channel through the dense lily-like fringe.

The lake is divided into a north and a south section by a dense strip of the floating lily-like vegetation mats approximately 25 m in width. The water is clear and fresh and is inhabited by various aquatic insects and fish. Birds and flying foxes abound and it is difficult to visualize that this area was settled some 50 years ago by the Japanese. It has since reverted to its present mature second growth or near climax state. Our co-worker, Joshua Eberdon, recalls visiting and playing in the area over 30 years ago and he states there were no crocodiles in the lake at that time. In all probability the crocodiles were there but scarce because the habitat was just recovering from the Japanese modification of the habitat, and *Crocodylus porosus* certainly occurs in the lake now.

During the nighttime survey we sighted 17 crocodiles, 4 (2-3'), 6 (3-4'), 3 (EO<6'), and 1 (EO). We had very close views of some of the smaller animals and they were definitely *Crocodylus porosus*. The larger animals were very wary. Undoubtedly the small but very important population has been hunted in recent times. The lake provides excellent habitat for *C. porosus* and animals from it must find their way into surrounding creeks and rivers, acting as a crocodile supply source. The lake is a source of the Ngerdorch River, the longest river in eastern Babeldaob.

This was only the second viable population of crocodiles we sighted in Palau. It is of the same size as that sighted on Belilou. All other sightings have been of isolated crocodiles, remnants of a once more abundant population.

7. Marine Lakes in the Rock Islands.

There have been many reports of sightings of crocodiles swimming in the clear waters of the Rock Islands. A number of the islands have lakes on them which can be reached after a vertical climb of 100+ feet through island rain forest vegetation growing on sharply eroded coralline limestone. Most of these lakes are tidal, brackish or saltwater, and are connected to the sea through eroded cracks and tunnels in the limestone. A few are freshwater.

Crocodiles have been sighted in several of the lakes. These have been in the (3-4') size class and most likely gained entry to the lake through one of the rock tunnels rather then by climbing over the limestone ridges. These animals are subadults and are those which have been excluded by adult crocodiles. They use areas such as the marine lakes as stockyards in which to grow (Messel et al, Monograph 1) and will endeavor to return in due course to the area where they were hatched. It is highly unlikely that adult *C. porosus* inhabit the marine lakes. There is simply no visible breeding habitat though small fish are plentiful for subadult food.

On the day and night of 24 June 1991, we surveyed 'Jellyfish Marine Lake' on Eil Malk Island in the Mecherchar Island Group, zero point coordinates 134°22.6'E, 7°09.7'N (see U.S. Geological Survey Map, Republic of Palau, Caroline Islands, 1/25,000 series, Chelbacheb sheet). To get to the lake required a climb of some 30 m over jagged coral rocks on a well defined trail and then a similar descent. We were able to carry in a 5 m ABS plastic canoe from which to do the night survey. We sighted 1 (EO<6') crocodile for some 30 seconds before it submerged. Undoubtedly it had become wary from the many tourists who snorkel in the lake to view the jellyfish. The subadult poses no threat or danger to tourists and in due course should leave.

DISCUSSION.

Habitat. The quality of the habitat for crocodiles in Palau generally is good, but the quantity of it is very limited. There are a number of small Type 1 tidal-freshwater systems and some of these have associated freshwater swamps. Such systems provide excellent breeding habitat. Often such systems are also associated with hypersaline coastal creeks (known as Type 3 systems) which provide rearing areas for subadult crocodiles.

The total land area of Palau is roughly 450 km^2. The largest island, Babeldaob, constitutes about 90 percent of this area and is roughly 40 km long and 16 km wide at its broadest point. Thus, there are no long meandering tidal waterways. The rivers and creeks rise in the hills immediately behind a narrow coastal fringe of mangroves and are short. Often there are villages upstream and the villagers trim the mangroves back from the edge of the waterway. Downstream *Rhizophora stylosa* the stilt-rooted mangrove dominates the saltwater channels.

During the rainy season, June-July, when we surveyed, heavy tropical downpours ensured that there was a heavy input of freshwater into the waterways. Thus, many of the coastal creeks, and tributaries of Type 1 freshwater systems, had salinities below that of seawater. During the dry season many of these waterways would be hypersaline or Type 3 waterways.

The swamp habitat associated with the tidal waterways is likewise limited, but is of great importance for breeding. Unfortunately, some of this habitat bas been drained for agriculture. Ngerdok Lake is the only major freshwater lake on inland Babeldaob. It has a perimeter of 1.8 km. It is heavily fringed with lily-like vegetation and provides excellent habitat for crocodiles.

The famous Rock Islands of Palau do not provide breeding habitat for *C. porosus* even though stragglers are often seen in the channels between the islands. These are either adult crocodiles on the move and feeding, or as mentioned previously, subadults which have been excluded from the breeding area by the territorial adults. Some of the marine lakes on the rock islands are used by these excluded crocodiles and thus when crocodiles are sighted in them, they are usually subadults. The Rock Islands certainly are not prime crocodile habitat.

The best overall crocodile system in Palau is the Ngerdorch River. Unfortunately, the crocodiles on this system have long since been shot out.

Aside from the fact that present-day Palauans hate crocodiles and kill them on sight, the additional major threat to *C. porosus* is destruction of habitat. Waterway after waterway is being trimmed and used as a boat highway. It is unlikely that this will decrease and hence one can predict the contraction of the areas where crocodiles can live. At best, we believe that a number of well chosen reserves need to be established where the habitat and crocodiles are protected.

Status. *Crocodylus porosus* is nearing extinction in Palau, after a determined effort by the U.S. Administration, with the help of Palauans, to eradicate the animal. We give below a summary of the results of our surveys.

Area	km surveyed	crocodiles sighted
Belilou Island	8.6	17
Airai	23.0	1
East Coast	34.5	0
Ngeremeduu Bay	25.7	3
Mid-west Coast	17.8	3
Ngerdok Lake	1.8	17
Jellyfish Lake	1.0	1
Totals	112.4	42

It is evident that only two very small viable populations of crocodiles remain in Palau, each with 17 animals sighted. The remaining 8 crocodiles sighted are remnants of former larger populations. It is important to note that we did not see a single hatchling or one year old crocodile on the 112.4 km of waterways surveyed.

What fraction of crocodile habitat was surveyed by us and how many crocodiles remain in the wild in Palau? After studying topographic maps, talking with former crocodile hunters, and reviewing the published literature and government records, we believe we surveyed at least 75 percent of those waterways worth surveying. Similarly, we surveyed at least 50 percent of the coast worth surveying.

Because of the few animals we encountered, using statistical means to gain an estimate of the actual uumber of crocodiles in Palau is meaningless. We do not believe that there is another viable population iu Palau the size of those in Ngerdok Lake and on Belilou Island.

There undoubtedly are more straggler crocodiles scattered throughout Palau than we sighted, but scattered singletons do not make a breeding population. Based on our estimate that 75 percent of the important waterways were surveyed, multiplying the 7 stragglers sighted, including the one in the marine lake, by 1.25 would provide an estimate of the number of crocodiles in Palau's waterways. Instead, we have been generous and multiplied the number by 10. Similarly, we have multiplied the one crocodile sighted along the coast by 10 instead of 2, thus making a huge correction for crocodiles not sighted. These two sources thus lead to a charitable estimate of 80 crocodiles. When standardized methods are used for surveying crocodiles, 66 percent of the crocodiles present are sighted and 33 percent remain unseen. Again, using a sighting fraction of 50 percent, rather than the usual 66 percent, for the 34 crocodiles in the two small viable populations yields an upper limit of $[(2x34)+80] = 148$ crocodiles. However, since too few animals were sighted to estimate the actual number of crocodiles in Palau, rather than use 148, which is an exact number and implies exact results, we prefer to say that there are fewer than 150 crocodiles remaining in the wild in Palau. This is an exceedingly small number for a population that is scattered in the wild and it highlights the serious plight of the crocodile resource in Palau.

How many crocodiles were in Palau in former times? There is no way to know for certain because no systematic survey of the crocodile population was ever conducted before and complete records of exports of crocodile skins were not maintained. Thus, we are forced to rely upon information from former crocodile hunters and to some degree upon guesses made by the U.S. Administration.

Robert Owen in 1969 estimated that there were 5,000 crocodiles in Palau though he apparently never made any personal attempt to verify that estimate with nighttime surveys and actively ignored the lower estimates of others. The Australian hunters estimated there were some 500 crocodiles in 1969. Rik-Rik Spis is reported to have shot some 200 by 1972. Joshua Eberdon estimates that between 500 and 1,000 crocodiles were shot during the crocodile hunting operation he oversaw in 1979-1981. There is no way to determine whether or not Hasegawa and Oshima sold additional skins to other buyers, but Yamatoshi Hikaku Co. Ltd. only received about 200 skins. From this we are guessing that the population was never more than about 1,500 animals in all size classes. This population, managed on a sustained yield utilization basis could have provided a valuable economic resource providing a substantial annual income to Palau. Instead, the resource has been almost destroyed. It will require a concentrated effort by the authorities to nurture the present scant resource, to conserve it and turn it to economic gain. In can be done and we make recommendations to this effect.

CONCLUSIONS.

1. During the German administration of Palau, 1899-1914, crocodiles were tolerated and protected in some areas. During the Japanese administration of the islands, 1914-1945, crocodiles were able to exist side by side with the general population -- an easy peace existed.

2. Since the beginning of the administration of Palau by the Office of Territorial and International Affairs, U.S. Department of the Interior, overseeing the Government of the Trust Territory of the Pacific Islands, dislike and active hatred of crocodiles by Palauans has increased. This was sparked by the crocodile fatality in Koror on 28 December 1965. The wish of many Palauans is to see the crocodile exterminated.

3. The U.S. Administration, during the late 1960's and 1970's did much to see that the wish of the Palauans was fulfilled and instituted a deliberate policy to eradicate crocodiles. That policy has been in violation of the U.S. Endangered Species Act of 1973 (ESA) since at least 18 December 1979 when the *Crocodylus porosus* was listed as Endangered. Section 2 (c) of the ESA requires that "...all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of this Act..."; Sec. 3 (12) specifically includes the Trust Territory of the Pacific Islands in the definition of 'States'; Sec. 6 (f) states that,

> "...Any State law or regulation which applies with respect to the importation or exportation of, or interstate or foreign commerce in, endangered species or threatened species is void to the extent that it may effectively (1) permit what is prohibited by this Act or by any regulation which implements this Act..."

and Sec. 7 states that,

> "...All other Federal departments and agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this Act and by taking such action necessary to insure that actions authorized, funded, or carried out by them do not jeopardize the continued existence of such endangered species and threatened species...."

Clearly, the 1979-1981 crocodile hunt in Palau authorized by the U.S. Administration was in violation of these provisions of the ESA. If the statute of limitations has not run out, the USDI officials responsible should be prosecuted under the ESA. The U.S. Government is responsible for the present sorry plight of crocodiles in Palau and for the wastage of a valuable economic resource.

4. The crocodile resource of Palau has been severely depleted and only a very small, widely scattered remnant population remains. We found only two small viable populations covering various size classes -- the 17 crocodiles sighted on Belilou Island and the 17 sighted in Ngerdok Lake. We estimate that the maximum number of crocodiles remaining in the wild in Palau to be fewer than 150.

5. Unless urgent and strict measures are taken to protect the species, the saltwater crocodile will soon become extinct in the wild in Palau and cause a further severe decrease in the species' range.

6. In view of the possible extirpation of *C. porosus* in the wild in Palau, the only viable genetic bank for Palauan *C. porosus* is the 41 crocodiles in Joshua Eberdon's farm. It is vital that this Palauan *C. porosus* gene bank be preserved.

7. The Eberdon crocodile farm has the potential to become an economically viable operation. The other much smaller captive crocodile operations contain too few animals and their facilities are unsuited for breeding and commercial propagation.

8. The crocodile resource remaining in the wild is so small that a crocodile ranching proposal is out of the question for a number of years.

9. There does not exist in Palau any legislation to protect and conserve the crocodile.

10. In spite of widespread and continued discussion over the past 30 years that 3 species of crocodiles exist in the wild of Palau, *Crocodylus porosus*, *Crocodylus mindorensis*, and *Crocodylus novaeguineae*, there is no evidence to support this belief. Only *Crocodylus porosus* occurs in Palau.

RECOMMENDATIONS.

We recommend that:

1. The wild crocodile population of the Palau remain on Appendix I of CITES and listed as 'Endangered' on the U.S. Endangered Species Act.

2. The total export ban on crocodile skins of all sizes and from all sources in Palau be effectively implemented and policed until such time as the wild crocodile population is recovered in Palau and/or a Palau crocodile farm becomes productive and is registered with the CITES Secretariat.

3. The Palau national and state government authorities immediately commence the task of educating the public about the vital importance of conserving their natural resources and their national heritage, including crocodiles, for the future benefit of their citizens.

4. The Palau national and state governments find some way to protect and conserve the remaining scant crocodile resource. The killing or taking of crocodiles in the

wild should be prohibited except by a licensed nuisance crocodile trapper.

5. The government institute a program to control individual nuisance crocodiles which pose a potential threat to humans. Such animals should be captured by a licensed trapper. Small crocodiles should be released in a reserve and large ones placed in a crocodile farm.

6. The U.S. Fish and Wildlife Service, coordinating with Palau's Bureau of Resources and Development, should act immediately to place the illegally held (i.e., non-permitted) crocodiles from the various small holdings in Palau onto one major crocodile farm which would serve as the gene bank for Palauan *C. porosus*. This farm of Palauan *C. porosus* could be made into an economically viable operation and, more importantly, into a major public education center for crocodile conservation.

7. Since his farm is the only program in Palau which has the chance to become a bona fide crocodile propagation center, the U.S. Fish and Wildlife Service, again coordinating with Palau's Bureau of Resources and Development, should immediately issue the necessary permit to Joshua Eberdon to hold his present crocodiles and to receive large crocodiles captured by the licensed nuisance crocodile trapper and to propagate them for conservation and commercial purposes. The permit should be issued contingent upon the Eberdon farm making available to conservation officials 15 percent of the (3-4') size class crocodiles raised on the farm for restocking specified areas where they can be adequately protected and where they pose no threat to humans, until such time as the wild population is well re-established.

8. The Eberdon farm should function as a professionally operated crocodile education and research center. Facilities and materials for such a center should be provided by the U.S. Government immediately and should include the provision for captive breeding.

9. The U.S. Fish and Wildlife Service, coordinating with Palau's Bureau of Resources and Development, should assist in the establishment of two additional captive breeding crocodile farms and assist each of them to obtain 50 pairs of breeding *C. porosus* from overseas sources. Even though they will utilize the same species, to preserve the genetic diversity of the Palauan crocodiles, offspring from these extra-national sources must not be released into the wild.

10. The appropriate Palauan authorities should establish a profitable sustained use program for crocodiles through encouraging wildlife tourism based on boat tours of scenic waterways with small and large crocodiles.

11. Establish three or four reserves, one on the east coast of Babeldaob, one ou a west coast waterway, and one on a southern waterway.

12. The government provide wildlife conservation curriculum material to the public schools of Palau so the role of important predators such as sharks and crocodiles can be understood.

13. The status of *C. porosus* in the wild of Palau be monitored systematically and carefully, at least once every three years.

SURVEY SCHEDULE

Saturday, 8 June 11:00 to 12:45 hrs aerial survey of Babeldaob, Belilou, Rock Islands using Paradise Air.

Monday, 10 June 09:00 hrs meet at the Marine Mariculture Demonstration Center (newly renamed the Belau Mariculture Demonstration Center) and use 23 ft boat with twin 75 hp outboard motors to go to Belilou. Day and nighttime survey of North Estuary, West Channel 18:48-20:06 hrs. Spend night at Keibo Hotel. Arrange for vehicle and small polyurethane foam boat for tomorrow's survey.

Tuesday, 11 June 06:30 hrs start daytime survey of North Estuary, East Channel, until 12:00 hrs. Move polyurethane boat to South Estuary. Start daytime reconnaissance survey 18:49-2004 hrs, then move boat back to East Channel at 20:30 hrs. Nighttime survey of East Channel, 21:10-22:52 hrs. Spotlight Milk Fish Pond from road, 23:51-00:02 hrs.

Wednesday, 12 June 08:30 hrs depart Belilou by boat for Koror. Work on data reduction for remainder of day.

Thursday, 13 June 07:00 hrs depart Koror for Ngeremeduu Bay in 23 ft boat. Daytime survey of Ngermeskang and Nkebeduul rivers. Back to Koror 14:15 hrs. 16:30 hrs drive back to wharf at Ngatpang (Ngeremeduu) to meet boat for nighttime survey.

19:00-01:00 hrs survey the two rivers and north shore of the bay.

Friday, 14 June 08:00-12:00 hrs drive to Ngatpang and carryout daytime boat survey of the Ngetpang and Tabecheding rivers. Return to Koror following daytime survey. 16:30 hrs drive to Forestry Camp dock on Tabecheding river to meet boat for nighttime survey. 18:30-20:15 hrs nighttime survey of Tabecheding and Ngetpang rivers and southern shoreline of Ngeremeduu Bay.

Saturday, 15 June 10:00-13:52 hrs daytime survey from Koror-Babeldaob causeway, Airai area to eastern mouth of Klai Channel, including Ngrikill River. 18:00-23:15 hrs nighttime survey of Airai area.

Sunday, 16 June Data reduction.

Monday, 17 June Storm, visit Airai and Nikko Hotel crocodiles; National Museum of Palau specimens; work on report.

Tuesday, 18 June 09:30 hrs depart for daytime survey of east coast waterways up to Ulimang. 21:30-01:15 hrs nighttime survey of coast and waterways from Ulimang to Ngechesar. Spend night in Ngechesar due to rain storm.

Wednesday, 19 June 06:15-10:15 hrs daytime survey of Ngerdorch River and creeks of Ngermecheraki. Return to Koror at 11:15 hrs. 17:00 hrs depart for nighttime survey of Ngerdorch River and creeks of Ngermecheraki, and eastern coastline. 19:00-22:00 hrs nighttime survey of these waterways. 23:00 hrs back in Koror.

Thursday, 20 June — 10:30-11:30 hrs boat trip to Melekeok then 4-wheel drive vehicle to Lake Ngerdok. Take small inflatable boat. 14:00-19:30 hrs clear trail into north and south sections of lake and do daytime and nighttime surveys.

Friday, 21 June — 09:30 hrs depart Koror for daytime survey of Imeong, Ngerutecher, Ngeremasech, Irur, and Iwekei rivers until 14:00 hrs. 18:30-0:00 hrs nighttime survey of the above rivers and NW coastline. Back in Koror 01:15 hrs.

Saturday, 22 June — Data analysis and report writing.

Sunday, 23 June — Report writing.

Monday, 24 June — 10:30 hrs depart Koror for Jellyfish Marine Lake on Eil Malk Island for daytime survey. 13:00 hrs back in Koror. 15:30 hrs depart for Jellyfish Lake transporting canoe. Complete nighttime survey at 19:10 hrs. Back in Koror at 20:30 hrs.

Tuesday, 25 June — Finish report on Palau crocodile survey.

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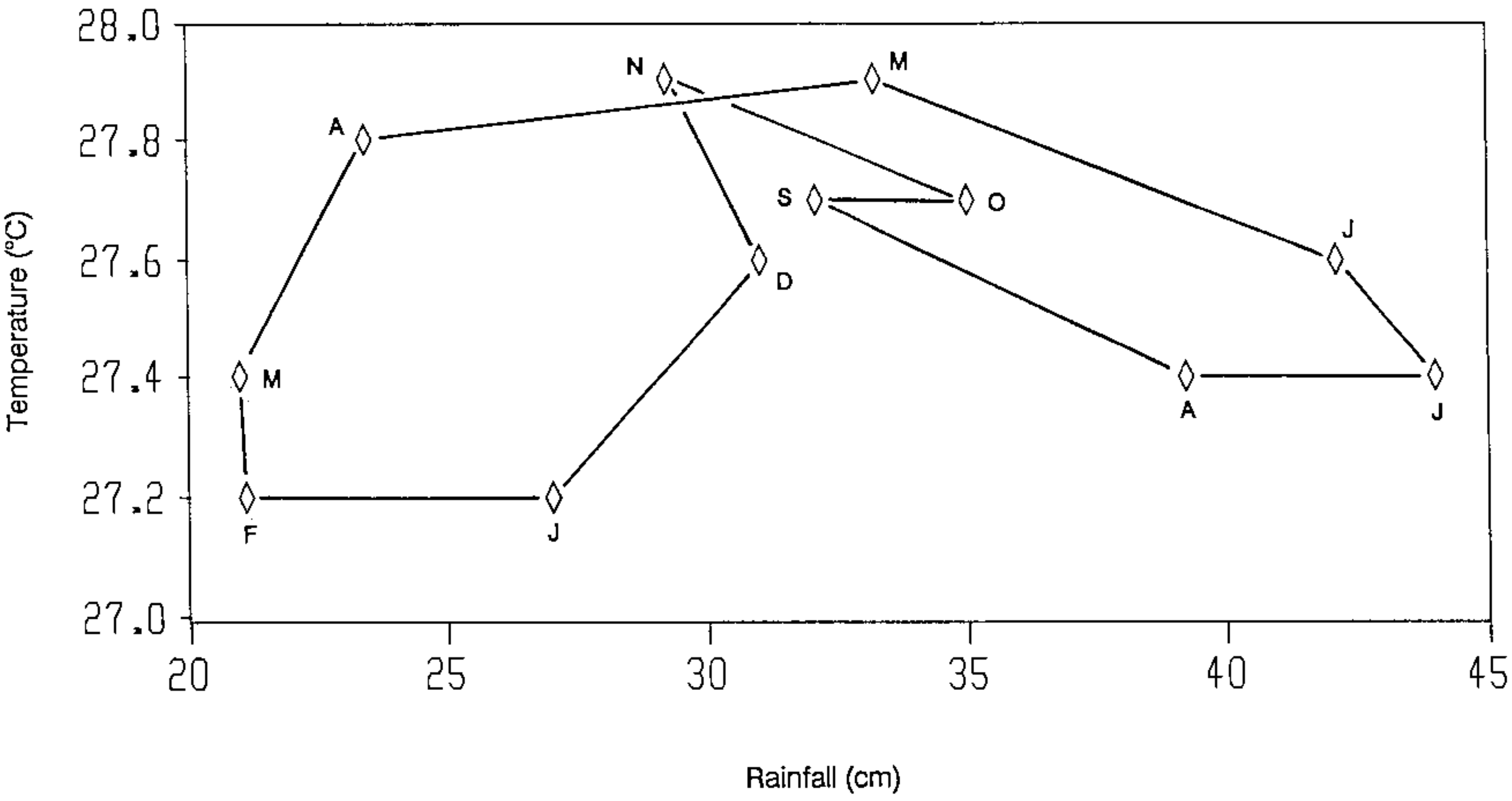

Figure 1. Climatograph of Koror, Palau. Monthly means of temperature and rainfall for the period 1961-1990.

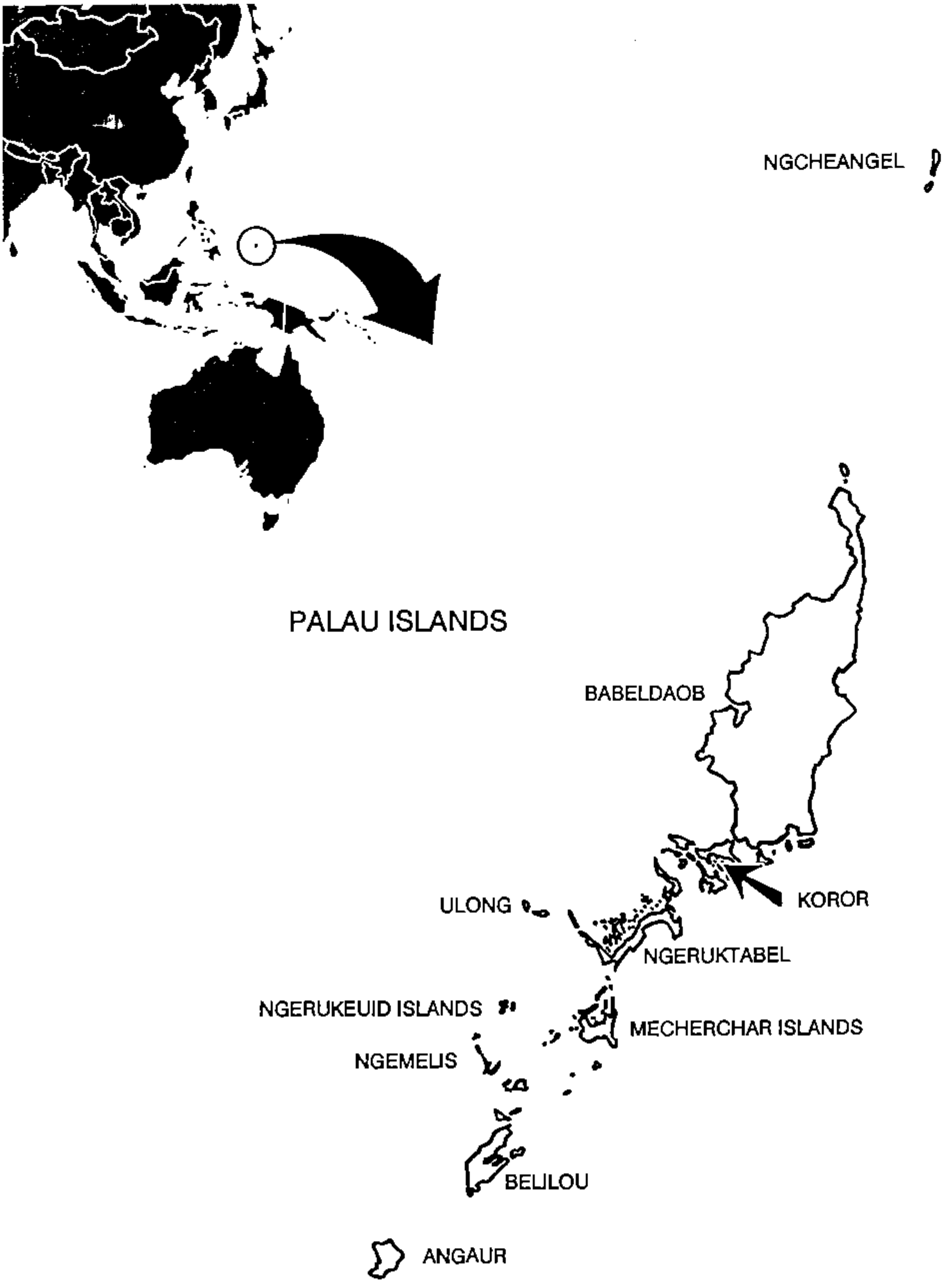

Figure 2. The Palau Islands archipelago lies on the Palau-Kyushu Ridge approximately 1,290 km southwest of Guam and 960 km east of the Philippines. The southwest island group of Fana, Sonsorol, Pulo Anna, Merir, Helen Reef, and Tobi lies 240 km southwest of Angaur and 300 km northeast of Indonesia, has no crocodile habitat, and is not shown here.

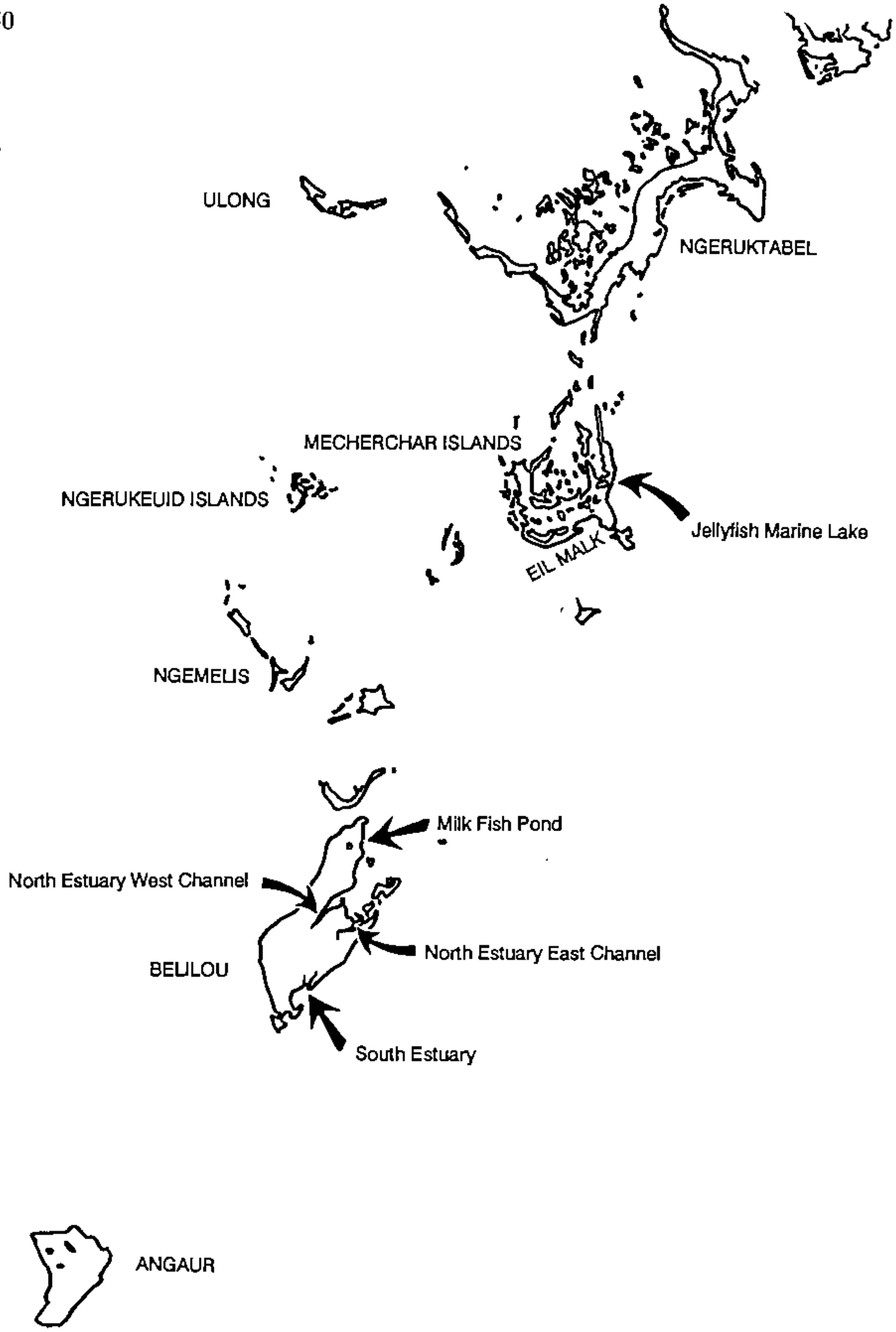

Figure 3. Waterways surveyed in Belilou and the Rock Islands. Island names are capitalized; survey localities are in capitals and lower case.

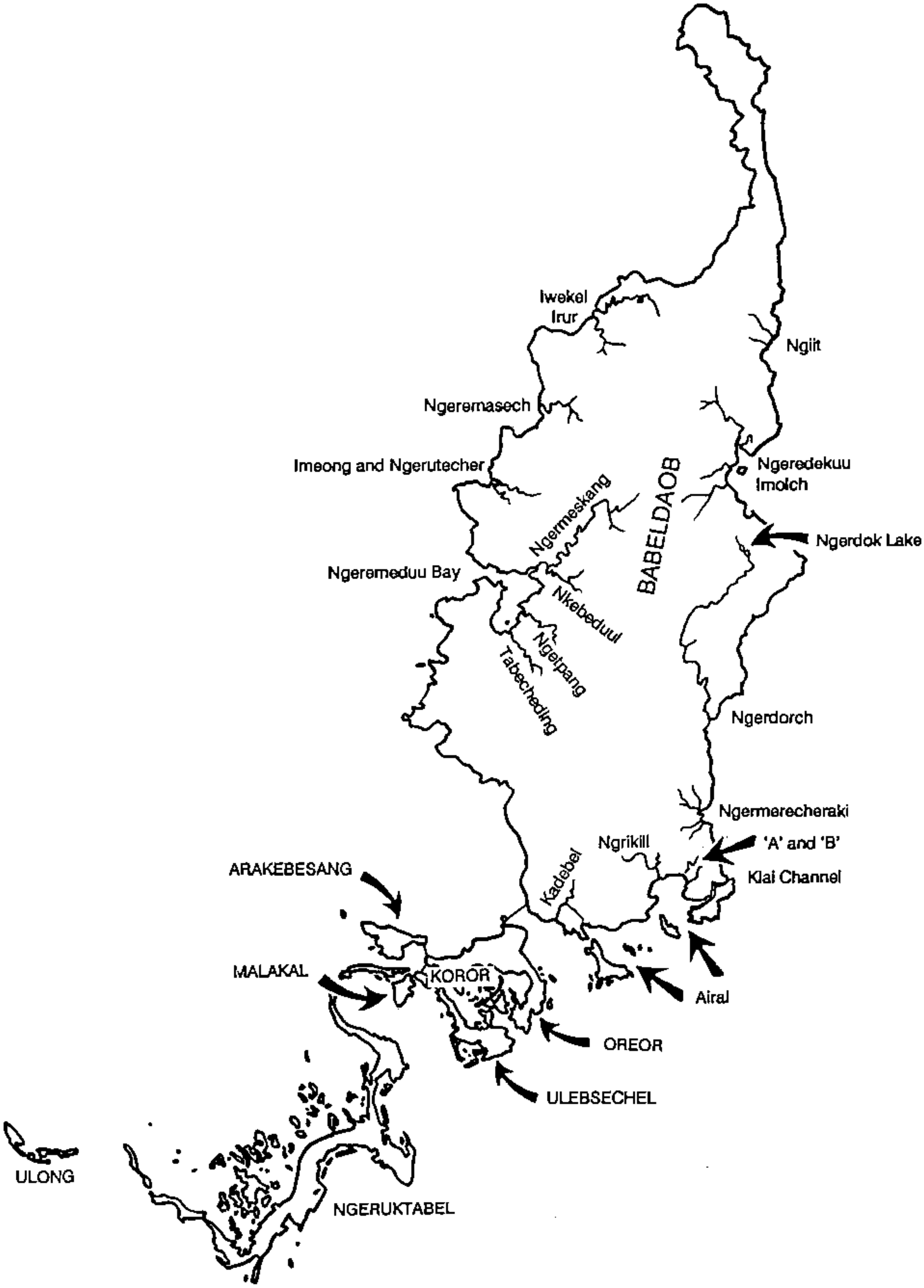

Figure 4. Waterways surveyed in Babeldaob and the vicinity of Koror. Island and city names are capitalized; survey localities are in capitals and lower case.