CROCODILES

9th Meeting
1988
Vol. 1

Special Reprint of the Proceedings of the 9th Working Meeting of the Crocodile Specialist Group

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

convened at

Lae, Papua New Guinea 19 - 21 October, 1988

(Unedited and Unreviewed)

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Species Survival Commission

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FOREWORD

This two volume publication is dedicated to Graham Goudie, an ardent conservationist who actively supported the Crocodile Specialist Group and other programs to conserve the world's biotic diversity. Graham became interested in crocodile farming in the early 1970s and, over the next decade and a half, he developed Mainland Holdings Crocodile Farm in Lae, Papua New Guinea (PNG), into the largest crocodilian ranching operation in the world. Not content solely to make the farm a financial success, Graham also made it a conservation success. In the late 1980s, when the PNG government terminated its monitoring program, rather than continue collecting wild eggs without knowing what impact that harvest was having on the parent populations, Graham agreed to underwrite the annual nest census program for the habitats that supplied eggs to Mainland Holdings. Graham travelled widely to learn what the conservation status of crocodiles was in other countries, and also what husbandry techniques were being used on other crocodile farms. At the time of his death in October 1989, Graham was a Vice Chairman of the CSG and energetically helping the chairman lay out the work of the group.

The two volumes of this PROCEEDINGS are a record of the presentations and discussions that occurred at the 9th Working Meeting of the Crocodile Specialist Group in Lae, Papua New Guinea, 19 to 21 October 1988. 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 critiqued, 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. F. Wayne King was 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 programs 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 organizations, 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 resources 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.

SUMMARY OF THE MEETING

The 9th Working Meeting of the IUCN/SSC Crocodile Specialist Group (CSG) was convened in Lae, Papua New Guinea, from 19 to 21 October 1988. Mainland Holdings, Pty. Ltd., hosted the meeting. Graham Goudie and the staff of Mainland Holdings worked round the clock for months prior to the meeting booking lodgings, checking flight schedules, arranging post-meeting fieldtrips, and finalizing arrangements for audiovisual and computer aids, and then throughout the conference continued to attend to details and to overcome a variety of problems that seemed to arise spontaneously. The success of the 9th Working Meeting was directly attributable to the unstinting efforts of Graham and the Mainland Holdings staff.

Prior to arriving in Papua New Guinea, most international attendees passing through Queensland, Australia, participated in pre-meeting fieldtrips to Edward River Crocodile Farm, or to Edward River and Weipa, the site of the Queensland National Parks and Wildlife Service *Crocodylus porosus* ecology study. The fieldtrips were hosted by the Queensland National Parks and Wildlife Service (QNPWS) and Edward River Crocodile Farm (ERCF). Special thanks are due the staffs of these two organizations, especially Drs. Laurie E. Taplin (QNPWS) and J.T. Victor Onions (ERCF), who not only handled all arrangements for the trips but also booked lodging in Cairns for many participants.

The 9th Working Meeting was open to anyone actively involved in crocodilian conservation, biological research, management, or farming. The conference was attended by 132 people, though only 114 registered. A total of 34 presentations were made at the meeting, all of which are contained in these two volumes. Four additional papers also appear in the volumes, papers which were submitted and were on the agenda but which were not presented because, at the last minute, the authors could not attend. The schedule of the 9th Working Meeting was:

Tuesday, 18 October:

Afternoon - registration.

Wednesday, 19 October:

08:00 - Registration.
09:00 - Official welcome by Jim Yer Waim, Papua New Guinea Environment and Conservation Minister, and Graham Goudie, Mainland Holdings.
- Announcements.
09:30 - 11:30 - Reports on the conservation status of crocodilians.
11:30 - 13:00 - Lunch.
13:00 - 15:00 - Continuation of status reports.
15:30 - 18:00 - Visit to Mainland Holdings crocodile farm.
18:00 - 22:00 - Reception party at Mainland Holdings farm.

Thursday, 20 October:

08:00 - 11:45 - Reports on farming/ranching programs.
11:45 - 13:00 - Lunch.
13:00 - 18:00 - Reports on management programs.
18:00 - 20:00 - Dinner.
20:00 - 23:30 - CSG business meeting.

Friday, 21 October:

08:00 - 12:00 - Workshop on programs that satisfy the requirements of CITES Article IV 2(a) and 3; Berne and Buenos Aires Criteria.
11:30 - 13:00 - Lunch.
13:00 - 18:30 - Reports on advances in crocodilian research.
18:30 - 20:00 - Dinner.
20:00 - 22:00 - Audiovisual presentations.
22:00 - 22:30 - Close of the 9th Working Meeting.

Saturday, 22 October:

Departure for post-meeting fieldtrips.

Following the meeting, many participants traveled to Ambunti on the Sepik River to participate in a helicopter survey of crocodile nests in the area that is monitored annually to verify the impact of egg harvest. Others visited Tari in the highlands and sites near Lae.

At the business meeting, held the evening of 20 October, the CSG Chairman, Professor F. Wayne King, announced that the group would undergo a reorganization in order to make it more responsive to the needs of members and governments. A Steering Committee will be appointed to aid the chairman and advise on all aspects of the work of the group. The Steering Committee will be composed of representatives from each of the five crocodile producing geographic regions, Africa, Asia, Australia and Oceania, Central and South America, and North America and the Caribbean, a representative for the hide and meat trade and one for a trade monitoring organization, plus the chairman and deputy chairman of the CSG. In so far as possible, regional concerns will be delegated to the regional representatives and trade and trade monitoring concerns delegated to those representatives of the Steering Committee. The chairman appointed Dr. Jon Hutton, Dr. Laurie Taplin, and Allan Woodward an ad hoc committee to recommend the names of people who might serve as Vice Chairmen. At the closing session the afternoon of Friday, 21 October, the ad hoc committee submitted a list of Steering Committee nominees to the chairman for his consideration. In keeping with IUCN/SCC procedures on appointments, the chairman received the list of nominees from the ad hoc committee and will review it for possible acceptance or modification. The chairman then will pass his recommendations on to the Chairman of the Species Survival Commission for a second review and final appointment. Rather than embarrass people who might have been nominated but not selected, the names of the nominees were not announced at the meeting.[1]

By the end of the workshop on the morning of 21 October, the following consensus had been reached on the position the CSG should take at the next CITES Conference of the Parties:

CSG POSITION ON AFRICAN ANNUAL EXPORT QUOTAS

- Ranching proposals will be supported if they contain some data on the wild populations, provided ranching depends on egg collection and a program to monitor the wild population. The management scheme should specify the catchment/drainage area and indicate that a suitable food supply is available.
- Harvesting wild crocodiles directly will be supported only if more data are available, data which clarify the size of animals harvested and from what areas, and how long the harvest will run (e.g., time period, yearly, forever). There should be a time limit on any wild harvest unless hard data are available. It is suggested that harvests be limited to belly hides less than 55 cm. width to protect the adults.

[1] The membership of the Steering Committee was announced in the Volume 8, January-March 1989, issue of the CSG NEWSLETTER.

- Stress support for ranching proposals and de-emphasize annual export quotas because of the inflexibility of quotas.
- A 4-year period for moving from wild quotas to ranching operations seems a reasonable timetable.
- Conf. 6.22, which calls for monitoring and reporting on ranching operations, needs to be fulfilled. The CITES Secretariat needs to monitor compliance with Conf. 6.22.

In the closing session on the evening of 21 October, the participants passed the following resolution endorsing the FAO program in Indonesia:

RESOLUTION OF THE IUCN/SSC SPECIALIST GROUP ON CONTROLLED CROCODILE SKIN PURCHASING IN IRIAN JAYA, INDONESIA

Recognizing the critical importance of the current FAO-PHPA project in Irian Jaya, establihed by a bilateral agreement between the Government of Indonesia and the United Nations Food and Agriculture Organization, to develop the crocodile industry on a sustainable basis,

Recognizing the Indonesian *Crocodylus porosus* export quota of 4,000 skins per year adopted by the Conference of the Parties at their 6th Meeting in 1987,

Recognizing the urgent need to arrest the decline of crocodile populations in Irian Jaya and to curtail current illegal trade, and to promote sustained utilization of the crocodile resource for the benefit of the people,

Recognizing Conf. 5.21, adopted by the Conference of the Parties to CITES in Buenos Aires in 1985, requiring monitoring of the status of, and trade in, species transferred from Appendix I to Appendix II subject to special quotas and trade control procedures,

Now Therefore, the IUCN/SSC Crocodile Specialist Group assembled in its 9th Working Meeting in Lae, Papua New Guinea, 19 to 21 October 1988,

Recommends the controlled purchasing of *Crocodylus porosus* and *Crocodylus novaeguineae* skins throughout Irian Jaya province, Indonesia, by approved exporters abiding by the following restrictions:

i. With respect to the current annual export quota of 4,000 *C. porosus* skins, only skins measuring 10-18 inches (=25.4 to 45.7 cm) belly width will be traded;

ii. minimum purchase prices will be set by the Government of Indonesia;

iii. all crocodile skins exported will be identified by individually numbered, non-reusable tags as recommended by CITES;

iv. purchasing will be supervised by appinted government officials; and

v. purchasing operations, records, and other relevant trade data will be monitored by the Government of Indonesia in accordance with CITES procedures, and if requested, this should be done in cooperation with the aforementioned joint FAO-PHPA project.

Further Recognizing that the continuing illegal trade in crocodile skins from Indonesia and manifold detrimental effects stemming therefrom, is perpetuated by CITES Parties maintaining reservations on Indonesian crocodilian species, and by non-Party states,

Further Recommends that the CITES Secretariat and all CITES member states urge through all apropraite means that Parties maintaining reservations on Indonesian crocodilian species, notably the Republic of Singapore, withdraw those reservations.

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THE POPULATION DYNAMICS OF ESTUARINE CROCODILES. I. AN ASSESSMENT OF LONG-TERM CENSUS DATA.

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The Proceedings of the 9th Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of the International Union for the Conservation of Nature and Natural Resources. October 1988, Lae, New Guinea.

SUMMARY

This paper updates current knowledge on the population dynamics of estuarine crocodiles through a reanalysis of long-term census data from the Liverpool-Tomkinson and Blyth-Cadell river systems in the Northern Territory. The approach taken is similar to key factor regression analysis, where annual variations in abundance of population classes are examined retrospectively in relation to density-dependent and density-independent factors.

Trends in hatchling (<2 feet) and non-hatchling (>2 feet) numbers were examined separately because of extreme differences in their size and mortality rates. Hatchling production was indexed by their relative density, and the annual exponential rate of increase summarised the population dynamics of non-hatchlings. Antecedent or past density was used to index density-dependent processes, and seasonal rainfall and water depth were used to index the level of available wetland resources.

The trends in hatchling density were unstable, and marked by variable high amplitude and high frequency fluctuations. In contrast, the trends in non-hatchling density were relatively stable. The Liverpool-Tomkinson system is characterised as a low density increasing population (average $\underline{r}$=0.08 p.a.), and that for the Blyth-Cadell a high density fluctuating population (average $\underline{r}$=0.00 p.a.). Closer examination of two major population classes

within the non-hatchlings (juveniles, 2-6 feet; sub-adults and adults, >6 feet) revealed important dynamical differences between the two populations: all non-hatchling size classes increased in density over time except juveniles in the Blyth-Cadell system, which decreased over time.

The density of hatchlings in each river system showed a tight non-linear relationship with water level (time lag=6 months): hatchling production increased with increasing water levels up until mean water level, but collapsed thereafter. That trend may reflect flooding losses, and/or the movement of a large proportion of breeding females out of the study area to nest in ephemeral wetlands created by flooding. Hatchling density also increased with an increase in the density of potential breeders (indexed by crocodiles greater than 6 feet).

The rate of increase of non-hatchlings in the high density Blyth-Cadell system was correlated positively with antecedent seasonal rainfall (time lag=12 months) and previous hatchling production (time lag=6 months), and negatively with antecedent density (time lag=6 months). The overall regression explained 93.0% of variation in the census data, and most of the negative density effects may derive primarily from processes affecting juvenile crocodiles. In contrast the low density Liverpool-Tomkinson system showed no correlation with previous density, but a more marked effect of antecedent seasonal rainfall and previous hatchling production. The overall regression explained 81.7% of the variability in the census data. Spatial (movements) and temporal (survival) effects are confused in these analyses because mortality and emigration could not be differentiated. However, both may be important components of the population dynamics of estuarine crocodiles.

The negative density-dependent effect detected in the Blyth-Cadell population is here labelled "provisional" until compensatory processes can be demonstrated by independent study. Only one out of three statistical tests detected density-dependence in the data, the other two suggest that the correlation was spurious. Key factor analysis hence could not provide conclusive evidence of compensation or density-dependent processes in response to a reduction in numbers. However long-term census data are necessary to generate compensation hypotheses to test by experimentation, and to assess the importance of environmental variability to population stability. We conclude that the future management of estuarine crocdiles, particularly sustained-yield harvesting, must be based on a sound knowledge of compensation processes, and must also consider the effects of environmental variability on numbers.

INTRODUCTION

The estuarine crocodile Crocodylus porosus is a valuable wildlife resource. The broad aims of their management in Australia are conservation and control: we need to conserve them in general yet at the same time reduce their numbers for public safety in areas where risk to people are intolerable. Another possible long-term aim is sustained-yield harvesting (Webb et al. 1984, Messel and Vorlicek 1986), which has the potential to provide economic incentives for conservation of habitat and a productive outlet for the control of problem animals. Both could involve substantial reductions in numbers in certain areas, yet we do not know how populations respond to such treatments. Populations could either compensate for removals by increasing survival and/or fecundity rates, or removal could be a totally additive process.

The aim of this paper is to re-examine existing long-term census data on estuarine crocodiles, to update current knowledge on their population dynamics, and to assess it's utility in providing relevant knowledge and predictions for future scientific management, such as sustained-yield harvesting. The approach and analyses are nothing new. Messel et al. (1981, 1984), Webb et al. (1984), and Messel and Vorlicek (1986, 1987) present comprehensive analyses of parts of the same data, and Nichols (1987), and Hines and Abercrombie (1987), discuss compensation with respect to population models and management of American alligators. We simply provide a different perspective which will hopefully reinforce the proposal in the second paper for further research into the population dynamics of estuarine crocodiles.

The method of analysis is similar to key factor regression analysis (Morris 1963a,b), where annual variations in abundance of population classes are examined retrospectively in relation to density-dependent and density-independent factors. It is basically a crude life-table approach developed to study mortality agents in the spruce budworm. The technique is suitable for insects because they have discrete generations and hence mortality factors which operate in a linear sequence. However, variations of this regression technique have been applied to other taxa, particularly vertebrate wildlife.

METHODS

Data Base.

The data are annual spotlight counts of *C. porosus* in the Liverpool-Tomkinson (1976-1983; n=8 years) and Blyth-Cadell (1974-1983; n=10 years) river systems. The survey methodology and data are summarised in Messel *et al.* (1981, 1984) Messel and Vorlicek (1986). All annual counts were standardised to relative densities (numbers per kilometre of river), and for years in which there were more than one survey, the mean was used. Crocodile size was estimated on those surveys and is used as an index of age in further analyses, although the relationship between size and age is extremely variable and hence generally unpredictable (Webb *et* al. 1983). For size-based cohort analyses, relative densities of each size class were corrected for visibility bias using the correction factors developed by Bayliss et al. (1986) for crocodiles in the Adelaide River. The generalisation of those correction factors is unknown, hence the analyses are only a first approximation.

Variables in the model

A. Dependent variable: rate of increase.

The exponential rate of increase is used as a direct and concise summary of crocodilian population processes (Bayliss 1987).

r = (births - deaths) + (immigration - emigration)

or **r = survival & fecundity effects + dispersal effects**

Rates of increase were standardised to annual rates (r p.a.). All data are summarised in the Appendix.

B. Independent variables: Factors that may affect rate of increase.

To use an archaic but familiar dichotomy, there are two classes of regulatory mechanisms that may affect the dynamics of a population and ultimately its abundance. These are (Royama 1977):

1. Density-dependent effects. The source of "compensation". Survival and/or fecundity rates decrease as density is increased.

2. Density-independent effects. Factors which operate independently of density. e.g. weather.

The two classes of regulation are not mutually exclusive. It is useful to point out here that the above classification of population regulation has been critically reviewed by Caughley and Krebs (1983), who suggest two new classes - extrinsic (=limiting resource) and intrinsic (=self) regulation. Caughley (1987) further suggests that density-dependent and density-independent terminology is confusing, however it is retained here for convenience.

Antecedent density.

We use antecedent or past density as an index of possible compensatory processes, whether they are intrinsic or extrinsic mechanisms, or a combination of both.

Environmental factors.

There are many environmental variables that could affect the population dynamics of estuarine crocodiles, but only two are used here - water level and seasonal rainfall. Seasonal temperatures are high and regular, and the possible effects of variations in salinity are assumed to be compounded with the effects of water level. The driving variable in Australia's wet-dry tropics is seasonal rainfall, which has high temporal and spatial variability (Taylor and Tullock 1985). Seasonal rainfall and water depth are used to index the level of available resources, such as the extent of wetland habitat for nesting and the quantity and quality of food supply, but the precise mechanisms linking those variables to crocodile productivity are unknown.

Seasonal rainfall data (October to April) for the years of survey were obtained from the Bureau of Meteorology, using Milingimbi as the reference station for both river systems. The mean rainfall for Milingimbi in 1983 was 1159 mm ($\underline{n}$=55 complete years), and was highly variable with a standard deviation of ± 315 mm (27.2%). Water level data for the Liverpool (GS 8230237: 12° 32', 133° 53') and Blyth (GS 824002; 12° 27', 134o 42') rivers were obtained from the Power and Water Authority of the Northern Territory. Water level is expressed as mean monthly maximum stage for the wet season period. Mean water level for the Liverpool River was 7.12 m ± 2.20 m (30.9%); and that for the Blyth River 10.03 m ± 2.62 m (26.15%). Both were highly variable, reflecting variable seasonal rainfall. All seasonal rainfall and water level data are summarised in the Appendix.

Measurements and time lags.

Rate of increase, measured over an interval of time, is centred instantaneously. Similarly for seasonal rainfall and water level effects. Because rate of increase was measured between two consecutive dry season density estimates, there were effectively two types of weather effects - antecedent (time lag = 12 months) and intermediate (time lag = 0) seasonal water level or rainfall.

Figure 1 outlines how all measurements were made, and demonstrates time lags.

RESULTS

Trends in numbers.

Figures 2 a-d show the trend in relative density of hatchlings and non-hatchlings in the Liverpool-Tomkinson and Blyth-Cadell rivers respectively (average annual exponential rates of increase, *r*, are indicated on each Figure). The Liverpool-Tomkinson system has a low density population which is increasing. The Blyth-Cadell has a high density population which is fluctuating but not increasing. The dominant trend in non-hatchlings of each population is only revealed after the "noisy" hatchling data are removed. Hatchling numbers are characterised by variable high amplitude and high frequency fluctuations, in contrast to the relatively stable trends in non-hatchling numbers. The dynamics of the two extreme size classes are very different, and hence will be analysed separately.

Figures 2 e-h are more detailed examinations of two major size classes within the non-hatchlings; the 2-6 foot and greater than 6 foot size classes. Those two classes are referred to as the juvenile non-breeders and sub-adult and adult potential breeders respectively. The increasing trends in density over time were similar except for one important difference: in the high density Blyth-Cadell system the density of juveniles decreased over time.

Figures 3 a-c illustrate the variability in seasonal rainfall and concomitant fluctuations in seasonal water level in the Liverpool and Blyth rivers for the duration of the study.

Relationships

Hatchlings

Figures 4 a-b show the relationship between the relative density of hatchlings and intermediate seasonal water level for the Liverpool-Tomkinson and Blyth-Cadell rivers respectively, and were fitted by eye. Similar patterns were obtained using rainfall, but the trends were not as distinct. Of the two, water level is the proximate index of hatchling dynamics. The trends are non-linear, and clearly illustrate that hatchling recruitment increased with increasing seasonal water level up to mean water level, declining at water levels above the mean. The shapes of the two curves probably reflect hydrological differences between the two river systems: the Liverpool-Tomkinson system may be more prone to flooding because of its narrower catchment. The relationship is difficult to interpret because spatial (movement) and temporal (fecundity and survival) effects may be confused. The rapid decline in hatchling numbers could reflect flooding losses, and/or alternatively the movement of a large proportion of breeding females to ephemeral nesting habitat outside the survey area. Hatchlings produced in ephemeral wetlands may not be detected unless they moved into the linear survey area, possibly as a larger size class.

Hatchling numbers were also related to the number of potential breeders, indexed by the relative density of large crocodiles (>6 feet). We assume that generally the number of hatchlings produced increased with the availabilty of potential breeders, until nest sites or spacing behaviour became limiting factors. For exceptions to that assumptions see Messel et al. (1984, pp. 123-124). Figures 4 c-d show the relationship between hatchling density and the density of large crocodiles in the Liverpool-Tomkinson and Blyth-Cadell rivers respectively. There was a strong linear relationship in the Liverpool-Tomkinson system, suggesting that nest sites were not limiting. In contrast, the high density Blyth-Cadell system shows a weak asymptoting trend, suggesting that whilst nest sites may be limiting the conditions for nesting may be variable.

The two key factors for the production of hatchlings were variable water level, possibily indexing the quantity and quality of breeding and nesting habitat, and the number of potential breeders. These regression results are summarised in Table 1a.

Non-hatchlings

In the high density Blyth-Cadell system there was a significant negative correlation between rate of increase and antecedent non-hatchling density. A new regression model was constructed whereby non-hatchling density was entered as two 'independent' variables- juveniles and larger crocodiles. Most of the relationship between rate of increase and non-hatchling was explained by juvenile crocodiles: the juvenille size class was a significant entry into the new regression, large crocodiles were not. However, antecedent seasonal rainfall and the previous years hatchling production also influenced rate of increase. In the Liverpool-Tomkinson system there was no correlation between rate of increase and non-hatchling density. However, rate of increase was influenced largely by the previous year's hatchling production and antecedent seasonal rainfall, and the effects of those variables were more marked than in the Blyth-Cadell system as suggested by the regression coefficients. These regression results are summarised in Table 1b.

Cohort analysis of the Blyth-Cadell data

The results of the previous section suggest that most of the dynamics of high density estuarine crocodile populations may be influenced by the density of juvenile crocodiles, a finding that warrants more detailed examination. The standing age distribution is usually used in fisheries analysis to estimate total mortality rate (z) via the log-linear decline in age frequencies. The analysis is often used to argue that rate of increase is zero. However, a log-linear decline occurs whether the population is increasing, decreasing, or stable (Caughley 1977). Because of unstable age/size distributions in both crocodile populations (see previous sections), standing distributions would not tell us much. Hence we use the temporal age/size distribution to estimate total annual mortality rate (z) of juvenile crocodiles (i.e. the decrease in numbers, transformed to natural logarithms, between the 2-6 foot and >6 foot size class). All data were corrected for size-based visibility bias and are summarised in Webb et al. (1984). Total mortality rate in this analysis is referred to as "loss rate" because temporal and spatial effects are confused: it is impossible to differentiate mortality from emigration without independent data on crocodile movements.

Figures 5 a & b compare the temporal loss rate of juvenile crocodiles for the Liverpool-Tomkinson and Blyth-Cadell River systems respectively. The low density Liverpool-Tomkinson system has a significantly lower juvenile loss rate than the high density Blyth-Cadell system (annual exponential rates of z=0.55 and -1.16 respectively; t=2.94, df=17, P<0.001). That result reinforces earlier analyses suggesting that populations of crocodiles at high density may have density-dependent regulation of numbers deriving primarily from processes affecting the juvenile class.

Regression analysis was also used to determined key factors affecting juvenile loss rate for both populations, and the results are summarised in Table 1c. Because z is an instantaneous rate centred between an interval of time, it has the same time lags to rate of increase. The loss rate of juvenile crocodiles in the Liverpool-Tomkinson system was only weakly (P=0.10) related to antecedent seasonal water level (time lag=12 months): as water levels increased, juvenile loss rate increased suggesting dispersal rather than mortality. In the Blyth-Cadell system juvenile loss rate increased as non-hatchling density increased (time lag=6 months). As for rate of increase, a new regression model was conducted differentiating non-hatchling crocodiles into juvenile and larger crocodiles as 'independent' variables. Most of the relationship between loss rate and non-hatchling density was explained by the density of juveniles themselves. Juveniles were a significant entry, larger crocodiles were not. The density of larger crocodiles are only weakly correlated to the dynamics of smaller crocodiles. Although these analyses suggest that juvenile crocodiles may predominantly regulate their own dynamics, we are cautious. The results may simply reflect the timing of surveys, and when more than one survey was conducted per year, the loss of information through averaging.

Confusion of spatial and temporal effects

The confusion of mortality and dispersal effects applies to the production of hatchlings, the rate of increase of non-hatchlings, and the loss rate of juveniles. In an attempt to clarify possible movement effects the densities of juvenile and large crocodiles were correlated with antecedent and intermediate seasonal rainfall and water level. Antecedent effects have an 18 month time lag, intermediate effects a 6 month time lag. There were no significant correlations in the Liverpool-Tomkinson data. However, in the Blyth-Cadell system the densities of juvenile and large crocodiles were correlated with intermediate seasonal rainfall and intermediate and antecedent seasonal water level respectively. The short 6 month time lag suggests dispersal rather than survival. The results (Table 1d) show that as intermediate seasonal rainfall increased, the density of juvenile crocodiles increased. In contrast, as both antecedent and intermediate seasonal water level increased, the density of larger crocodiles decreased, suggesting movement out of the study area. Why juveniles respond positively to seasonal rainfall and larger crocodiles negatively to seasonal water level is unknown. Clearly, there is a complex tangle of time lags and intercorrelations of variables, and therefore no clear-cut conclusions can be made without an independent study on movements. Regardless, spatial dynamics (movements) appear just as important as temporal dynamics (fecundity and survival), as suggested by Messel et al. (1984).

Overall stochastic model

Figure 6a and b summarises all results, and illustrates that, regardless of possible density-dependent effects in the Blyth-Cadell system, the general dynamics were similar for both populations. (Percentage standard deviation of density variation in each size class are indicated above the data points). Hatchling density was extremely variable because of its strong relationship with variable water level. The density of larger crocodiles was relatively dynamic, most likely reflecting dispersal about the linear study area. Caught between the two are juvenile crocodiles whose numbers were relatively stable. They therefore may be in a strategic position to confer stability on overall numbers. Messel and Vorlicek (1986) conclude the same, and aptly called this size class the "bottleneck", (particularly the 4-6 foot size class).

Spurious density-dependency

The preceding key factor analyses appear very encouraging. The strong negative correlation detected between rate of increase and density, and between juvenile loss rate and density, surely must indicate the existence of compensatory mechanisms to a reduction in numbers for the Blyth-Cadell population. Unfortunately life was not meant to be easy. Figure 7a & b represents a hypothetical correlation between rate of increase and density emanating from non-independent data subject to random sampling errors, and demonstrates that a significant negative slope is the expected result. Hence the null hypothesis for a test of density-independence is not a slope of zero, but a negative slope. The harsh reality is that density-dependence (=compensation) can never be demonstrated reliably from annual census or life-table data alone. Regardless, there are many statistical tests to detect "provisional" density-dependence (Pollard, Lakhani and Rothery 1987): that is, if the test result is positive, then density-dependence is assumed cautiously until it can be demonstrated with independent data or experimentation. We used three tests to search the Blyth-Cadell census data for "provisional" density-dependence.

Test 1: Juvenile mortality test (includes Liverpool-Tomkinson system)

Figure 8a illustrates a hypothesis of density-dependence where juvenile loss rate (z) changes over time ($Zt_{+1} > Zt$) because of the time trends in the density of juvenile and large crocodiles. Figure 8b & c compares the slopes of the regression lines (z's) of all complete temporal size distribution data for crocodiles between 2 and 7 feet long for the Liverpool-Tomkinson and Blyth-Cadell rivers respectively. The dependent variable is numbers of crocodiles (transformed to natural logarithms) in one foot size categories. The analysis excludes hatchlings and crocodiles over 7 feet in the Blyth-Cadell rivers: and that for the Liverpool-Tomkinson rivers, hatchlings, 2-3 foot and greater than 7 foot long crocodiles. The independent variable is crocodile size. Each size class was corrected for size-based visibility bias as outlined in the methods section, and the data are summarised in Webb et al. (1984) as crocodile year classes from 1.3 to 5.3 years old (truncated at 1983). Covariance analysis shows that, for both river systems, the slopes of all cohort regressions were not significantly different (Liverpool-Tomkinson: F=0.567, df=3/12; Blyth-Cadell: F=0.934, df=5/23), suggesting density-independence. The reason for the unusual depressed frequency pattern of crocodiles in the 2-3 foot size class for the Liverpool-Tomkinson rivers is unknown, but may reflect the absence of that class from the river system at the time of survey.

Test 2: Varley-Gradwell test

Morris (1963) suggested that if the slope of the regression between Nt_{+1} and Nt was significantly less than one, then density-dependence may exist. The null hypothesis is a line with a slope equal to one. Figure 9 illustrates the Morris null hypothesis. However, because both Nt_{+1} and Nt are subject to random sampling errors, most slopes are less than one. Varley and Gradwell (1963) therefore suggest using two regressions (Nt_{+1} vs Nt and Nt vs Nt_{+1}), and provisional density-dependence is accepted only if (a) both slopes are significantly less than one, and (b) both are on the same side of unity. This is the most conservative density-dependence test (Vickery and Nudds 1984) and has a high rejection rate. A *t*-test showed that both slopes were significantly less than one ($t1 = 3.103$, $df=1/7$, $P<0.01$; $t2 = 3.045$, $df=1/7$, $P<0.001$), and provisional density-dependence is therefore accepted, for the Blyth - Cadell population.

Test 3: Randomisation test

This is a distribution-free likelihood ratio test, using the observed correlation coefficient between rate of increase and density to define the null hypothesis. The test is described in detail by Pollard, Lakhani and Rothery (1987), and failed to detect density-dependence in the Blyth - Cadell data.

Hence we have two failures and one pass, based on three different statistical tests for density-dependence. Those results are ambiguous. Even if all three tests had passed, density-dependence can only be regarded as "provisional" until verified by independent data: it is possible that a positive result can be derived from density-independent processes (Pollard, Lackhani and Rothery 1987).

DISCUSSION

The results of these analyses generally support previous published work on the population dynamics of estuarine crocodiles (Messel et al. 1981, 1984; Webb et al. 1984: Messel and Vorlicek 1986). Hatchling production was extremely variable, in concert with fluctuating seasonal water level and the effect that that may have on the quantity and quality of breeding and nesting habitat. Many vertebrate species exhibit variable recruitment in relation to environmental variability (Nichols 1976), and this may also apply to crocodilians (Fogarty 1974, Joanen and McNease 1975, Nichols 1987). Flooding of nests of both the American alligator and estuarine crocodile varies with water level, and may affect nesting success (Nichols 1987, Hines et al. 1968, Joanen 1969, Webb et al. 1977). Large crocodiles (>6 feet) in both river systems also exhibited some temporal instability, most likely reflecting dispersal between ephemeral and permanent wetlands as a result of variable seasonal water level. In contrast, and trapped between the two dynamical extremes, were juvenile crocodiles whose numbers exhibited overall stability. Juveniles had high "loss" rates (emigration or mortality), and that rate was greater in the high density Blyth-Cadell population. All analyses suggest that estuarine crocodiles at high density may exhibit density-dependent mechanisms of population regulation, mostly emanating from the juvenile class. Hence although the rate of increase of non-hatchlings was a function of seasonal rainfall and the production of hatchlings, crocodiles may not be at the complete mercy of the weather. Nonetheless, we could not demonstrate conclusively the existence of density-dependence and hence compensation responses to a reduction in numbers. Two out of three statistical tests failed to detect "provisional" density-dependence, and hence the test results were ambiguous. We cannot ignore the possibility that the negative correlation between rate of increase and density found for the Blyth-Cadell population was artefactual, and that the observed trends in crocodile density may simply reflect the cumulative effects of environmental perturbations (via a random walk model).

It is almost impossible to verify density-dependence within a series of census data without independent study. For estuarine crocodiles, such studies are lacking, and that is probably the most significant deficiency in our knowledge of their population dynamics, particularly with respect to sustained-yield harvesting. The following paper suggests a more rigorous approach to the study of estuarine crocodile population dynamics, called experimental management. We conclude, however, that long-term census data are necessary to generate tight compensation hypotheses to test by experimentation in the first instance, and to assess the importance of environmental variability to population stability. These conclusions are supported by other studies. Messel et al. (1981), and Messel and Vorlicek (1986), suggested experimental harvests of juvenile estuarine crocodiles because of their high loss rate Nichols (1987) suggested that experimental science and management should be integrated as a means of improving management through better knowledge on population dynamics . Nichols (1987) addresses also the importance of environmental variability on life-history parameters in population models of the American alligator.

Both compensation and environmental variability are important management considerations. We cannot have sustained-yield harvesting unless populations compensate for removals. Even if compensation is demonstrated, environmental variability has the potential to lower yields. Although the present debate on harvesting centres on compensation (Anderson and Burnham 1976, Caughley 1985), the conventional theory of harvested populations (Schaefer 1957, Beverton and Holt 1957) ignores environmental variability. Beddington and May (1977) suggest that harvested populations take longer to recover from environmental perturbations, lowering potential yields. That conclusion is generally supported by empirical observations from fisheries research (Doubleday 1976, Sissenwine 1977, Staples 1986), and has recently been demonstrated for red kangaroos (Caughley 1987). However, depending on the the nature of the compensatory response, opposite effects may occur (May *et al*. 1979, Shepherd and Horwood 1979, Horwood *et al*. 1979). We suggest that the future management prospects for estuarine crocodiles in Australia, particularly sustained-yield harvesting, depend on research which address the problems of compensation and the likely impact of environmental variability on potential yields.

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Table 1. Key factor regression analyses of estuarine crocodile population dynamics in the Liverpool-Tomkinson (1976-83) and Blyth-Cadell (1974-1983) river systems, Northern Territory.

Liverpool-Tomkinson	Blyth-Cadell
(a) Hatchling production	
$H=f(WL)$: non-linear but polynomial not fitted	$H=-2.9+0.9WL-0.004WL^2$ ($R^2=72.5\%$, $P<0.001$)
$H=-1.12+4.96C_6$ ($R^2=62.3\%$, $P<0.02$)	$H=f(C_6)$: non-linear, but $P<0.10$
(b) Non-hatchling rate of increase	
$r=-0.86+0.16H+0.0007RF$ ($R^2=81.7\%$, $P<0.05$)	$r=0.58-0.37NH+0.02H+0.0002RF$ ($R^2=93.0\%$, $P<0.001$)
(c) Juvenile loss rate	
$z=0.04+0.08WL$ ($R^2=45.9\%$, $P<0.10$)	$z=-3.35+1.49NH$ ($R^2=72.0\%$, $P<0.001$)
(d) Spatial effects	
None, but see z above	$C_{2-6}=0.97+0.153IRF$ ($R^2=60.7\%$, $P<0.01$)
	$C_6=1.15-0.031WL-0.044IWL$ ($R^2=72.3\%$, $P<0.02$)

Symbols used

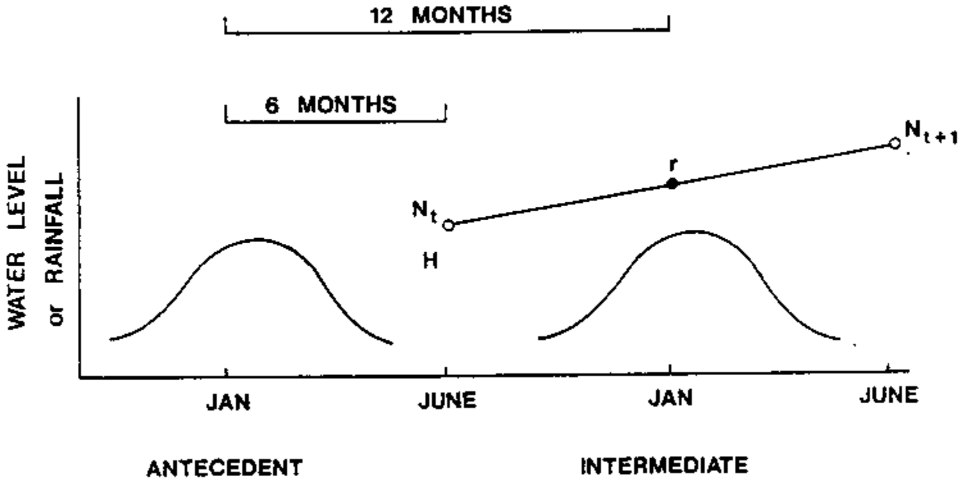
H = relative density hatchlings (km^{-1} river)
NH = relative density non-hatchlings (km^{-1} river)
C_{2-6} = relative density of juveniles (km^{-1} river)
C_6 = relative density of adult and sub-adult crocodiles (km^{-1} river)
WL = antecedent water level (maximum mean annual stage, m)
IWL = intermediate water level (maximum mean annual stage, m)
RF = antecedent seasonal rainfall (October-May, mm)
IRF = intermediate seasonal rainfall (October-May, mm)
r = annual exponential rate of increase non-hatchlings
z = annual exponential "loss" rate of juveniles estimated from temporal size distribution.
R^2 = percentage explained variance of regression equation

Appendix. Summary of data used in analyses.

Year	Water level	Rainfall	Rate of increase	H	NH	C_{2-6}	C_6
			Liverpool-Tomkinson Rivers (1976-1983)				
1976	9.32	1162	-0.02	0.11	1.44	1.13	0.31
1977	7.89	1093	-0.01	0.36	1.41	1.17	0.24
1978	7.65	1150	0.04	0.26	1.39	1.11	0.28
1979	6.54	992	-0.20	1.54	1.44	0.99	0.45
1980	5.19	1157	0.01	0.50	1.59	1.23	0.36
1981	13.32	1326	0.13	0.21	1.60	1.21	0.38
1982	5.82	1026	0.11	1.20	1.82	1.34	0.48
1983	5.90	886	-	0.65	2.04	1.69	0.35
			Blyth-Cadell Rivers (1974-1983)				
1974	12.87	1686	-0.02	0.97	3.24	3.17	0.07
1975	14.03	1405	-0.14	0.53	3.19	3.04	0.15
1976	14.26	1162	0.02	0.78	2.78	2.55	0.23
1977	11.77	1093	-0.02	1.07	2.84	2.62	0.22
1978	10.73	1150	0.26	1.80	2.77	2.53	0.24
1979	8.79	992	-0.18	1.29	3.60	3.02	0.58
1980	8.60	1157	-0.02	1.28	3.02	2.68	0.34
1981	12.90	1326	-0.07	0.82	2.97	2.54	0.42
1982	9.35	1026	0.15	1.35	2.76	2.18	0.58
1983	7.81	886	-	1.25	3.21	2.74	0.47

H = relative hatchling density, < 2 feet (numbers km^{-1})
NH = relative non-hatchling density, > 2 feet (numbers km^{-1})
C_{2-6} = relative density juveniles, 2-6 feet (numbers km^{-1})
C_6 = relative density sub-adults & adults, > 6 feet (numbers km^{-1})

Fig 1 MEASUREMENTS AND TIME LAGS



= SEASONAL RAINFALL (mm) or WATER LEVEL (m)

$r = LOG_e \left(N_{t+1} / N_t \right)$ INSTANTANEOUS RATE OF INCREASE

H = HATCHLING DENSITY

N_t = NON-HATCHLING DENSITY AT YEAR t

N_{t+1} = NON-HATCHLING DENSITY ONE YEAR LATER

ANTECEDENT = PAST

INTERMEDIATE = PRESENT

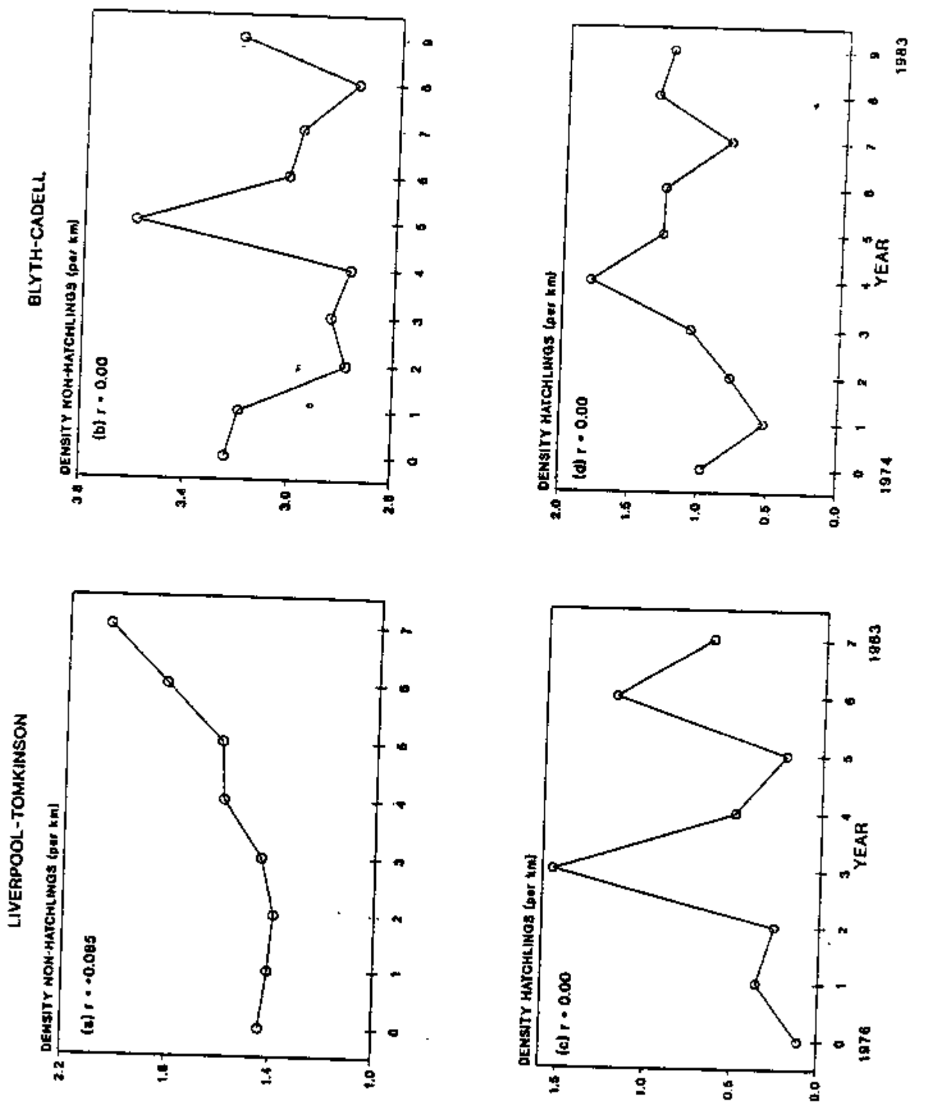

LIVERPOOL-TOMKINSON
BLYTH-CADELL
DENSITY NON-HATCHLINGS (per km)
(b) r = 0.00
DENSITY HATCHLINGS (per km)
(c) r = 0.00
(d) r = 0.00
YEAR
1976
1983
1974
1983

Fig. 2 a-d

Fig. 2 e-h

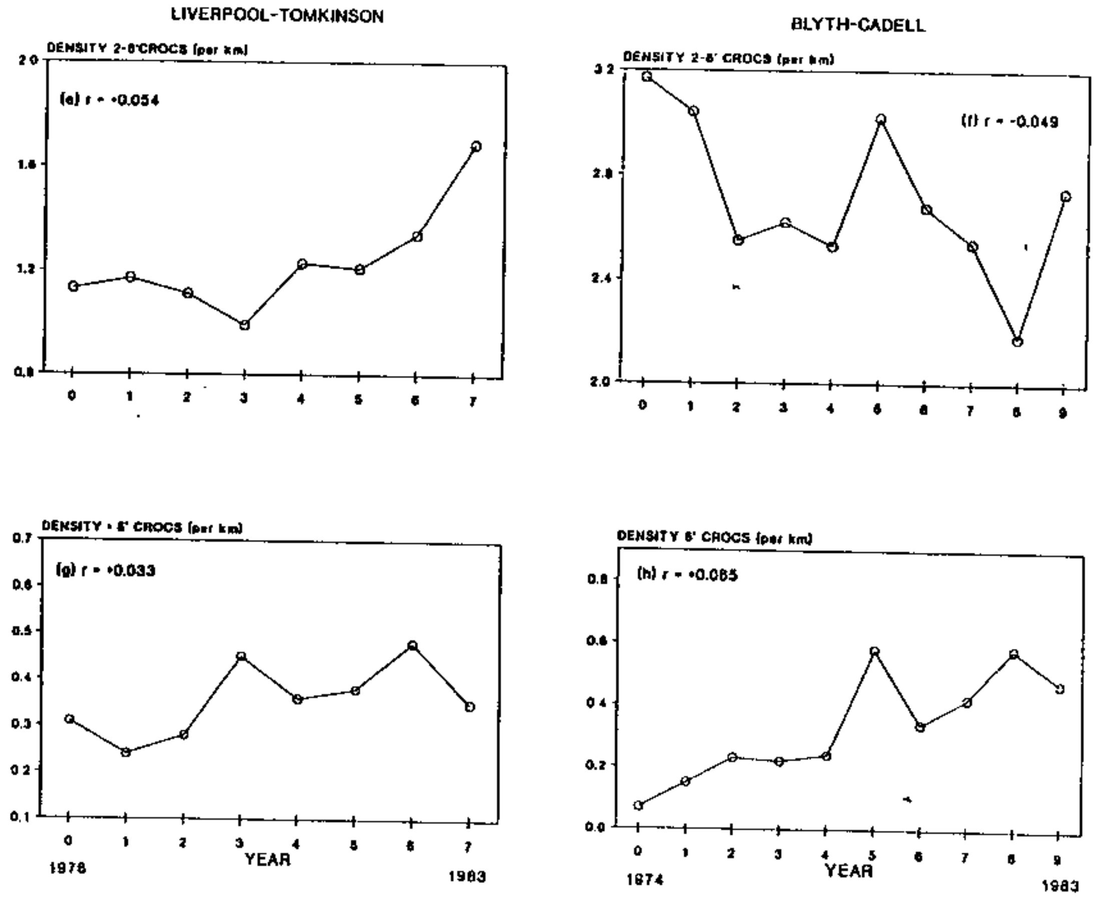

LIVERPOOL-TOMKINSON
BLYTH-CADELL
DENSITY 2-8'CROCS (per km)
(e) r = +0.054
DENSITY 2-8' CROCS (per km)
(f) r = -0.049
DENSITY > 8' CROCS (per km)
(g) r = +0.033
DENSITY 8' CROCS (per km)
(h) r = +0.065
YEAR
1976
1983
YEAR
1974
1983

Fig 3a-c RAINFALL AND WATER LEVEL VARIATIONS

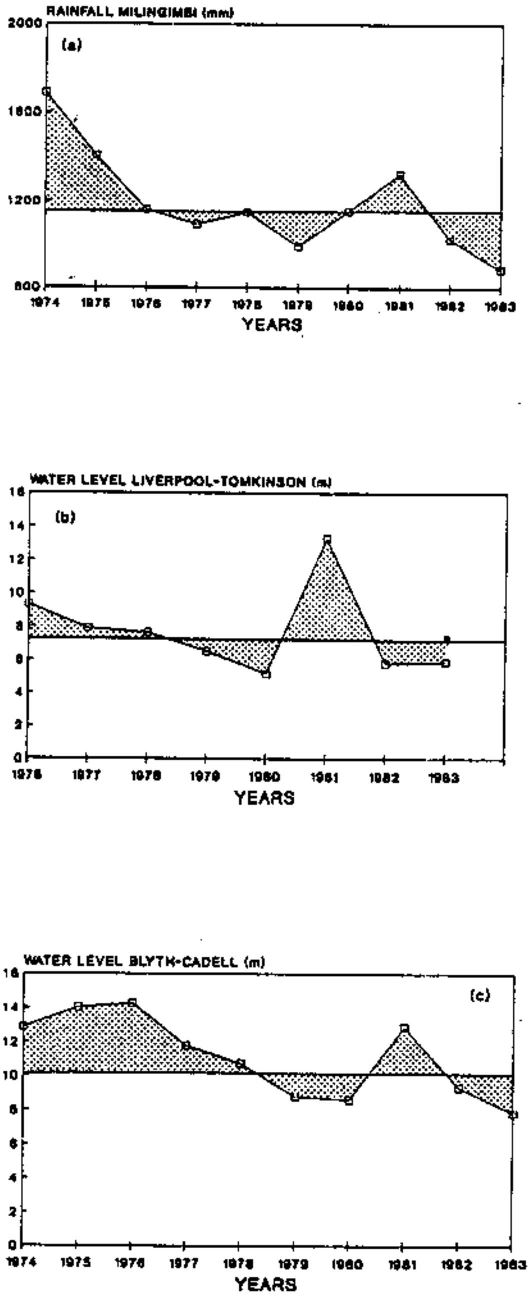


Fig 4a-d HATCHLING DYNAMICS

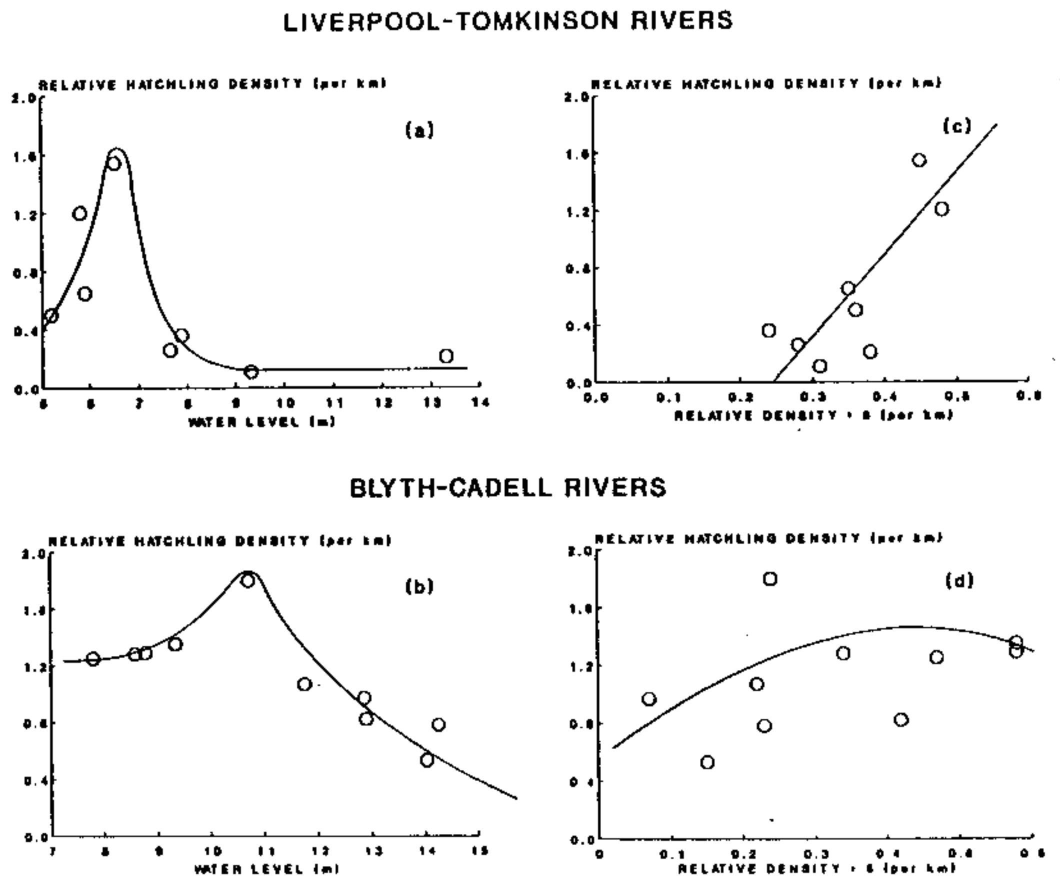


Fig. 5a & b JUVENILE LOSS RATE USING TEMPORAL SIZE DISTRIBUTION

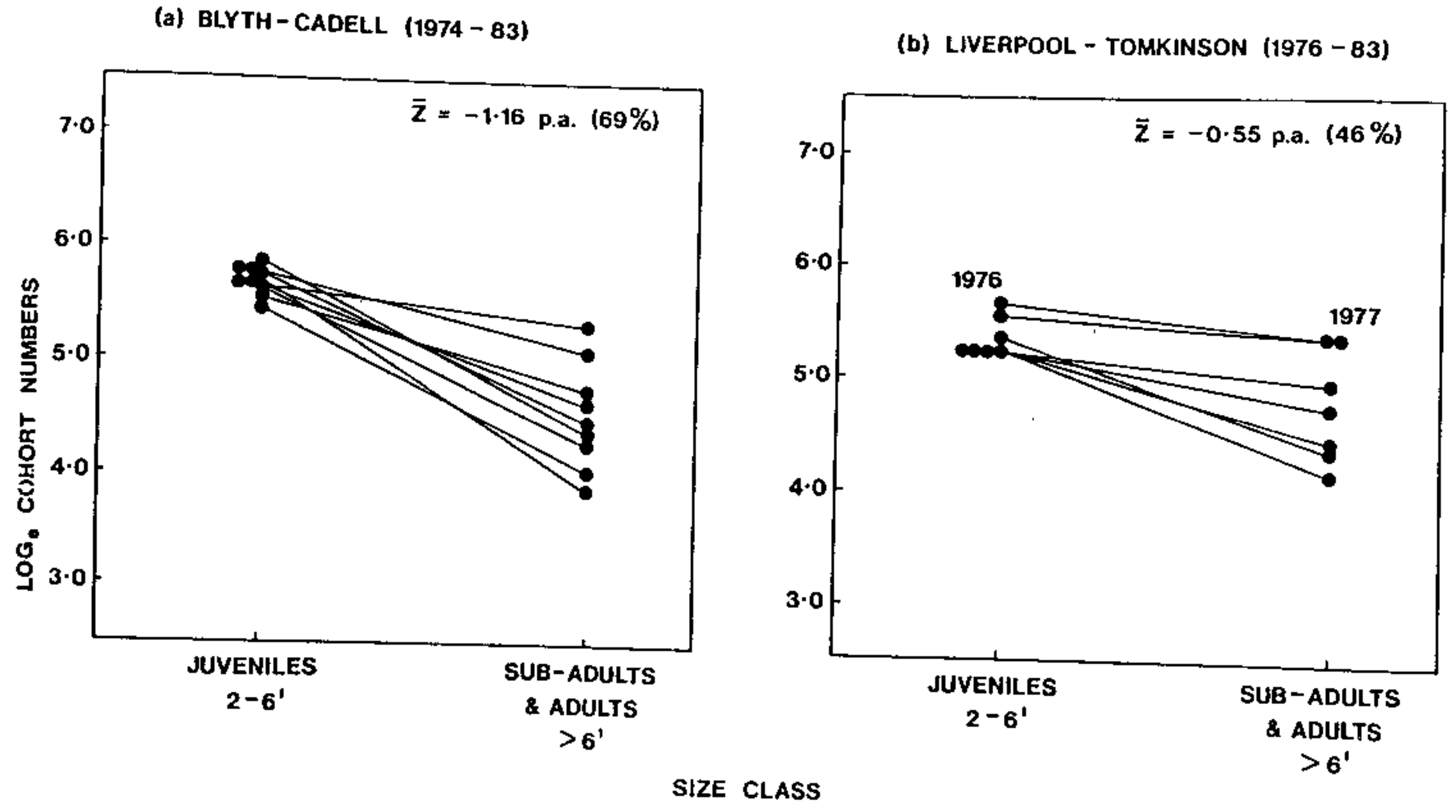


Fig 6a & b FLUCTUATIONS IN NUMBERS OF DIFFERENT SIZE CLASSES IN ESTUARINE CROCODILES

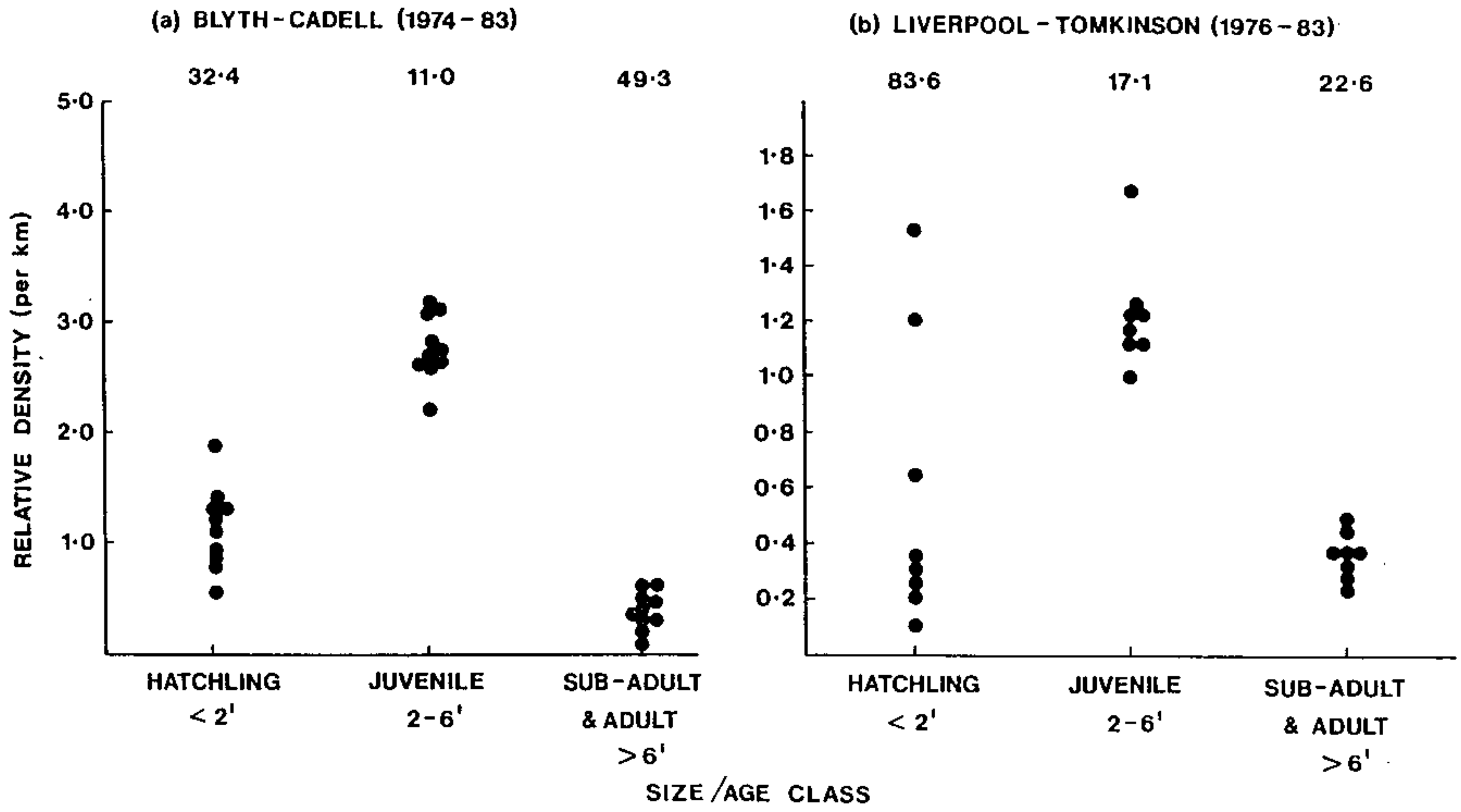
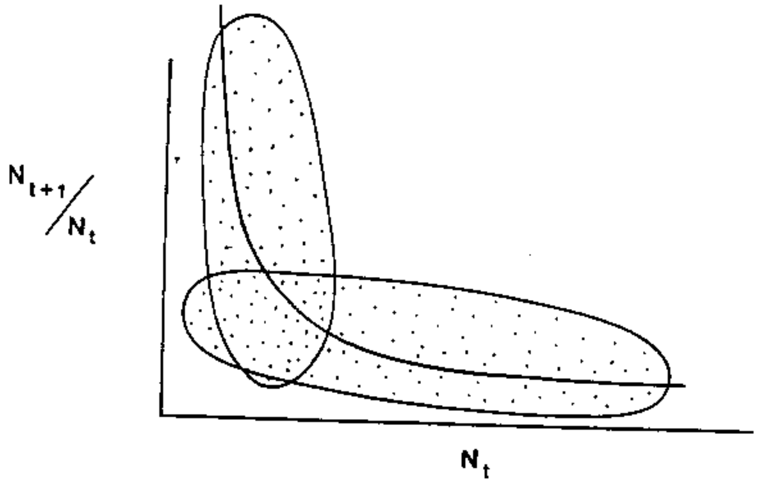
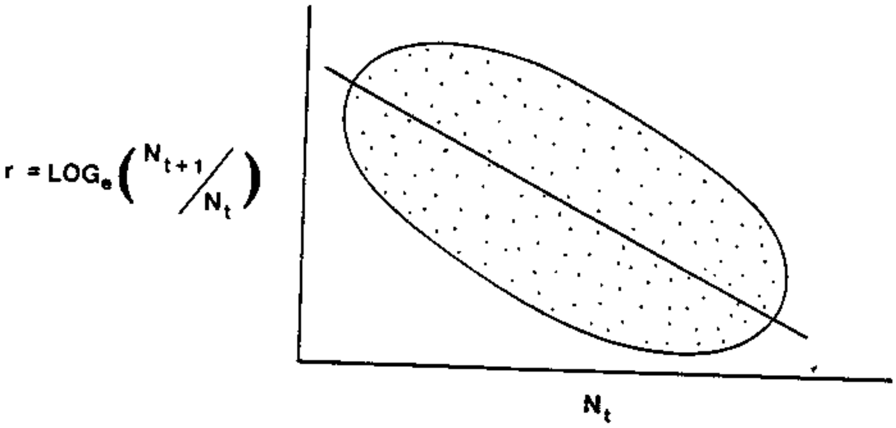


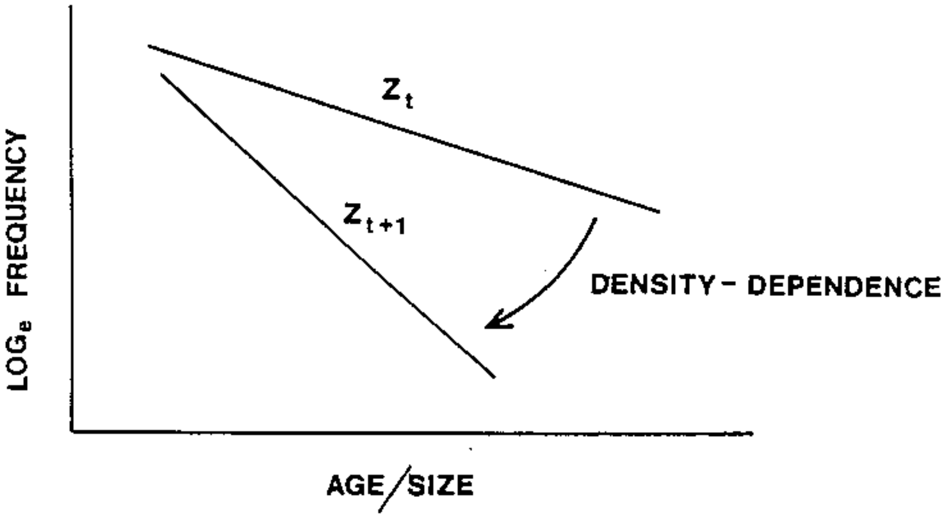
Fig 7a & b CHANGE IN DENSITY vs ANTECEDENT DENSITY





RANDOM SAMPLE VARIATION

Fig 8a JUVENILE MORTALITY TEST USING TEMPORAL SIZE/AGE DISTRIBUTION



DENSITY - INDEPENDENCE $Z_{t+1} = Z_t$

DENSITY - DEPENDENCE $Z_{t+1} > Z_t$

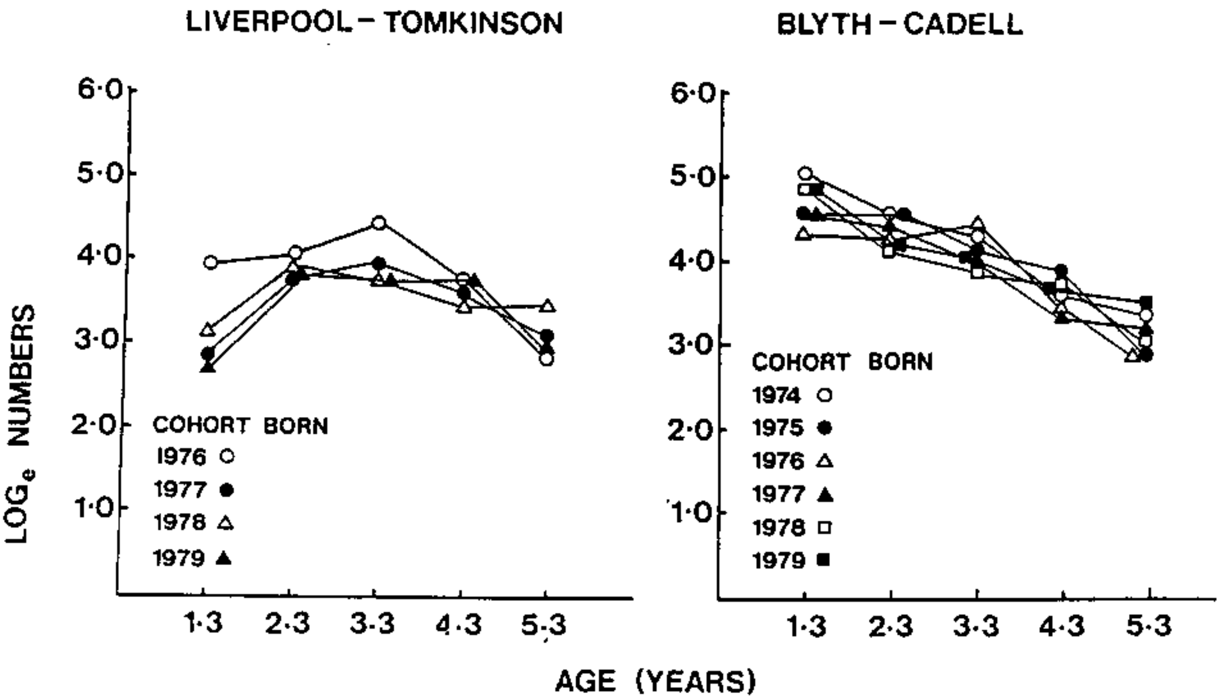
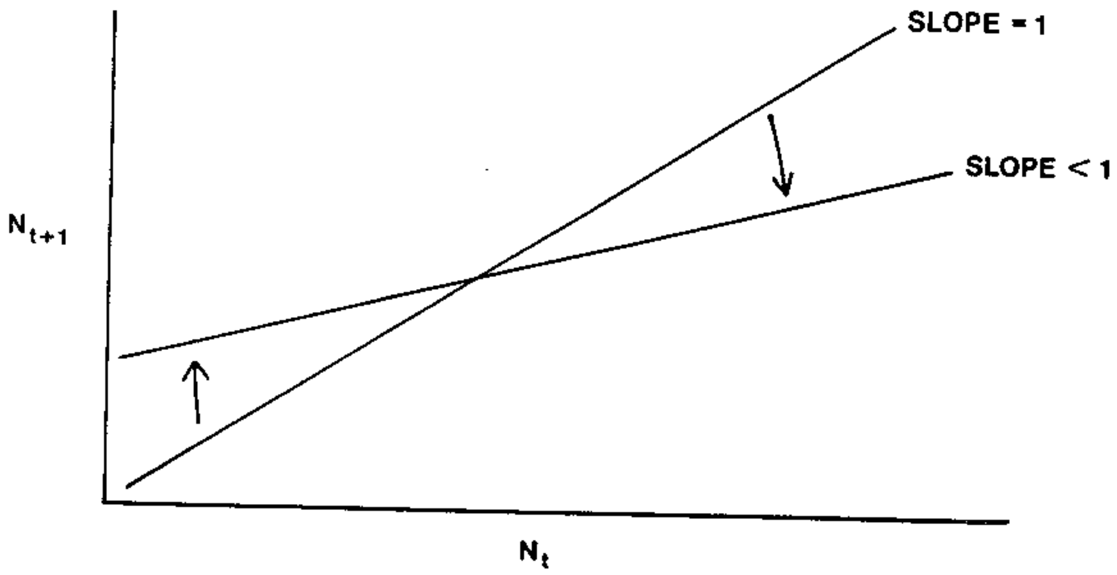


Fig 9 MORRIS NULL-HYPOTHESIS



DENSITY-INDEPENDENCE SLOPE = 1 & INTERCEPT > 0

DENSITY-DEPENDENCE SLOPE < 1

THE POPULATION DYNAMICS OF ESTUARINE CROCODILES. II. EXPERIMENTAL MANAGEMENT IN WEIPA, NORTH QUEENSLAND.

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SUMMARY

The first paper in this series highlighted the lack of basic knowledge on the population dynamics of estuarine crocodiles, and predicted that it will be a significant impediment to their future management. In this paper a research program is proposed to overcome that deficiency, and is based on experimental management. Experimental management views research and management as complementary processes: the essential dynamics of a population are learnt opportunistically through an experiment centred on the need to manage by removal. We propose to use that concept to integrate a disciplined study of the population dynamics of estuarine crocodiles with their day-to-day management at Weipa, a remote mining town in north Queensland. We plan to investigate the biology of possible compensatory processes through detailed studies of reproduction, survival and movements in tandem with a carefully controlled reduction in numbers. At the end of that study we will assess the future management options for estuarine crocodiles in Queensland, particularly the economical and biological feasibility of ranching.

INTRODUCTION

The estuarine crocodile is a large and potentially dangerous animal which shares the waterways of northern Australia with large numbers of people. Its future conservation in many areas will depend on our capacity to actively manage populations whose numbers are controlled in one way or another. Population control is simply harvesting under another name and demands the same understanding of population processes and responses to harvesting. Our present knowledge of population processes in crocodiles is limited despite the many opportunities which exist worldwide to integrate scientific experimentation with practical management (Nichols 1987). This paper examines the rationale for an experimental approach to population management and sets out the framework of an experimental harvest project in northern Queensland. The project aims to provide precisely the integration of science and management which Nichols (1987) has called for from crocodile biologists. For an interesting discussion on wildlife management as scientific experimentation, readers are referred to a paper by John Macnab (1983).

Aims of Population Management

Populations are managed with one or more of three principal aims in mind (Caughley, 1977);

1. <u>Conservation</u>: density is increased or maintained through measures such as regulatory actions and habitat conservation.

2. Control: density is lowered through removal of animals or manipulation of habitat.

3. Harvesting: animals are exploited from a population on a sustainable basis usually with a view to optimizing or maximizing biological or economic yields.

Control and harvesting are two sides of the same coin, imposing similar impacts on the population but differing in the end-product they aim to achieve. Control measures may aim to reduce a population to the lowest level possible in specific areas, ignoring the impact that very low population levels may have on the economic yield from the programme. A harvest programme, on the other hand, will usually demand that the population is maintained at a moderately high level, allowing a substantial and sustainable yield to be taken. In practice, most control programmes become exercises in sustained-yield harvesting, whether that was the original intention or not.

The present management of crocodiles in Queensland revolves around conservation and control measures, with sustained-yield harvesting a future option under active investigation. The need for control of crocodile numbers in some parts of Queensland is not at issue. What does need to be addressed is the scientific framework on which a programme of control or harvesting is to be constructed and the means by which we can maximize the conservation benefit flowing from a management programme. The latter question has been addressed broadly in terms of the geographical and social contexts of crocodile management in Queensland by Taplin (this proceedings). The focus here is on the means by which we can best advance our understanding of crocodile population dynamics, given that a control programme offers opportunities for a broad range of scientific investigations.

Compensation processes and population management

There are two fundamental principles of population and harvesting dynamics (Caughley, 1985). These are:

1. If some animals are removed from a population, the fortunes of the others will be enhanced, and their fecundity and/or survival rates will rise to compensate for the removals.

2. If the rate of removal is too high, the population will be unable to compensate and will slide towards extinction.

Most people would agree with those two deceptively simple principles. Disagreements might arise over the form and strength of compensation, if any, which may be triggered by removals in specific populations. Caughley (1985) identified three possible forms of compensation - complete, partial and zero - which may differ in strength and in the way they are mediated within the population.

1. Complete Compensation.

Here, compensation is absolute. Numbers will average the same, year after year, whether the population is harvested or not. Removals do not affect the population size unless they exceed the extinction threshold rate set by the animals maximum rate of increase.

While this appears an unlikely model, it would be dangerous to dismiss it as simply theoretical. Animals such as small mammals and birds may exhibit complete compensation. Anderson and Burnham (1976) argued that this model applies to mallards in North America. Such a finding has the potential to change cautious management practices because of the unavoidable conclusion that hunting does not affect numbers. Thus regulations such as seasons or bag limits become unnecessary. However, Anderson and Burnham's conclusion was based on statistical inference from uncontrolled data (band returns) and needs to be verified through independent study.

2. Partial Compensation.

Under partial compensation continued removal at any intensity reduces population size below the unharvested density. Resources per head of the reduced population increase because there are fewer animals. Concomitantly, fecundity and survival rates rise, generating a potential rate of increase that would be realised if removals were ceased. Up until maximum rate of increase, the greater the reduction in numbers, the higher the potential rate of increase. When the potential rate of increase equals the rate of removal, the population stabilises at a lower equilibrium density. If the rate of removal exceeds the population's maximum rate of increase, the population slides towards extinction. Figure 1 outlines the essential features of partial compensation, as exemplified by a simple logistic model.

3. Zero Compensation.

Under the zero compensation model, harvesting mortality is completely additive. Populations do not compensate for removals by either reduced natural mortality or increased fecundity. Zero compensation is typified by the additive mortality model, which ignores the effects of fecundity. This model is described in detail by Nichols (1987). The model assumes that there is no interaction (=compensation) between natural (n) and harvest (h) mortality rates, and that total mortality (z), across all population classes, is at first glance partitioned thus:

$$z = h + n$$

However, the two mortality rates h and n are not independent. If removals ceased, natural mortality would increase because animals that would have been removed are now at risk from natural agents. Hence when both types of mortality are operating <u>together</u> there is competition between them because an animal can only die once. Simply adding h and n gives an estimate of z which is too large by the amount of overlap in the Venn diagram in Figure 2, the product nh. The correct relationship is given by

$$z = n + h - nh$$

Ricker (1958) found that in making use of this relationship there is no need to assume that the rates of harvesting and natural mortality are proportional throughout the year. Hence, the relationship holds if the two rates act consecutively or concurrently.

The model may apply to components of a population, such as eggs, in which we might expect no compensation to occur unless there is further egg-laying after a harvest. For example, a typical and erroneous argument goes like this - natural egg loss is 75%, therefore 75% or a large number of eggs are potentially harvestable without impact on the wild population. The false assumption is that there is independence between natural and harvest mortality, and the two forms of mortality are interchangeable. As we have demonstrated, this cannot be. The correct value for z of the remaining wild population is 0.94 in the presence of both agents of mortality, not zero by replacing h with n.

Of the three compensation models, partial and zero compensation are the most likely forms in crocodiles and are the most important as they require very different approaches to management. A population that exhibits zero compensation but is managed under the assumption of partial compensation may easily be overharvested. On the other hand, a population that exhibits partial compensation but is harvested under zero compensation assumptions may be significantly underutilised. For game harvest management that may be of little importance, but for efficient commercial utilization of a wildlife resource it may be very important. To this we can add the complication that, depending on the nature of the industry, if population growth rates are less than discount rates of interest, then the most economical option for harvesting may be to exploit the population to economic or even biological extinction (May 1976). Hence questions of compensation and maximum rate of increase are central to decisions about future management options for crocodiles. Despite this, compensatory responses have been demonstrated convincingly for only a handful of wildlife species, amongst which crocodiles do not figure largely. The reason for this may be found in the predominance of observational studies of crocodilians over manipulative studies, exemplified by the two basic approaches to population dynamics - key factor analysis and experimentation (Krebs 1985).

Key factor analysis

Key factor analysis is basically a life-table approach which examines, retrospectively, year to year changes in the density of different classes within a population in relation to factors such as age (e.g. the life-table), population density, predation rates, rainfall, temperature and other environmental variables. It aims to identify the 'key' mortality agents which have a major impact on population fluctuations from year to year. It also provides estimates of the variation in impact of different mortality factors as a function of population density. By plotting mortality rates against density we can search for possible density-dependence in the population dynamics of a species, and hence speculate upon the existence of compensatory processes. Unfortunately, the regression techniques used for testing density-dependence can do little more than generate worthwhile hypotheses for further field investigation. The techniques suffer from all the limitations of correlative analyses in which density provides only an index of the regulatory mechanisms underlying population processes, whether these are intrinsic to the population (e.g. spacing behaviour), extrinsic (e.g. limiting resources), or a combination of both. Furthermore, demonstrating density-dependence in a series of census data is almost impossible because of sampling variation and the non-independence of successive measurements of population change (see Bayliss and Messel, this proceedings).

Over and above these statistical and inferential problems, however, key factor analysis can fail to reveal crucial details of vertebrate population dynamics because most populations show little change under natural conditions. A costly and laboriously constructed life-table for a population more or less in "equilibrium" may reveal little about its population dynamics. Whether such equilibrium studies run for 5 years or 50 years is irrelevant because only the equilibrium state variables can be measured. The compensatory forces contributing to the dynamics of the population remain hidden. To study change you need change. If we are lucky we may be able to follow the consequences of environmental perturbations such as bad weather, or people-induced perturbations such as a known harvest or the cessation of an intensive harvest (as has happened with estuarine crocodiles). However, even these opportunities are likely to be of limited value because we remain completely dependent on undisciplined correlative data.

Bayliss and Messel (these proceedings) use a form of key factor analysis to examine population processes in the estuarine crocodile. The results are certainly interesting and contain all sorts of intriguing implications. However the analysis cannot demonstrate convincingly the existence of compensation because it is the wrong sort of data. It can only point us in the direction of testable hypotheses amenable to experimental investigation. To take our understanding of crocodile population dynamics into realms where the processes operating in harvested or controlled populations can be understood, we need to start manipulating populations within an experimental framework.

Experimentation.

An experimental approach to investigation of population dynamics can provide direct tests of competing compensation hypotheses and, if designed carefully, can reveal the form and strength of any compensation detected. The approach is based on disciplined data from carefully constructed trials in which crucial factors influencing population processes are controlled experimentally. Foremost among these is the density of the population itself - a factor over which we can exercise considerable control by direct manipulation. Of course, a wide variety of extrinsic factors such as weather variables impinge upon experimental systems and introduce ambiguity into the results. Nonetheless, through appropriate use of controls, treatments and replication the influence of extrinsic factors on the experimental system can be estimated and separated out from the treatment response to some extent. Experimentation provides no perfect solution to the problems of population dynamics, but it does offer better approximations to the truth than are likely to emerge from purely observational studies.

THE WEIPA EXPERIMENTAL HARVEST PROJECT

The opportunity to investigate the population dynamics of the estuarine crocodile from a experimental framework derives from the socialogical problems surrounding crocodile management in north-western Cape York, their key conservation area in Queensland (Taplin, these proceedings). The Queensland National Parks and Wildlife Service plans to establish place a project which capitalizes on the need for active management of the interface between crocodiles and people in Albatross Bay (site of the Weipa township) to advance our understanding of the population dynamics of exploited crocodile populations. Its principal long-term scientific aims are to measure the response of a crocodile population to a harvest regime and, by providing estimates of the annual yield that the population can sustain, to define more clearly our options for future active management of crocodiles throughout the State.

In the short-term it will aim to;

1. identify and quantify the form and strength of compensation, if any, that is triggered by a harvest;

2. design and implement an effective monitoring system to measure the impact of removals in terms of percentage offtake and recovery rate;

3. maximize the conservation benefit deriving from the harvest by using them as breeding stock for farms and zoos, thus supporting the "value-added" philosophy of crocodile conservation (Hines and Abercrombie 1987) in Queensland; and

4. gain new insights into the movement patterns, habitat utilization, reproduction and mortality of crocodiles.

Our expectations of this project are realistic. The minimum achievable result is a clear measure of the response of a crocodile population to a harvest regime, and a string of insights into little-known details of crocodile biology. These alone will be sufficient to chart a path for crocodile management in Queensland in the short-term. Over and above these, however, are opportunities to reveal the way in which compensatory processes are mediated in the population, through impacts on survivorship, reproduction and movements. It is not realistic to expect that a detailed understanding of these complex processes will emerge without an enormous amount of work. Nonetheless, the project provides an excellent opportunity to carry these studies forward and better define the questions to be asked and the means by which they can be addressed.

Experimental design

The study area takes in the Albatross Bay system at Weipa and the Port Musgrave system some 70 km to the north (Figure 3) - see Taplin (this proceedings) for a broader perspective on the study area. The Mission, Pine, Embley and Wenlock rivers are breeding systems, whilst the Hey and Pennefather rivers are non-breeding hypersaline systems. The Mission and Pine rivers are subjected to heavy recreational use, and contain the highest densities of large crocodiles close to Weipa (Table 1).

Removal strategy

We plan to undertake an unselective harvest of non-hatchlings in proportion to their representation in the population. The reasons for using this strategy initially are outlined below.

1. Intensive past hunting has undoubtedly created unstable size/age distributions, introducing the potential for variable reactive time lags within the population treatments. These may confound comparisons with the dynamics of control populations. We have chosen to maintain the existing size/age structure after the first harvest through proportional removal because we do not know what the stable size/age distribution should be.

However, the size/age structure should continue to move towards its stable form and will differ from the unharvested stable size/age structure.

2. We wish to identify the components of rate of increase where compensation, if any, is being effected. Removal of juveniles, sub-adults and adults provides the opportunity to study compensation processes in both survival and fecundity rates.

3. In terms of the experiment succeeding, it is safer to "get a hit" before attempting a "home run". Hence, as a first step, we need to understand the basics before we dive into the complexities of selective harvest strategies. Given point 2 above, the effects of selective harvest (sex and/or size) can be more easily inferred from an unselective harvest than vice versa.

4. Eggs and and hatchlings are not incorporated in the harvest at this stage because this would simulate failed recruitment, the effects of which probably linger through the life expectancy of a cohort. That would confound interpretation of experimental results for the non-hatchlings. It is not logistically possible to include it as an extra treatment requiring further replicates. Nor is it necessary because such studies have been

conducted in the Northern Territory (Webb et al. 1986). In addition, continued hatchling recruitment will act as a "safety buffer" for the population during the currency of the experiment.

5. A removal regime which ignores the need to harvest large crocodiles as part of a control programme fails to address one of the central problems of crocodile management in populated areas (Taplin, this proceedings).

Treatments

An initial large reduction is necessary to:

1. reduce the treatment population to a density which is low enough to generate a high rate of increase, improving the chances of detecting compensation responses given the expected measurement problems; and

2. minimize the period of time necessary for the treatment population to settle to the new reduced equilibrium density with the chosen harvest rate.

The removal treatment is tailored to the fact that we do not know either the maximum rate of increase of the population or the potential carrying capacity of the system. The removal treatment will consist of an estimated 50% reduction in density on the Mission and Pine Rivers providing two replicate systems, against which the Embley and Wenlock Rivers will provide replicate controls (Fig. 3). Allowing for the fact that populations are still recovering from past hunting, the most optimistic calculations suggest that a 50% reduction is needed to detect statistically any compensation response in rate of increase, if it exists. After the initial reduction, the annual rate of increase will be measured and that increment will form the treatment harvest rate. At present we do not have absolute estimates of population size in each treatment river. However, results of a helicopter survey in May 1988 suggest that a total of approximately 100-150 non-hatchlings will need to be be removed initially (Table 1). The annual harvest to follow should amount to only 15-20 animals assuming crocodiles exhibit generous compensation at 10% p.a. The preliminary estimates are very low and cast doubt on the capacity of the system to support any large-scale industry requiring a sustained high level of offtake. The essence of the experiment, however, is to determine whether these initial optimistic estimates are grossly in error or not.

The study will have three basic components (Fig. 5). Survey work will combine spotlight and helicopter surveys to estimate change in population size from year to year and also the size structure of the population. These data will be used to determine the size and composition of the harvest from year to year. Removal of juveniles and sub-adult crocodiles will be concentrated into the October-December period of each year to take advantage of the very restricted tidal regime in the region. Removal of large crocodiles will be spread throughout the year, particularly the dry season, to allow adequate time to trap these wary animals. A key component of the survey and removal programme will be a detailed investigation of the relationship between spotlight counts, helicopter counts, and crocodiles actually present in the system. Catch-per-unit effort and index-manipulation-index estimates during the harvest operation will provide revised population estimates from which harvest calculations can also be revised as necessary.

The movement study will focus on radio-telemetry and tagging studies to identify movements within and between rivers and river systems. This component will assist in separating local effects of the harvest on survival and fecundity from dispersal effects. It will provide invaluable insights into the scale on which crocodile management in the region has to operate, especially the scale of movements undertaken by mature male and female crocodiles. It will also clarify patterns of habitat utilization of crocodiles of different sex and size - an issue of crucial importance to the design and management of areas of protected habitat about which we know very little at present. The movement study alone provides an oustanding opportunity to fill one of the biggest gaps in our knowledge of crocodile biology in Australia.

The third component of the study, revolving around nesting, will address aspects of the reproductive biology of estuarine crocodiles which have not been examined previously. In particular, the harvest of crocodiles across a wide range of sizes (ages) and times will allow detailed analysis of reproductive maturation and gonadal cycles, based on our existing experience with laporoscopy on live animals (Taplin and Limpus, unpublished). Together with information of movement patterns of nesting female crocodiles in the swamplands of the Weipa Peninsula and Tentpole Creek, and assessments by helicopter survey of nesting effort in the experimental and control systems, the nesting studies will fill a major gap in knowledge.

Potential problems

Few people would argue against the need to manage populations experimentally. Instead the focus usually shifts to its practicalities (e.g. Allen and Kirkwood 1976 on whales). We should not sympathise with these complaints if we advocate harvesting or control as management options for species which are long-lived, have a slow population growth rate, and demonstrate little resilience to habitat change: crocodiles fit this bill.

Certainly the experimental project will encounter many problems. Among these we can identify the following;

1. Time lags in the response of fecundity and survival schedules to a reduction in numbers. The paper by Bayliss

and Messel (this proceedings) suggests a 12 month time lag between a change in density and a detectable response in rate of increase, but it may be longer because dispersal effects could not be differentiated in that analysis. Opportunities will exist to extend the experiment if we detect the beginnings of a delayed response.

2. Accuracy and precision of density estimates. We need to account for the possibility of variable catchability and sightability bias over time, and achieve a standard error of approximately 1-2% on estimates of density. Index-manipulation-index and catch-effort analyses provide first approximations of absolute estimates (to match against offtake), to be refined further by mark-recapture. Replicated boat and helicopter surveys can provide density estimates with the desired level of precision.

3. Initial harvest rates may be set too high. We will use the observed rate of increase after the first year's reduction to set the treatment harvest rates. However these may have to be refined if treatment populations show a continual decline or fail to equilibrate.

4. Confusion of spatial and temporal effects. The movement study will involve radio-telemetry and intensive mark-recapture of crocodiles in all treatment and control areas to tie down this problem.

5. Unstable age/size distribution. Our unselective harvest of non-hatchlings in control and treatment may offer some insight into how the size/age distribution is reacting to harvesting. This may prove to be the biggest problem and may require longer than 3 - 5 years to solve.

6. If environmental variability is extreme over the study period and overshadows the influence of density on population processes, then the experimental effect will be masked by this. Control systems offer the opportunity to remove secular effects, but this may be limited by differences in habitat quality and the age structure of the populations. We assume that the treatment and control systems are more similar than different, and will respond to environmental perturbations in similar fashion. We may have to extend the time period of the experiment if annual environmental variability is too high, or unstable size/age distributions introduce variable responses to treatments.

Regardless of these difficulties, the experimental approach and this project offer better opportunities to advance our understanding of crocodile biology in Queensland in areas central to population management than any other approach we might adopt.

ACKNOWLEDGMENTS

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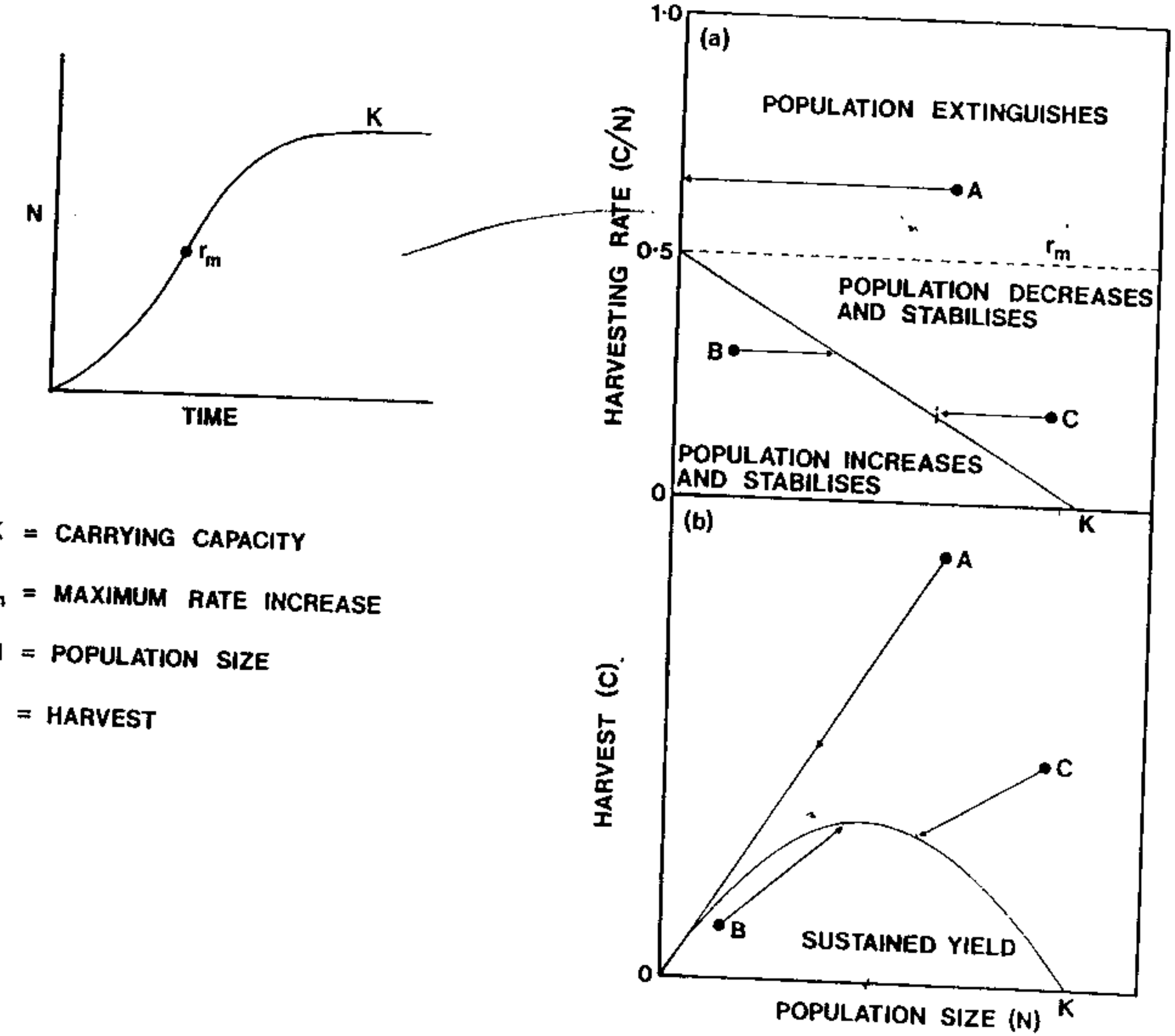
Table 1. First approximation of crocodile numbers in each of four size classes in the experimental rivers, and the number that need to be removed. Estimates are derived from the May 1988 helicopter survey.

River	Observed numbers	Corrected numbers[1]	50% reduction	Maximum annual removal[2]
MISSION R. TREATMENT				
Small <6'	37	74	37	3
Medium 6-10'	23	46	23	3
Large 11-15'	24	48	24	2
Very large >15'	10	20	10	1
Total	94	188	94	9
PINE R. TREATMENT				
Small <6'	38	76	38	4
Medium 6-10'	16	32	16	2
Large 11-15'	6	12	6	1
Very large >15'	0	0	0	0
Total	60	120	60	7
Overall·total treatment	154	308	154	16
EMBLEY R. CONTROL				
Small <6'	26	52	0	0
Medium 2-10'	4	8	0	0
Large 11-15'	10	20	0	0
Very large >15'	4	8	0	0
Total	44	88	0	0
WENLOCK R. CONTROL				
Small <6'	123	246	0	0
Medium 2-10'	56	112	0	0
Large 11-15'	52	104	0	0
Very large >15'	6	12	0	0
Total	237	474	0	0
Overall total control	281	562	0	0

1. Conversion for helicopter to spotlight counts of non-hatchlings is about 1:1 for both banks in the study area (Bayliss and Taplin, unpublished). Therefore combined helicopter counts from river mainstream and tidal creeks are corrected to estimates of absolute numbers using a conservative spotlight correction factor of 2.0 (mean of upstream, downstream and tidal sidecreeks, from Bayliss 1987).

2. The ceiling for maximum rate of increase of non-hatchlings is set at 10% p.a., the observed rate estimated for recovering populations in the Northern Territory (Webb et al. 1986). Actual observed rates of increase after reduction, and hence treatment harvest rates, are expected to be much lower than this.

Fig 1. PARTIAL COMPENSATION - LOGISTIC MODEL (From CAUGHLEY 1985)



K = CARRYING CAPACITY

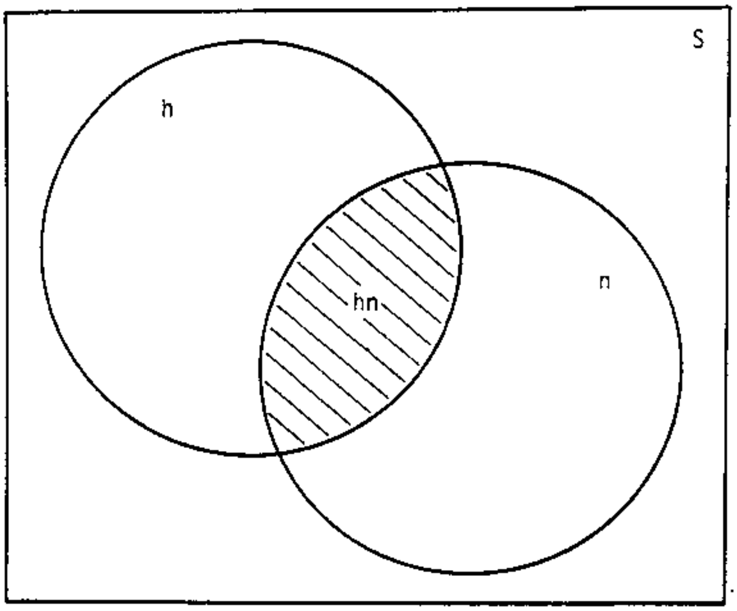
r_m = MAXIMUM RATE INCREASE

N = POPULATION SIZE

C = HARVEST

Fig 2. ZERO COMPENSATION - ADDITIVE MORTALITY MODEL

VENN DIAGRAM



S = PROPORTION SURVIVING

h = PROPORTION THAT WOULD DIE IF THERE WERE NO NATURAL MORTALITY

n = PROPORTION THAT WOULD DIE IF THERE WERE NO HARVEST MORTALITY

hn = COMPETITION BETWEEN TWO TYPES OF MORTALITY

Z = TOTAL MORTALITY

$$S = 1-Z \quad \text{where} \quad Z = n+h-nh$$

FIGURE 3. WEIPA EXPERIMENTAL MANAGEMENT STUDY AREA

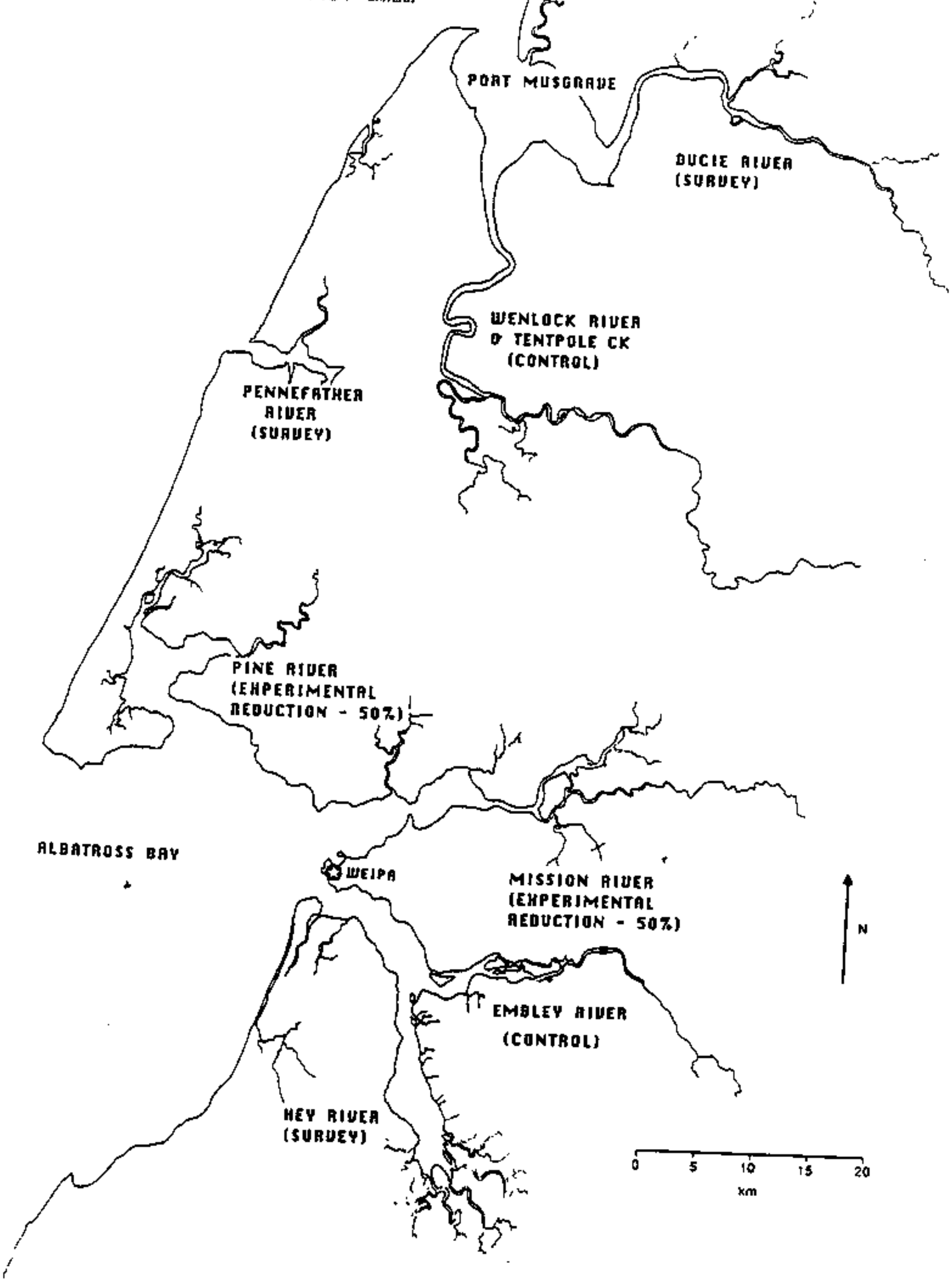


Fig. 4 EXPERIMENTAL SCHEDULE - WEIPA EXPERIMENTAL HARVEST PROJECT

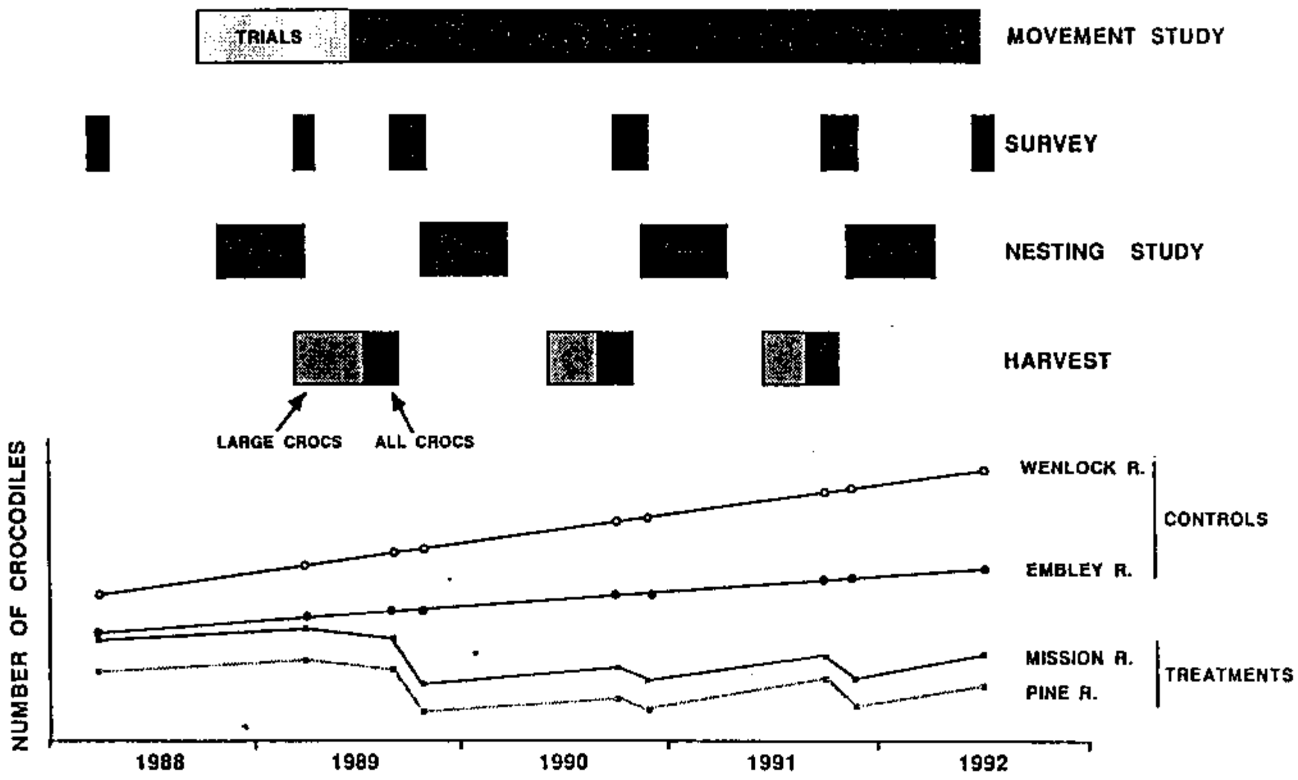
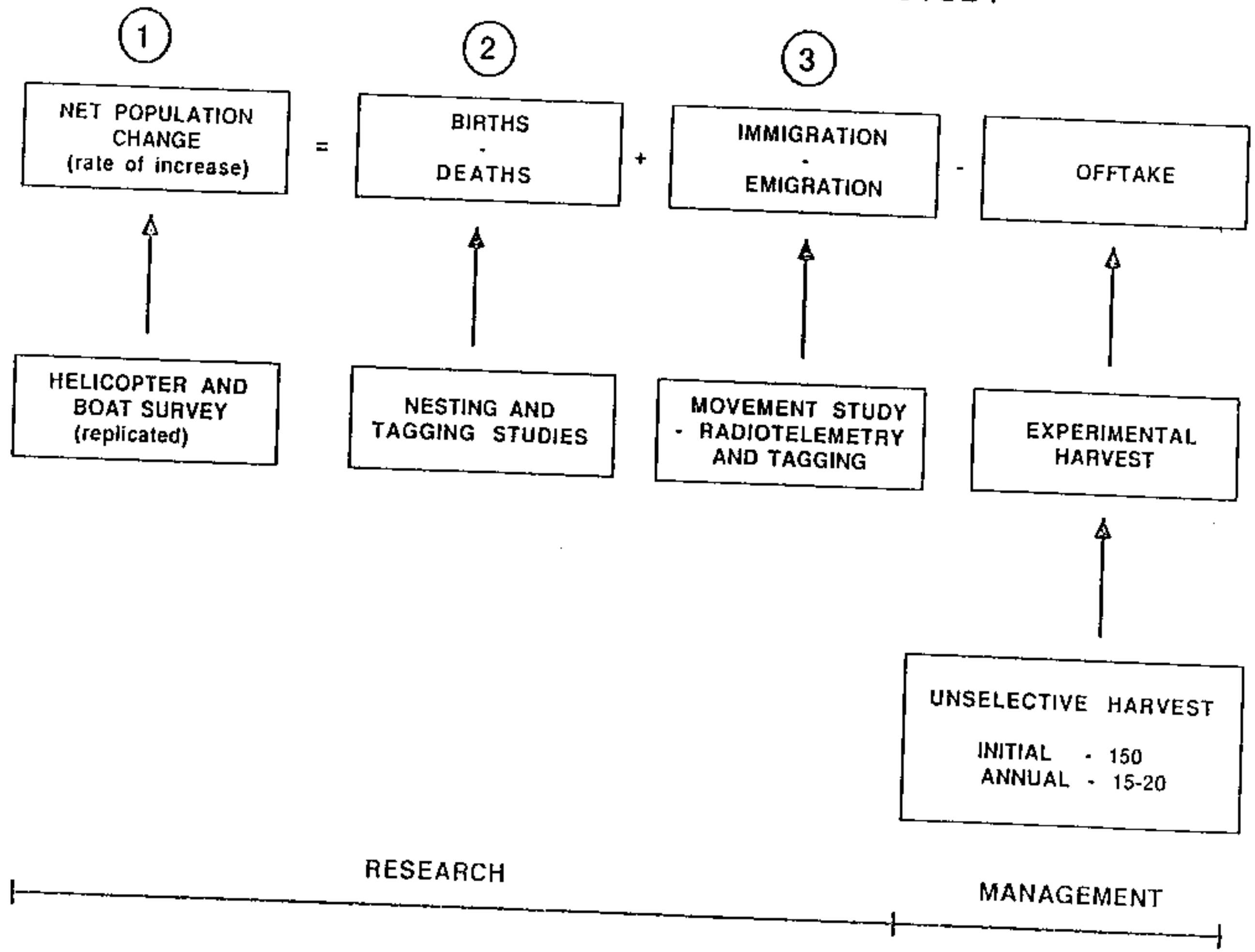


FIGURE 5.1 COMPONENTS OF THE STUDY



NATAL PARKS BOARD POLICY ON CROCODILIANS

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1 BACKGROUND

It is generally accepted that the crocodile is:

a) a key component in many aquatic ecosystems;

b) a valuable natural asset as a source of high grade leather, if wisely exploited;

c) a valuable tourist attraction, and is of immense scientific interest as the only surviving member of the long extinct Archosaurian group of reptiles.

It can be a problem animal and (under certain circumstances) conflicts with genuine human interests but is vulnerable and comparatively scarce in parts of Natal (and elsewhere in Africa) due to past over-hunting and the modification of its essential habitats.

Natal still has large populations, the conservation of which is sensible, practical and profitable, provided that the resource is afforded adequate protection leading to proper scientific management.

2 NATAL GENERAL

2.1 Crocodiles will be protected throughout Natal with a view to nurturing optimum populations commensurate with the availability of suitable habitats. This protection will ensure that significant breeding sites are protected against undue human disturbance. In most recreational areas, crocodiles will be tolerated only in so far as their presence is compatible with the recreational activities permitted in the area.

2.2 Problem crocodiles in serious conflict with legitimate human interests will only be destroyed where it is not possible to capture and relocate them elsewhere. Mature crocodiles, and more especially large individuals, represent a considerable biological investment and their destruction under any circumstances will be discouraged. Where they become problem animals every effort will be made to capture them.

2.3 The conservation of wild populations will be encouraged throughout Natal, where appropriate, but where necessary or desirable the exploitation of any significant wild populations in any waters in Natal will be regulated. These measures will apply especially to those waters having crocodile populations which are shared on a year round basis by one or more properties or land classes.

3 NATAL PARKS BOARD GENERAL

3.1 Crocodiles will be conserved in all appropriate Natal Parks Board areas and on all land and in any water for which the Board is directly responsible for the control of the wildlife as a resource. Conservation of wild populations as applied in this section shall be directed towards their long term survival and utilisation.

3.2 The Board shall appoint an Officer to see to the conservation and management of crocodiles in Natal and the development of a viable crocodile industry.

3.3 The Natal Parks Board will strive to educate the public as to the biological and economic value of crocodiles and in so doing, aim to counteract the stigma the crocodile has in the mind of the public.

3.4 The Board will comply with international criteria suggested for the conservation and management of crocodiles where this does not conflict with specific local requirements and see to it that these standards are not lowered by other internationally interested parties. It will consider applications from appropriate foreign government agencies in Africa who require Nile crocodiles for restocking depleted areas of the species' former range.

3.5 As a management authority under the CITES Convention the Board will implement CITES regulations relating to crocodiles.

4 UTILISATION AND HUNTING

4.1 The Board will not authorise the harvesting of wild crocodiles in Board areas unless they are satisfied that such removals are necessary for sound management purposes.

4.2 Any harvesting of wild laid eggs will be strictly controlled and in accordance with the criteria laid down in section 4.3.

4.3 The harvesting of wild eggs in any area will be only by permit issued by the Director in relation to a pre-determined quota or quotas for any given season(s).

4.4 The hunting of crocodiles for recreational purposes will not be permitted in Board areas, except in areas zoned for controlled hunting.

5 RESEARCH AND MONITORING

Research on crocodiles will be according to the overall research policy of the Board. In addition to monitoring wild populations and investigating the species' biology, it will monitor the production, processing and marketing of the crocodile industry.

6 COMMERCIAL CROCODILE FARMING

6.1 Commercial crocodile farms will be encouraged, but their number will be limited where their activities are dependent upon the tourist trade.

6.2 The Board will lay down regulations for the establishment and running of commercial crocodile farms. Such commercial crocodile farms will operate by permit issued by the Director which will be subject to conditions as laid down by the Board from time to time. Such farms will be required to:

6.2.1 provide the Board with such information and statistics o their operations as it may require;

6.2.2 participate in the interpretation of the value of crocodiles and of appropriate aspects of their biology to the general public.

7 PROBLEM CROCODILES

Any problem crocodile captured or destroyed will be dealt with as follows:

7.1 crocodiles captured by Board personnel, if not required for restocking by the Board, will be offered for sale to commercial crocodile farmers;

7.2 crocodiles destroyed by the Board personnel will be disposed of at the discretion of the Director subject to Section 10.2;

7.3 the Director may issue permits for the capture or destruction of crocodiles where they are a threat to human life and/or stock and Board personnel are unable to deal with the situation;

7.4 crocodiles destroyed or captured without a permit because they were a threat to human life and/or stock, must be surrendered to the Board;

7.5 all such crocodiles will be disposed of as in Section 8, or in the case of destroyed crocodiles at the discretion of the Director subject to Section 10.2.

8. DISPOSAL OF NILE CROCODILES

Nile crocodiles from the Board areas, either wild or reared, when available for restocking or sale will be disposed of in the following ways:

8.1 stocking areas under the Board's control;

8.2 disposal to other nature conservation organisations in South Africa;

8.3 purchase by the Natal crocodile farmers subject to the criteria laid down in Section 10.1;

8.4 purchase by crocodile farmers and other agencies outside Natal subject to the criteria laid down in Section 10.1;

8.5 supply to other formal conservation authorities in Africa for restocking purposes as laid down in Section 3.4;

8.6 by such other means as the Board may decide.

9 INTERNATIONAL BREEDING BANK - NON-INDIGENOUS SPECIES

9.1 The Board will offer facilities or facilitate the rearing of other crocodilian species in captivity, with a view to safeguarding them from extinction.

9.2 In the case of hatchlings being available from the breeding bank already established at the St Lucia Crocodile Centre, they will be held or disposed of as follows:

9.2.1 suitable numbers to be held for breeding and display at the St Lucia Crocodile Centre;

9.2.2 supply to other formal conservation authorities in Africa for restocking purposes;

9.2.3 sold to other agencies or crocodile farms within Africa;

9.2.4 offered in exchange for other species that the Board may consider holding for exhibit or breeding purposes.

10 RETENTION OF CROCODILES OR CROCODILE SKINS

10.1 Subject to 8.6 live Nile crocodiles will only be made available for retention in captivity when the Board is satisfied that the ultimate recipient is capable of caring for the animals both under proper scientifically and aesthetically acceptable conditions.

10.2 Permits for export or retention of crocodile skins will only be issued to persons who are managing and conserving the resources, who are registered with the Board and with whose operations the Board is satisfied, or to persons who have acquired skins from registered crocodile producers, or to persons who have acquired skins from the Board, or to licenced trophy hunters.

(Original compiled by Warden, St Lucia Crocodile Centre, August 1987).

CROCODILES HELD AS PART OF THE INTERNATIONAL BREEDING BANK

David K. Blake, c/o Natal Parks Board Crocodile Centre, St. Lucia 3936 Natal, South Africa.

1. Dwarf Crocodiles - Osteolaemus t. tetraspis

Since the establishment of the breeding bank at St Lucia Crocodile Centre in 1975 the holding was reduced to two males by 1984.

In 1985 one male was placed on indefinite loan to the Port Elizabeth Museum as they held a mature female. From this female, a clutch of eggs was obtained in 1986 which were unsuccessfully incubated. In 1987 19 eggs were obtained but only two hatched. It has since been established that this was due to the fact that the female was removed from the male when she was considered gravid, with the result that most of her eggs were not fertilised.

In June 1988 two female Dwarf crocodiles were obtained from a commercial crocodile farm (Crocworld) in exchange for two female Nile crocodiles.

These females, each c. 1,2m in length, were introduced to the male, c.1,7m in length. The male promptly attacked both females and after one day they had to be separated. Unfortunately the smaller female died as a result of her injuries. The remaining female is being held in an adjacent pen until it is considered the male will accept her.

2. Long Snouted Crocodiles - Crocodylus cataphractus

The holding is currently two adult males, one adult female and six two year olds. The female and one male are kept as a pair in one pen with the other male in the adjacent pen to allow stimulation between the males.

Unfortunately since 1975 only one laying has taken place. This was in the 1985/86 season. From this laying 11 hatchlings were obtained. In early 1987 four hatchlings succumbed to food poisoning and one to other causes. The remaining six are doing well and after the current winter will be moved to an external pen.

In order to stimulate laying, the main holding pen will be concrete lined to give a permanently deep pond (current droughts have meant a severe drop in the water table and the ponds being reduced to puddles), as well as spray systems to simulate rain during drought periods.

3. General

While the breeding bank has only had limited success to date, it is hoped improved holding pens will induce successful breeding.

In April 1988 the holding pens were included in the public area and have proved an interesting draw card, most public being unaware of other species of crocodiles in Africa. The crocodiles would appear to be unaffected by this move and it should not affect their breeding capability.

STATUS OF THE NILE CROCODILE IN NATAL, SOUTH AFRICA - AUGUST 1988

David K. Blake, c/o Natal Parks Board Crocodile Centre,
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1. Taxonomy

1.1. CLASS - Reptilia
1.2. ORDER - Crocodylia
1.3. FAMILY - Crocodylidae
1.4. SPECIES - Crocodylus niloticus laurenti 1768
1.5. COMMON NAME - Nile Crocodile

2. Status

2.1. Vulnerable

2.2. Threat to Survival

The main threat to survival of the Nile Crocodile within Natal is competition with human interests. These take the form of a growing human population whose land use and raising of domestic stock preclude crocodiles being tolerated in waters in their areas. Other threats to their survival are recreational usage of waters as well as commercial fishing.

Poaching would also appear to be a bigger threat to crocodiles in Natal than was considered in the past. There is evidence of organised poaching for trade in crocodile products for use by n'Dangas (tribal doctors) rather than in skin. This trade is being actively investigated by the Natal Parks Board's Investigation Branch and it is hoped to break it in the near future. The demands of n'Dangas can be met by supplies from commercial crocodile farms.

2.3. Survival

Outside the main areas of Natal such as Ndumu Game Reserve and Lake St Lucia where it is afforded full protection, its chances of survival are minimal.

3. Distribution

Sparsely distributed throughout north-eastern Natal from the Mocambique border in the north to the Tugela River in the south. Odd individuals may occur further west and south, especially during the summer rains when they tend to move over flooded coastal areas and up flooded rivers.

4. Population

Crocodiles are widely scattered throughout northern Natal. An accurate estimate of the population is difficult. The major populations occur in the Ndumu Game Reserve and in the Lake St Lucia System.

In an attempt to estimate the population, annual aerial counts have been made over a number of years. A number of factors influence counts. In the case of St Lucia the major problem is the distribution of freshwater in pans around the lake, to which crocodiles move as the salinity of the lake increases, making aerial counts difficult.

Counts for various areas of Natal are reflected under Appendix A. From these counts the estimated population of crocodiles in Natal is circa 4 000. This estimate is based on the fact that most crocodiles counted from the air are 2 metres or more in length and that there is an equivalent juvenile population. This is based on the highest counts achieved to date. From 1988 night counts have been introduced which will be used to correlate aerial counts.

5. Commercial Use of Wild Populations

There is no official commercial use of wild populations except for the odd problem crocodile which is captured and sold to crocodile farmers. As stated, there is a trade in crocodile products for medicinal purposes from poaching. It is hoped to put a stop to this poaching and legitimze the trade in products with supplies from commercial farms.

A proposal does lie before the Natal Parks Board for the collection of eggs from the St Lucia System. This proposal is based on the rational use of a resource that is annually wasted due to non-hatching of eggs or predation and/or destruction of hatchlings, large numbers being washed out to sea. The loss to recruitment by removal of eggs could be replaced by rearing a percentage of hatchlings for restocking purposes if considered necessary.

6. Crocodile Farming

There are currently six commercial crocodile farmers in Natal plus the St Lucia Crocodile Centre. These farmers operate independently from the crocodile population within Natal, stock having been obtained in the main from Zimbabwe and Botswana. The odd problem crocodile is sold to them by the Natal Parks Board as well as hatchlings reared by the Natal Parks Board at the St Lucia Crocodile Centre. The farms and their stock holdings are shown under Appendix B.

7. Conservation Measures

While crocodiles are protected throughout Natal, growing human interests are a constant threat. Unless specific conservation measures are taken and crocodiles are shown to have a commercial value, they face extinction outside the main reserves.

8. Policy

A new policy in respect of crocodiles has been drawn up for and accepted by the Natal Parks Board. This policy has been brought into force in 1988 and should lead to the conservation of the crocodile within those areas controlled by the Natal Parks Board. It is hoped that the Kwazulu Government will accept the policy in respect of the crocodiles falling under their protection.

The policy covers all aspects of wild populations as well as commercial crocodile farms. It also covers aspects of utilisation of wild populations, although such aspects may never be introduced.

APPENDIX A

CROCODILE COUNTS IN NATAL 1985 - 1988

AREA	1985	1986	1987	1988	ESTIMATED
St Lucia Lake	546	286[a]	851	579	1 700
Ndumu Game Reserve	515	503	296[b]	-[c]	1 000
Umfolozi Rivers	99	128	119	-[d]	200
Hluhluwe River	37	33	41	-[d]	60
Mzingazi Lake	-	1	6	6	20
Other areas - Estimate only - Not counted.					1 000
				TOTAL	3 980

a) Count Eastern Shores only.
b) Count combined with hippo count - not accurate.
c) Reserve now in hands of Kwazulu Government.
d) Count still to be done for 1988.

APPENDIX B

NATAL CROCODILE FARMS - 1988

Name of Farm	Date Established	Breeding Stock		Rearing Stock			Hatchlings	Totals	Owners
		Male	Female	Male	Female	Not Sexed			
Stewarts Farm	1981	7	31	-	-	65	318	421	G. Stewart
River Bend	1981	20	88	-	-	34	350	492	Mrs S. Kelly & Mr Kennet
Crocodile Creek	1983	4	70	-	-	138	34	246	Mr & Mrs P. Watson
Crocworld	1984	12	66	-	-	1652	1807	3537+	Crookes Bros Ltd
Shongweni Crocodile Farm (PTY) Ltd	1986	4	21	-	-	14	10	49	R.O. Bristow
Assagay Safari Park	1988	12	18	11	7	190	140	378	A. Wilmans
SUB-TOTALS		59	294	11	7	2093	2659	5123	
St Lucia Crocodile Centre	1975	2	15	-	-	46	74	137+	Natal Parks Board
TOTALS		61	309	11	7	2139	2733	5260	

+Nile Crocodiles only.

THE ROLE OF CROCODILE RANCHING IN RURAL DEVELOPMENT

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As might be expected, where funding for crocodile projects has been made available through the Food and Agriculture Organization of the United Nations the long term objective has been to improve the welfare of people in the Third World. This may also apply to funding under some bilateral agreements and it is significant in that it tends to place project operations in a different perspective than might be the case if one were working with a narrower, purely scientific objective. This paper pulls together some thoughts on ranching the present commercial species and its role in rural development in the Third World.

The Papua New Guinea Experience

It is nearly twenty years since the idea of crocodile ranching was first taken seriously in PNG (Downes, 1971). By the early 1970s Government extension workers were assisting villagers to set up simple pens and pools and were distributing booklets on how to rear crocodiles for the value of their skins. It was hoped that the benefits of the new policy would be threefold: the status of the resource would improve, earnings from the industry would increase and there might be social benefits in countering the urban drift from villages that could provide little or no paid employment of any other sort. The scheme attracted much interest in Papua New Guinea and overseas.

The reasons why things did not work out entirely according to plan have been quite well documented (Bolton, 1981, Bolton & Laufa, 1982, Hollands, 1987) and it is now generally known that we had to shift the emphasis of the plan so as to give large commercial farms a more central role. This led to the present situation in which the majority of villagers choose to sell young crocodiles shortly after capture and most of the rearing is carried out in two large holdings which use poultry offal as crocodile food. This is a successful arrangement insofar as the villagers earn much more money with less impact on the crocodile populations and the resource itself is evidently in far better shape than it was in the mid 1970s (Hollands, 1987). The various trade controls have been described by Hollands (1987) but it may be mentioned here that the size restrictions were introduced only after the villagers had seen for themselves that the legislation would be in their own interests.

The question that now arises is whether the New Guinea model can or should be copied overseas. To answer this it will be useful to consider what might have been done in PNG if there had been no large poultry farms because that is the case in several African and Asian countries where crocodile ranching is being considered. It is also true in other parts of the South Pacific and it is still common to hear people express the belief that crocodiles are best reared by many people each keeping a small number of crocodiles which will be easy to feed. So, with hindsight, it is worth taking another look at the reasons why small village pens were generally not successful in PNG.

The Limitations of Village Farms

Apart from human and social factors there were difficulties in providing all three of the basic requirements of the crocodiles themselves - water, warmth and food. In some circumstances it can be quite impracticable to keep water in earth pools with only small manual pumps. On parts of the Sepik, for example, water levels commonly fluctuate by up to ten metres and the soil is porous. Plastic liners, old dugout canoes and sawn-off oil drums were all tried but the limitations are obvious. The problem is compounded by low temperatures even in the South Pacific. Small volumes of water are usually at ambient temperature by the early hours of the morning and this can be 7°C or more below the temperature of the large water bodies where wild crocodiles spend the night. This almost certainly contributed to the incidence of disease. Where deeper pools can be provided they will hold heat for longer but large water volumes present other management problems if the scale of operations is not proportional to the work and cost of maintaining the water.

The ideal, from a cost-benefit point of view, would seem to be to heat the pools at night and allow them to warm in the sun during the day. This can be arranged with a combination of a solar heating system and a well-ventilated greenhouse arrangement but a back-up system with electricity would be an obvious advantage for cold, wet days and it is difficult to see how any of this could be simply and cheaply set up in remote villages.

This is not to suggest that everything else was tried. In some situations, for instance, both water and temperature problems might have been solved with some sort of floating cage arrangement in lakes or backwaters but innovations need to be developed and tested before the needs become pressing. There is still scope for experimental work at this basic level. To take an extreme example; it was recently reported that two young C. porosus more than doubled their weight in three months without access to any water at all. They were kept in a deep rubbish pit with a concrete slab cover. It was constantly warm and humid and was swarming with cockroaches - which the crocodiles presumably lived on. (Mc.Queen, 1988. Pers. comm.). While this may have no practical application at all it does show that conditions for successful rearing might be reached from entirely different starting points.

Ultimately, given that water and temperatures are at least adequate and that stock is available, the scale of operations will be determined by food supply. And, unless there is a nutritional breakthrough, this means a supply of high quality protein. We know that proteins are species specific and hatchlings do seem to make rapid growth on invertebrate diets such as cockroaches and prawns but vertebrate meat generally has to be used. The possibilities can be listed under four categories:

- fishing or hunting primarily for crocodile food
- breeding fish or other animals primarily for crocodile food
- collecting waste from abattoirs, canneries, hunting or

other onshore activities

- collecting waste from offshore

In Papua New Guinea it was expected that most farms would be sustained by the first option - fishing. Fish are abundant in the crocodile habitats of PNG and often the catches are surplus to the needs of the people. The problem is that fishing is not consistent and there are times when it is impossible to use nets. Inconsistency is a familiar feature of fishing everywhere and in many countries there are never any fish surplus to human needs. Hunting for crocodile food is even less likely to be successful and in at least one instance has actually threatened another wildlife resource.

It is sometimes suggested that fish or other animals, such as guinea pigs, be bred to feed crocodiles but the economics seem to get overlooked. If one is able to produce high quality protein then it usually makes more sense to produce a saleable meat so that feeding crocodiles becomes a secondary concern. One proposal that was put forward for external aid was to breed quail for crocodile food!

Using waste from an existing source is ideal but in the absence of poultry farms supplies of waste protein are generally scarce. The biggest abattoirs and canneries are likely to have a blood and bone or fish meal plant and the investment inevitably puts a price on any alternative use for the waste. The smaller, rural slaughterhouses often have an irregular or even seasonal output and there is very little meat from a cow or a pig that can not be sold for human consumption. In PNG, compared with much of Africa and Asia, there is no shortage of protein but even here lungs, spleens and stomachs can be sold at the slaughterhouse door for more than it would be wise to pay for crocodile food. An exception is the blood, which usually runs to waste. Blood, coagulated with lime, is well known as a good food for pigs, but, to the author's knowledge, it is not being used for rearing crocodiles.

The final possibility, collecting fish waste from offshore, has enormous potential but in PNG it proved surprisingly difficult to realise. Prawn trawlers operating in the Papuan Gulf commonly take two to four tonnes of fish as by-catch for every tonne of prawns. For economic reasons the trawlers can not bring this ashore as crocodile food so it would have to be collected from the trawlers at sea. It was estimated that this would be worth doing for a big crocodile farm located near the harbour but there would be a two month offseason and a disturbing number of things that could go wrong. In Asia trash fish may be easier to recover but it may not be regarded as trash. There are certainly parts of Asia where fishermen with cast-nets will work all day for a catch that would be treated as rubbish in PNG.

The recovery of fish by-catch from offshore might have supported a large, centralised rearing scheme such as is presently based on poultry farms but it would not have helped to rear crocodiles in scattered village holdings.

The Advantages of Centralised Rearing

Centralised rearing has very clear advantages and if food is conveniently located near a town the advantages multiply. There is likely to be electricity, skilled labour, lower construction costs, technical expertise and altogether easier circumstances for running a business. Moreover current research on crocodile husbandry is likely to increase the benefits of sophistication through techniques such as controlled incubation, sex determination and possibly hormone treatments. As well, there may be opportunities to make money from tourists and from the sale of meat that the health authorities can approve. It is also easier to see that crocodiles are kept and killed humanely in a small number of large farms.

In summary, to answer the question: should the PNG model of ranching be copied overseas? the answer seems to be a clear 'yes' but one should not be too optimistic. To answer the question: what would we have done in the absence of poultry farms? we should probably have tried to exploit the offshore fish potential. Failing that we should have had to fall back on a careful selection of smaller possibilities, perhaps combining some of the food sources such as abattoir blood with fish as available, but there would have been far fewer crocodiles in captivity and it may have been impossible to persuade villagers to accept some of the present legislation, notably the size restrictions. There are implications here for crocodile conservation and for CITES.

Ranching and Conservation

The laws of land tenure and legal rights with regard to wildlife vary from 90% traditional ownership in the South Pacific to almost total state control in some African and Asian countries. But in most cases it is probably true to say that crocodile survival depends mainly on the people who share the remaining habitat. International trade restrictions do not soften their attitudes to crocodiles. There have been some impressive, even spectacular, recoveries of crocodile populations since it became unprofitable to hunt for skins (the Rift Valley lakes of Ethiopia are a notable example) but crocodiles and habitat in other places are dwindling largely because people are not prepared to tolerate them. Some people eat the eggs or meat while others just regard crocodiles as worthless, dangerous vermin. In such cases a positive incentive to value the resource might be a more effective conservation measure than preventing the export of skins. Ranching can provide that incentive if the expectations are realistic but it should be recognised that the models have been established by countries that have particularly favourable circumstances.

The International Response

Three years ago Indonesia and a number of African countries were able to downlist their crocodile populations subject to an annual quota being agreed under Resolution Conf. 5.21. This, in effect, recognised that there was at least a prima facie case for permitting a limited trade. But the procedure laid down by Resolution Conf. 5.21 is widely regarded as a provisional or temporary measure and the earlier criteria (Resolution Conf. 3.15) are still held as the standard and the ultimate goal. This is a fine ideal; if only it can be achieved. The submissions from Zimbabwe and Australia were based on years of survey work and involved funds, resources and expertise which are just not available in most Third World countries. And where food supplies are also limiting and will not support a large, organized rearing scheme then ranching is likely to consist of a collection of small enterprises based on whatever sort of food happens to be locally available. In terms of a national or even provincial economy it may never be significant. The value of this level of ranching lies in the fact that a lagoon, a lake or a stretch of river might be managed as a crocodile sanctuary as long as it is worth it to the locals. Of course, only governments can ensure that village people get a fair deal but international opportunities can at least make this possible.

There is a final option that some countries might wish to consider in order to overcome feed constraints and that is to extend the centralised rearing system beyond national boundaries by exporting hatchlings. There are willing buyers in industrialised countries with a big capacity for rearing crocodiles. If this sort of trade becomes prevalent it could be more difficult to regulate than small-scale ranching for skins under a quota system and if it were to result in a significant supply of captive bred animals then it could even be counter-productive in terms of conserving the wild animal in its natural environment. It seems reasonable to conclude that ranching can play a part both in rural development and crocodile conservation but in some cases it may have to be quite a small part. Making the most of the opportunities will require very detailed proposals from the countries concerned and specific, finely-tuned responses from international conservation bodies. Quotas, troublesome as they are, appear to be unavoidable as long as small ranching operations are part of the conservation scene.

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A SUMMARY REPORT OF THE CITES CENTRAL SOUTH AMERICA CAIMAN STUDY: PHASE I : BRAZIL.

17 June 1987 to 30 November 1987

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30 November 1989

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INTRODUCTION

The crocodilians of Brazil have long been the subject of considerable scientific and commercial interest. These include the black caiman *Melanosuchus niger*, the common caiman *Caiman sclerops sclerops*, the yacare caiman *Caiman yacare*, the broad-nosed caiman *Caiman latirostris*, the dwarf caiman *Paleosuchus palpebrosus* and the smooth-fronted caiman *Paleosuchus trigonatus*. The black caiman and broad-snouted caiman are listed under Appendix I of CITES and as Endangered Species under the United States Endangered Species Act. While the yacare caiman is listed under Appendix II of CITES, it is also listed as an endangered species under the U.S. Endangered Species Act.

With the exception of *Paleosuchus*, all of the Brazilian caiman have historically been utilized by the exotic reptile leather industry. Today, the common caiman and the yacare caiman are the mainstay of the crocodilian skin industry. Large numbers of caiman skins, estimated at perhaps up to a million a year, particularly those of *Caiman yacare*, continue to be taken from Brazil in violation of national wildlife regulations. The commercial hunting of all wildlife in Brazil has been banned since 3 January 1967 under Law No. 5917.

Under the CITES Central South America Caiman Study, field studies (Phase I - Brazil) commenced in June 1987. The field team included Peter Brazaitis (International Coordinator), George Rebelo of the Instituto Nacional de Pesquisas da Amazonia (INPA), and Carlos Yamashita of the Instituto Brasileiro de Desenvolvimento Floristal (IBDF) who also acted as Country Coordinator. Field operations under Phase I were completed on 18 November 1987. The team continues investigations in the eastern and northern regions at the present time under the sponsorship of World Wildlife Fund/Traffic U.S.A.

METHODS

Over 5,250 km were covered during the survey (Figure 1.) in the states of Acre, Amazonia, Goias, Rondonia, Mato Grosso and Mato Grosso do Sul. Nine main river systems, 20 tributaries, and associated wetlands were surveyed, including 49 localities more than 50 km apart. Surveys were conducted by boat at night, utilizing headlamps and high intensity spotlights, as well as by truck and by foot during the day and at night.

The team made every effort to complement and continue surveys by the Bolivian and Paraguayan field teams, as well as previous surveys conducted by Federico Medem (1983). Localities within suggested caiman habitats were selected from the literature, past experience of the field team, and aerial and land maps. Sites on the upper and lower reaches of main rivers as well as sites in between were visited, as well as associated lowland areas. For comparative purposes, sites suggesting poor caiman habitat were also surveyed. Numbers and species identities of crocodilians, size classes, sex, preferred habitat characteristics and general ecological information were noted. Time limitations precluded the making of definitive population estimates, but every effort was made to observe relative population densities between sites. Specific transects were conducted in typical habitat situations in each region. Travel was planned to maximize the visitation of sites during comparable environmental and climatic conditions.

The team encountered an estimated 15,000 to 25,000 caiman, representing all of the endemic species, during the survey. Over 1,500 skin and blood samples were collected for biochemical systematics studies. Caimans are regularly consumed by local peoples and extensively consumed by workers in gold mining opererations. These sources provided additional study materials such as tissue, stomach contents, parasites, gonads, and internal organs for pathology studies. All animals were photographed in the field and morphological data were recorded.

For purposes of this report, the taxonomic structure follows Medem (1983).

RESULTS

POPULATION:

Tables I indicates the population densities, total numbers of animals, and numbers of animals per kilometer surveyed in 11 regions.

Population densities ranged from .34 animals per kilometer in the state of acre to 30 animals per km. on the Rio Sepotuba in the state of Mato Grosso. On the surface it may appear that populations of yacare caiman are extraordinarily high along the Transpantaneira in the region of Pocone in the state of Mato Grosso, often reported as the highest concentrations in the Pantanal. Crawshaw and Schaller reported about 200 animals per km in 1982; Brazaitis, Cintra and Yamashita observed 6 animals per km in 1985; this team surveyed 17.1 animals per km in 1987. At the time of the latest survey water levels were at the lowest, animal concentrations were at their highest, and ponds surveyed represented the only major water sources in the surrounding region.

Table II indicates the total numbers of animals and size classes for 14 localities where transects were conducted.

By and large, most individuals encountered were in the 90 cm to 1.5 m size range.

Figure 2. indicates the size class composition for an example river population observed in Rondonia and Figure 3. indicates the dry season pool population observed near Pocone.

Table III indicates the sex ratio of animals captured in 13 localities during the survey.

Caiman populations are generally depleted in Acre and regions in Rondonia. Yacare caiman populations have declined in many regions and are at least stable in others. The species can be found in varying population densities in most areas where suitable habitat exists. Small average size, extreme wariness, and large numbers of males might be indicators suggesting that caiman populations have been seriously abused with emphasis on the taking of females at a time when they are most vulnerable.

Black caiman populations within the study area indicated the species to be seriously depleted. However, the study area lies largely in the southern limits of the range of the species. The main range of the species in Brazil is presently targeted for study.

Broad-snouted caiman populations are also depleted throughout the study area, and are under hunting pressure as a source of food. Much of the species range in Brazil has yet to be surveyed.

DISTRIBUTION:

Figure 4. indicates the present distribution of yacare caiman Caiman yacare in Brazil (vertical lines). Spotted area indicates the reported distribution of common caiman Caiman s. sclerops. We noted in the field a probable zone of integration between the common caiman and yacare caiman in a zone which loosely follows the Bolivia/Brazil border in the north, eastward through Acre and north to Amazonia along the Rio Madeira and Rio Abuna in Rondonia, based on jaw patterns and general morphology.

Caiman yacare is found in southwestern Brazil from the Rio Abuna in Acre and the Rio Madeira in Rondonia, southward through western state of Mato Grosso and Mato Grosso do Sul to the Paraguayan border. The northern limits of the species lies approximately 150 km north of the northern border of Bolivia and Brazil.

Caiman s. sclerops is largely restricted to the drainages of the Amazon river system in the study area.

Figure 5. indicates the direction of river flows which may help account for the present distribution of Caiman s. sclerops and Caiman yacare in Brazil.

Melanosuchus niger is also restricted to the Amazon river drainages in the study area, with the southern limit of the range placed at Pontes Lacerda in the state of Mato Grosso. The eastern limit appears to be the Rio Tocantins as far south as Peixe in the state of Goias.

Distributions for other endemic species will be given at the conclusion of field studies in northern regions. However, Paleosuchus is not endemic to the Pantanal proper.

SYSTEMATICS AND MORPHOLOGY:

Figure 6. and 7. indicate the gradation in jaw patterns and skull shape of Caiman yacare and Caiman s. sclerops in Brazil, in the study area. Also indicated by the dotted line in the vicinity of Pocone and Cuiaba is the line of demarcation suggested for Caiman c. matogrossiensis and Caiman c. crocodilus by Fuchs (1971, 1974) and Wermuth and Fuchs (1978). We also surveyed the region of southern Mato Grosso do Sul where Caiman c. yacare and Caiman c. matogrossiensis are said to overlap in distribution. This

team could not find any gross morphological evidence, environmental or ecological conditions, or geological basis to support Fuchs' (1971, 1974) Caiman crocodilus subspecific designations for caiman endemic to Brazil. In fact, most of the demarcation regions are under common levels of water during much of the wet season each year. Biochemical assays of tissue samples from these regions and examination of all of the study materials from the three countries under survey may further clarify these questions.

HABITAT AND ECOLOGY:

It is estimated that the entire range of yacare caiman in Brazil occupies approximately 500,000 square km., of which about 175,000 are composed of Pantanal, a preferred habitat.

Both common caiman and yacare caiman inhabit a wide variety of habitats and are quick to occupy man-made habitats. We found b2oth in vegetated and non-vegetated large open rivers, secondary rivers and streams, flooded lowland and forests, roadside ditches and canals, ox-bows, large and small lakes and ponds, cattle ponds and streams. Pantanal appears to be the preferred habitat. Either species may be found sympatrically with black caiman and Paleosuchus. They are generally not found at elevations above 600 m.

Black caiman appears to prefer large open slow moving rivers and ox-bow lakes with peripheral vegetation. We found the species in waters with a pH as low as 4.5.

While Paleosuchus trigonatus was largely an inhabitant of black water streams, we did find the species in roadside ponds and white water rivers in regions where black water and forest streams were common. Paleosuchus palpebrosus appeared to occupy large and small open rivers, often in the same localities as Caiman.

HUNTING AND ENVIRONMENTAL PRESSURES:

Illegal hunting in south central Brazil is well organized, well funded, and widespread.

Habitat loss is rapidly ongoing as well as pressures from increasing human populations.

Figure 8. indicates regions of intensive gold mining where large quantities of mercury are being dumped into river systems in increasing amounts.

CONSERVATION and MANAGEMENT:

IBDF, INPA, EMBRAPA, FUNDAPAN, SODEPAN, private landowners, state and local governments all are cognisant of the present threat to Brazil's caiman populations and are striving to develop a comprehensive plan for the management and conservation of crocodilians. To date, no comprehensive plan has been developed nor is in place. This team,in collaboration with private interests and conservation organizations in Brazil, and WWF/Traffic U.S.A., is assisting all agencies and parties in developing a comprehensive management and conservation plan. That plan includes the protection and management of the wild populations, controlled utilization through captive husbandry programs, and the development of a comprehensive industry within Brazil to maximize benefits from the utilization of the caiman wildlife natural resource for the people of Brazil.

Phase I studies continued in the Amazonian regions in Brazil where the main populations of Brazil's endangered species of crocodilians occurs, commencing in December 1988. This team wishes to emphasis that any conservation and mangement program for the utilization of caiman in Brazil must include and be based on data generated from studies yet to be completed in northern Brazil in conjunction with data from studies completed to date, and the biochemical systematics studies now ongoing. While the present surveys are largely cursory, and are not meant to be definitive unto themselves, they do serve to target species and areas of concern and scientific interest for more comprehensive and definitive research.

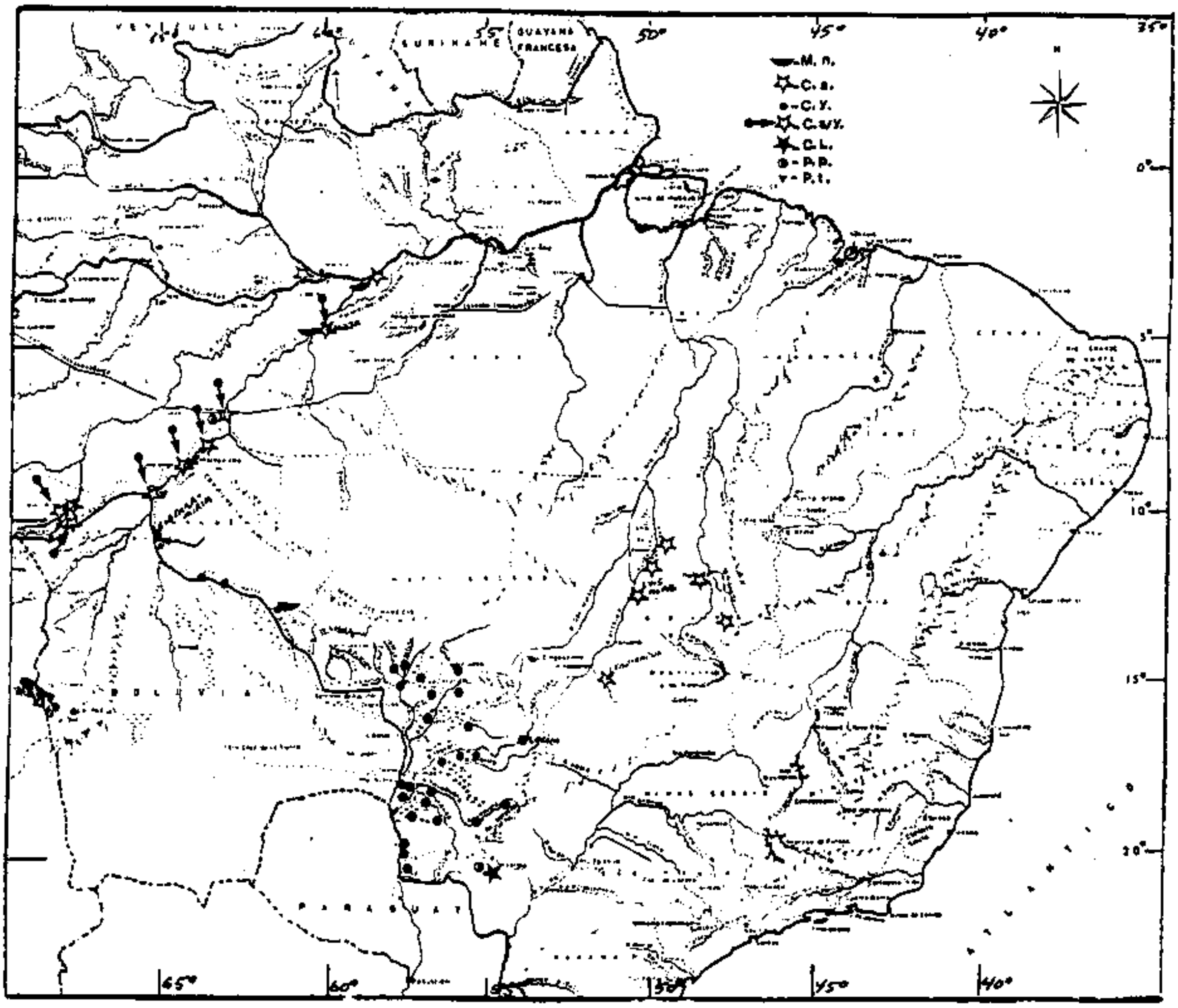


Figure 1. Shows all data and sample localities for Phase I surveys. The map is adapted from Medem, 1983.
Legend: M.n. = Melanosuchus niger, C.s. = Caiman sclerops, C.y. = Caiman yacare, C.s./y. = Caiman sclerops/C. yacare, C.l. = Caiman latirostris, P.p. = Pleosuchus palpebrosus, P.t. = Paleosuchus trigonatus

STATE	REGION	HABITAT	KM/TRNSCT.	C. yac.	CAIM./KM	PAL.	PAL./KM	M.niger	M.n./KM	UNIDEN.	TOT. ANIM.	TOTAL/KM
A-ACRE	BRASILEA/RIO BRANCO	RIVER/PONDS/VEGET.	75	24	.32	1	.013	NM	-	-	25	.34
B-RONDONIA	ABUNA/HUMAITA	RIVER/PONDS/VEGET.	500	85	.17	9	.018	-	-	-	94	.18
C-RONDONIA	GUAJARA MIRIM	RIVER/VEGET.	15	12	.80	24	1.60	REPORTED	-	6	42	2.80
D-MATO GROSSO	RIO CABACAL	RIVER/VEGET.	2	7	3.50	-	-	-	-	10	17	8.50
E-MATO GROSSO	RIO PARAGUAY	RIVER/VEGET.	4	20	5.00	2	.50	-	-	-	22	5.50
F-MATO GROSSO	RIO SEPOTUBA	RIVER/VEGET.	2	20	10.0	3	1.50	-	-	37	60	30.00
G-MATO GROSSO	RIO GALERA	RIVER/OXBOWS/VEGET.	3.5	9	2.57	-	-	7	2.0	9	25	7.14
H-MATO GROSSO	POCONE/TRANSPANTANEIRA	PANTANAL/RIVERBED/PONDS/VEGET.	107	1830	17.10	OR	-	OR	-	-	1830	17.10
I-MATO GROSSO do SUL	JACADIGO	LARGE LAKE/SHORE/VEGET.	5	48	9.6	-	-	OR	-	-	48	9.60
M-MATO GROSSO do SUL	CORIM	RIVER/VEGET.	6	24	4.0	-	-	OR	-	-	24	4.00
N-MATO GROSSO do SUL	RIO NEGRO	RIVERSIDE/PONDS/VEGET.	40	69	1.72	-	-	OR	-	-	69	1.72

Table I. Indicates the population densities for Caiman sclerops/Caiman yacare, Paleosuchus, and Melanosuchus niger. Indicated are total numbers of animals and numbers of animals per transect kilometer.

STATE	REGION	HABITAT	(50 CM	>50CM - 1M	>1M - 1.2M	>1.2M - 1.5M	>1.5M - 1.8M	>1.8M - 2.0M	>2.0M	TOTL. NO.
A-ACRE	BRASILEA/RIO BRANCO	RIVER/PONDS/VEGET.	10	3	3	0	0	0	0	24
B-RONDONIA	ABUNA/HUMAITA	RIVER/PONDS/VEGET.	29	10	20	8	0	0	1	76
C-RONDONIA	GUAJARA MIRIM	RIVER/VEGET.	4	3	2	0	1	0	0	10
D-MATO GROSSO	RIO CABACAL	RIVER/VEGET.	4	7	5	5	0	0	0	21
E-MATO GROSSO	RIO PARAGUAY	RIVER/VEGET.	3	4	1	0	1	1	0	10
F-MATO GROSSO	RIO SEPOTUBA	RIVER/VEGET.	2	1	3	4	4	3	0	17
G-MATO GROSSO	RIO GALERA	RIVER/OXBOWS/VEGET.	0	2	3	1	1	0	0	7
H-MATO GROSSO	POCONE/TRANSPANTANEIRA	PANTANAL/RIVERBED/PONDS/VEGET.	30	210	303	839	247	53	34	1724
I-MATO GROSSO do SUL	JACADIGO	LARGE LAKE/OPEN WATER/VEGET.	0	0	24	24	0	0	0	48
J-MATO GROSSO do SUL	FAZENDA SAO. VICENTE	DRYBED RIVER/2 PONDS W/VEGET.	0	80	120	60	0	0	0	260
K-MATO GROSSO do SUL	FAZENDA NHUMIRIM	6 PONDS/VEGET.	6	4	7	4	3	0	0	20
L-MATO GROSSO do SUL	FAZENDA PROMISSAO	LARGE POND	0	16	299	415	200	0	0	930
M-MATO GROSSO do SUL	CORIM	RIVER/VEGET.	0	0	12	12	0	0	0	24
N-MATO GROSSO do SUL	RIO NEGRO	RIVERSIDE/PONDS/VEGET.	29	12	4	5	0	0	0	50

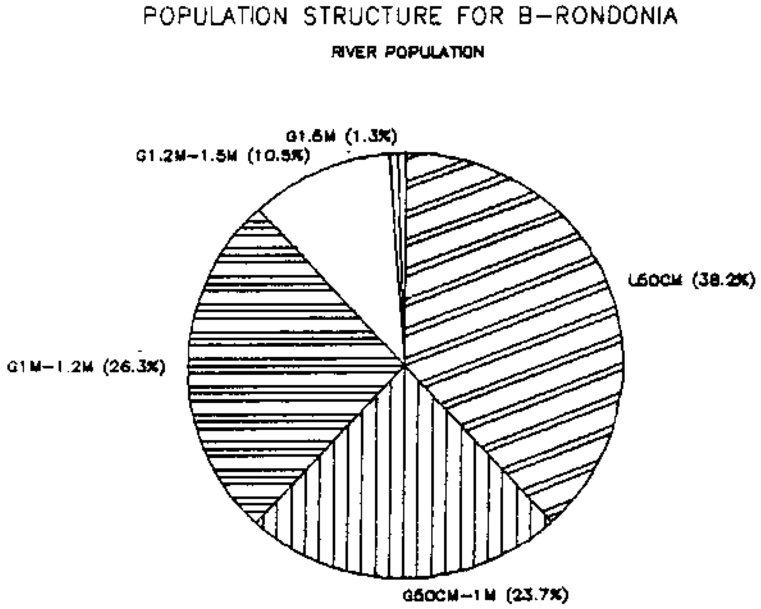
Table II. Indicates the total numbers of animals and the numbers of animals in each size class in each of 14 localities where transects were conducted.

SEX DISTRIBUTION OF Caiman yacare IN THIRTEEN AREAS

(CAPTURED ANIMALS)

State	Locality	Proportion Males:Females
Acre	Brasileia/Rio Branco	4:1
Rondonia	Guajara Mirim	5:2
Mato Grosso	Rio Cabacal	5:2
	Rio Paraguay	5:0
	Rio Jauru	1:1
	Rio Sangradouro	5:2
	Cuiaba	4:0
	Transpantaneira	5:3
	Vila Bela	7:0
Mato Grosso dO Sul	Fazenda Nhumirim	2:1
	Fazenda Sao Vicente	3:2
	Fazenda Promissao	5:0
	Rio Negro	4:0

Table III. Indicates the proportions of male to female Caiman yacare the team encounterd during the course of the survey. Animals were in the 90 cm to 1.5 m size range. Areas in Acre and Rondonia are river situations, as are the Rio Cabacal, Paraguay, and Jauru in Mato Grosso. All other areas are dry season pools and road surveys of roadside ponds and pools.



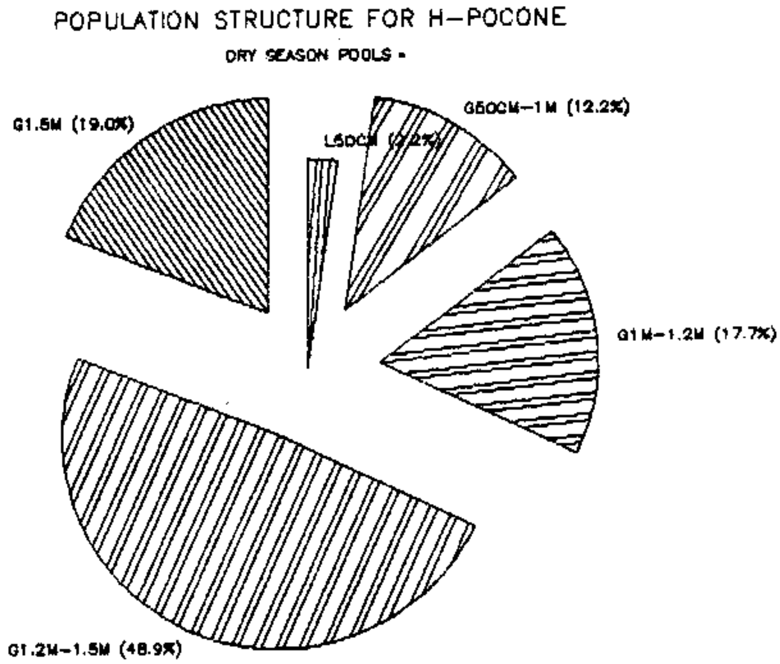


Figure 2. (TOP) Indicates the size class composition of a river population in the State of Rondonia.

Figure 3. (BOTTOM) Indicates the size class composition of a dry season pool population in the Pantanal.

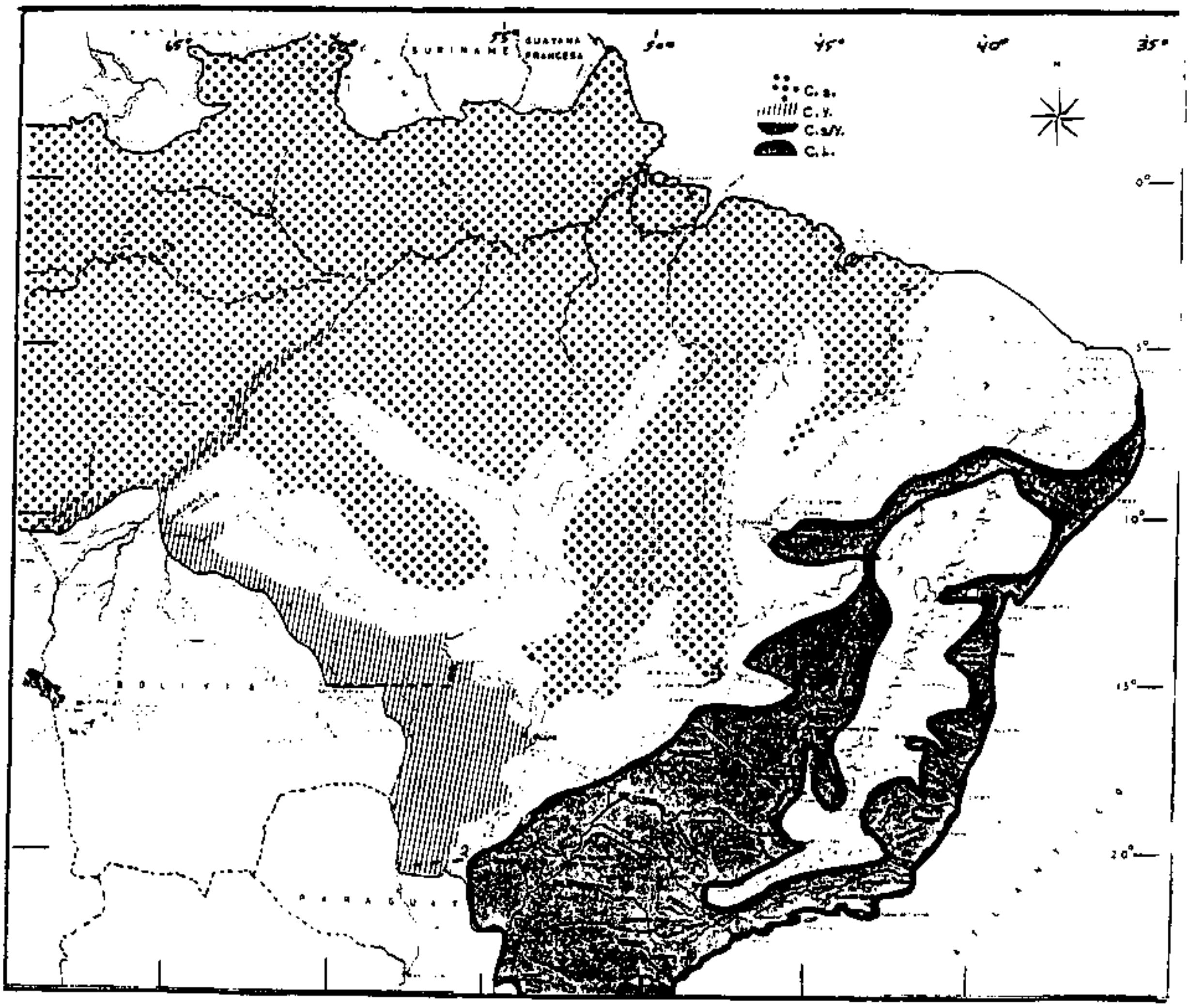


Figure 4. Indicates the distribution of Caiman yacare in Brazil, based on the present survey.
The dotted line[1] near the center of the map indicates the distribution limits for Caiman sclerops and Caiman c. matogrossiensis, while the dotted line[2] indicates the northern limits of Caiman c. yacare (Fuchs, 1971, 1974; Wermuth and Fuchs, 1978; CITES Manual, 1983.) Distributions for Caiman latirostris (= C.l.), Caiman sclerops (= C.s.) and Melanosuchus niger (= M.n.)are projected based on Medem (1983) and Rebelo and Yamashita (personal observations). Note the shaded area indicating a zone of intergration between Caiman sclerops and Caiman yacare (=C.s./y.) along the Rio Madeira and Rio Abuna.

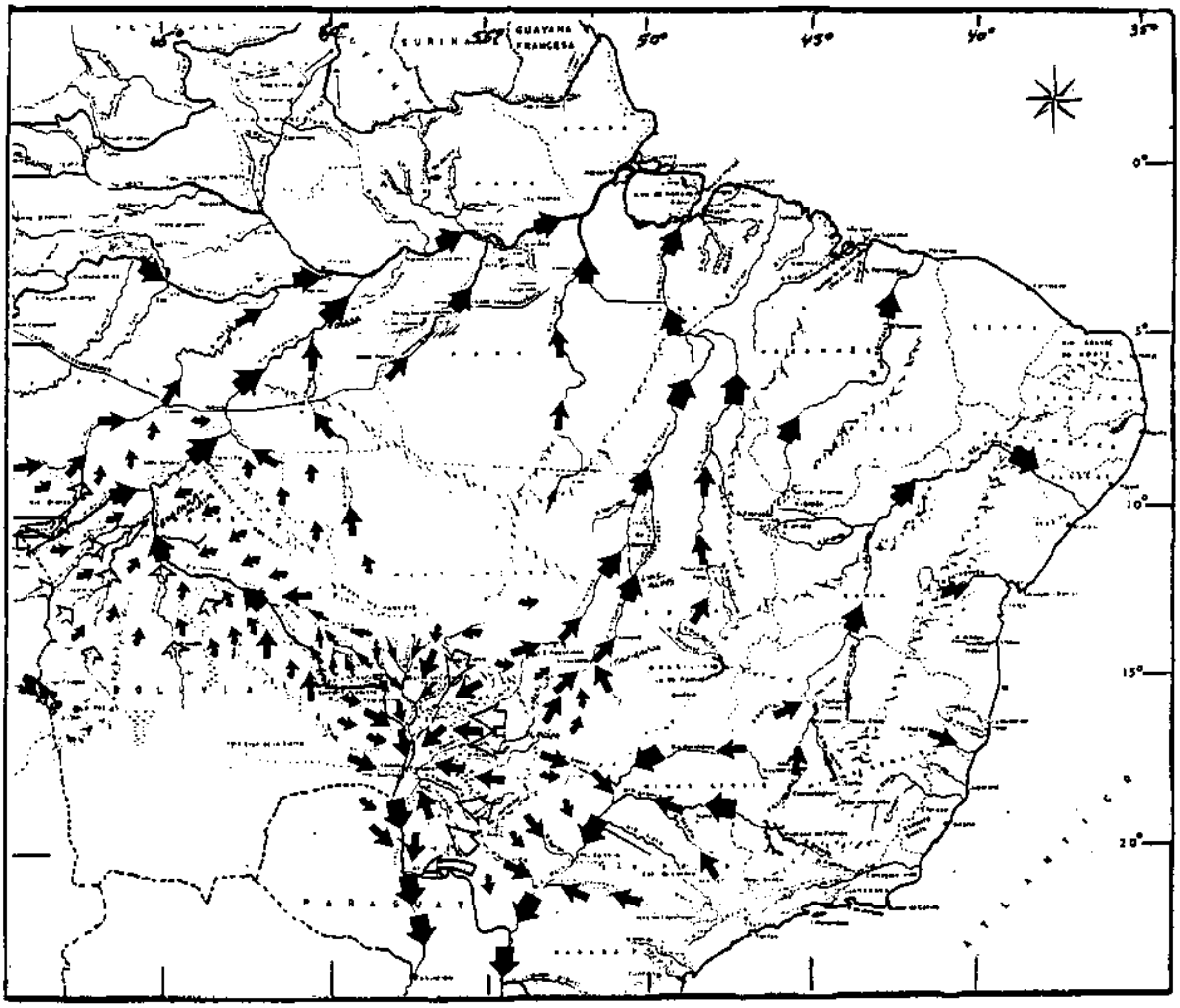


Figure 5 . Indicates the direction of flow of the major river systems and their drainages in the study area. Note that the Rio Guapore flows northward to the Rio Madeira from the State of Mato Grosso, while the Rio Paraguay flows southward. See Figure 9. for species distributions.

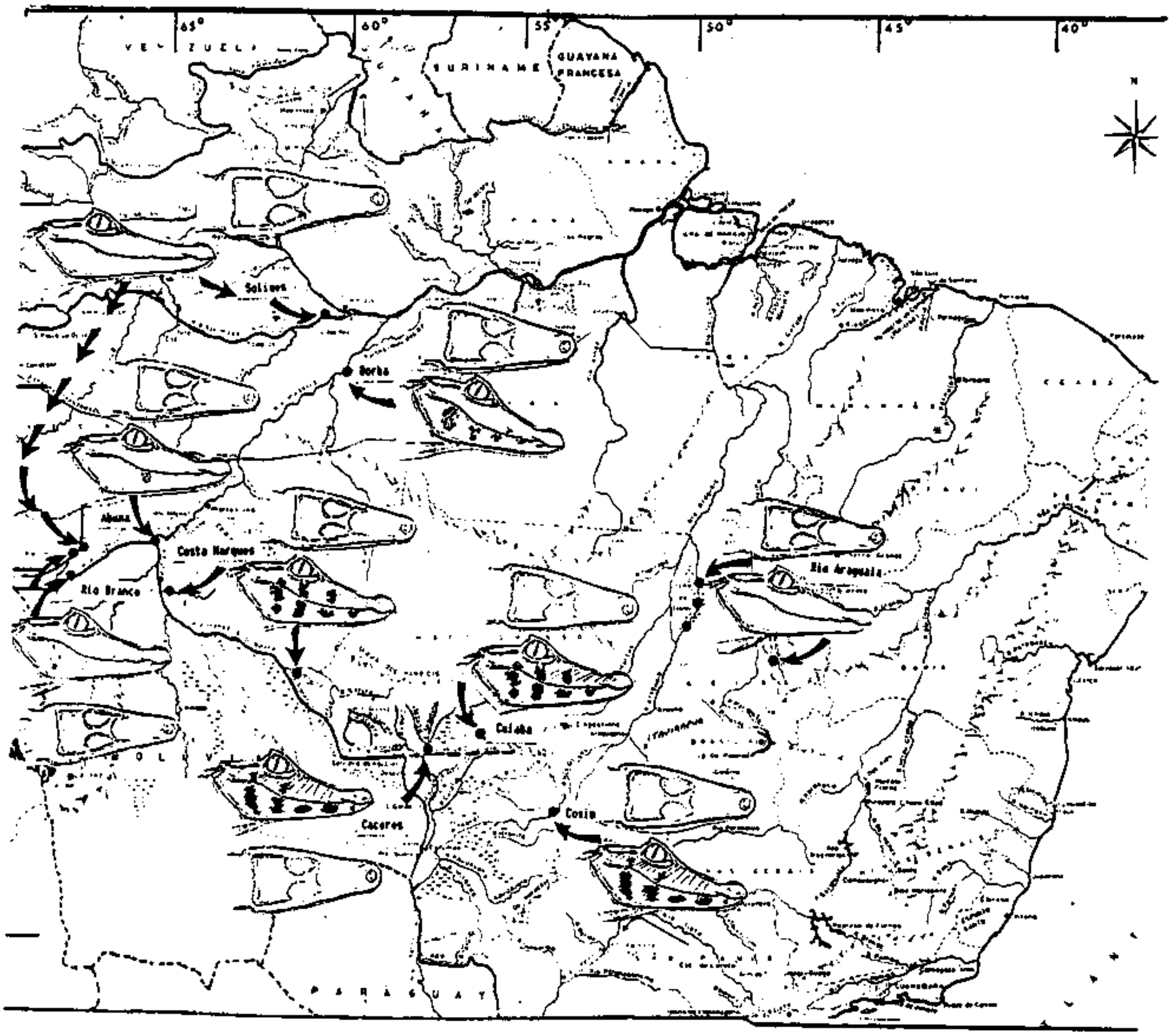


Figure 6 . Shows the gradation in jaw pattern from south to north, for Caiman yacare. Note the fading of jaw blotching south of Rio Branco in Acre, from Abuna to Borba on the Rio Madeira in Rondonia and Amazonia; the absence of jaw blotching on the animals in the drainages of the Amazon in Goias and north of Rio Branco in Acre. See Figure 5. for pattern details. Map is adapted from Medem, 1983.

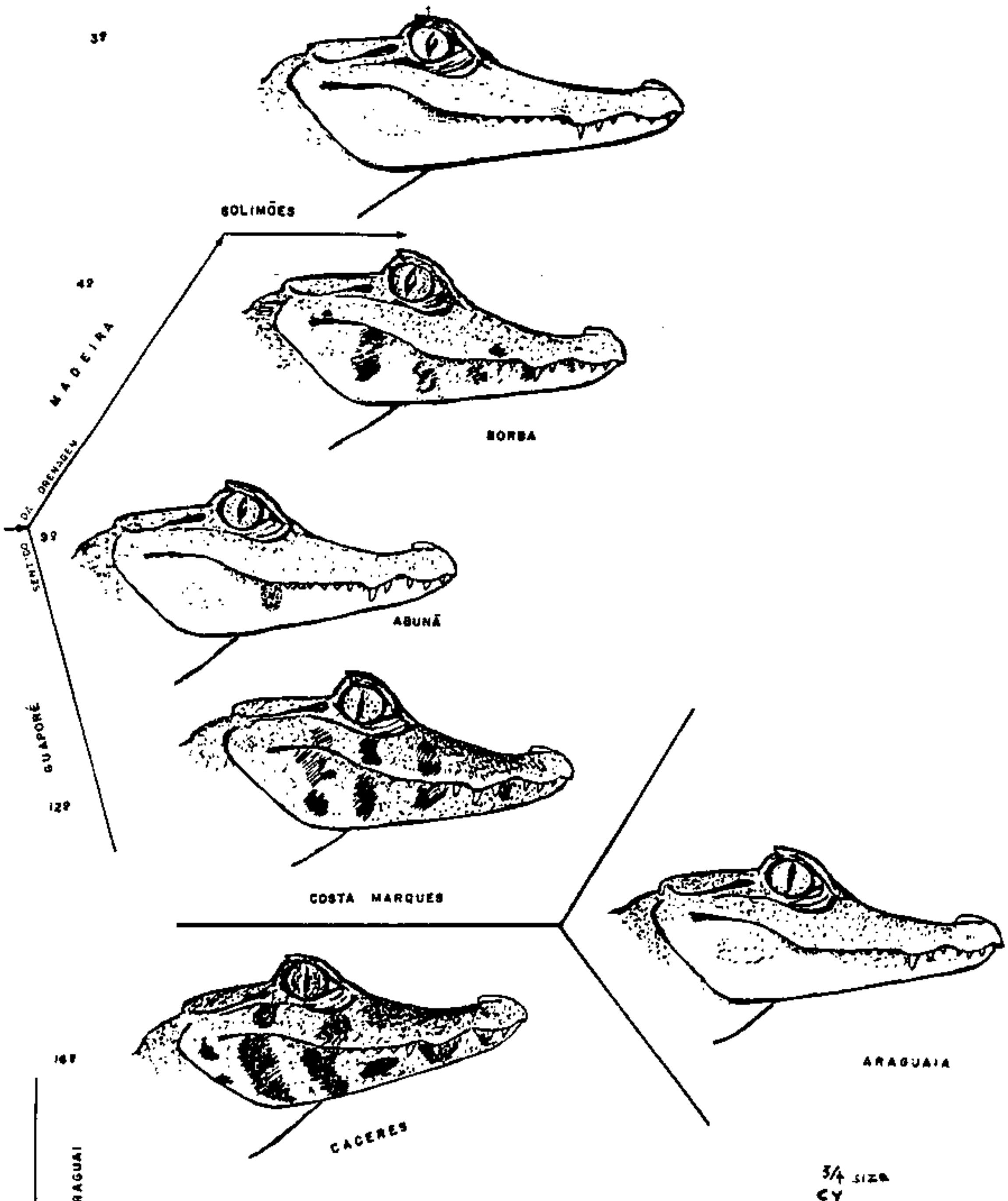


Figure 7. Is a detailed presentation of jaw patterns of *Caiman sclerops* and *Caiman yacare* types in the regions indicated. The illustration is by Carlos Yamashita.

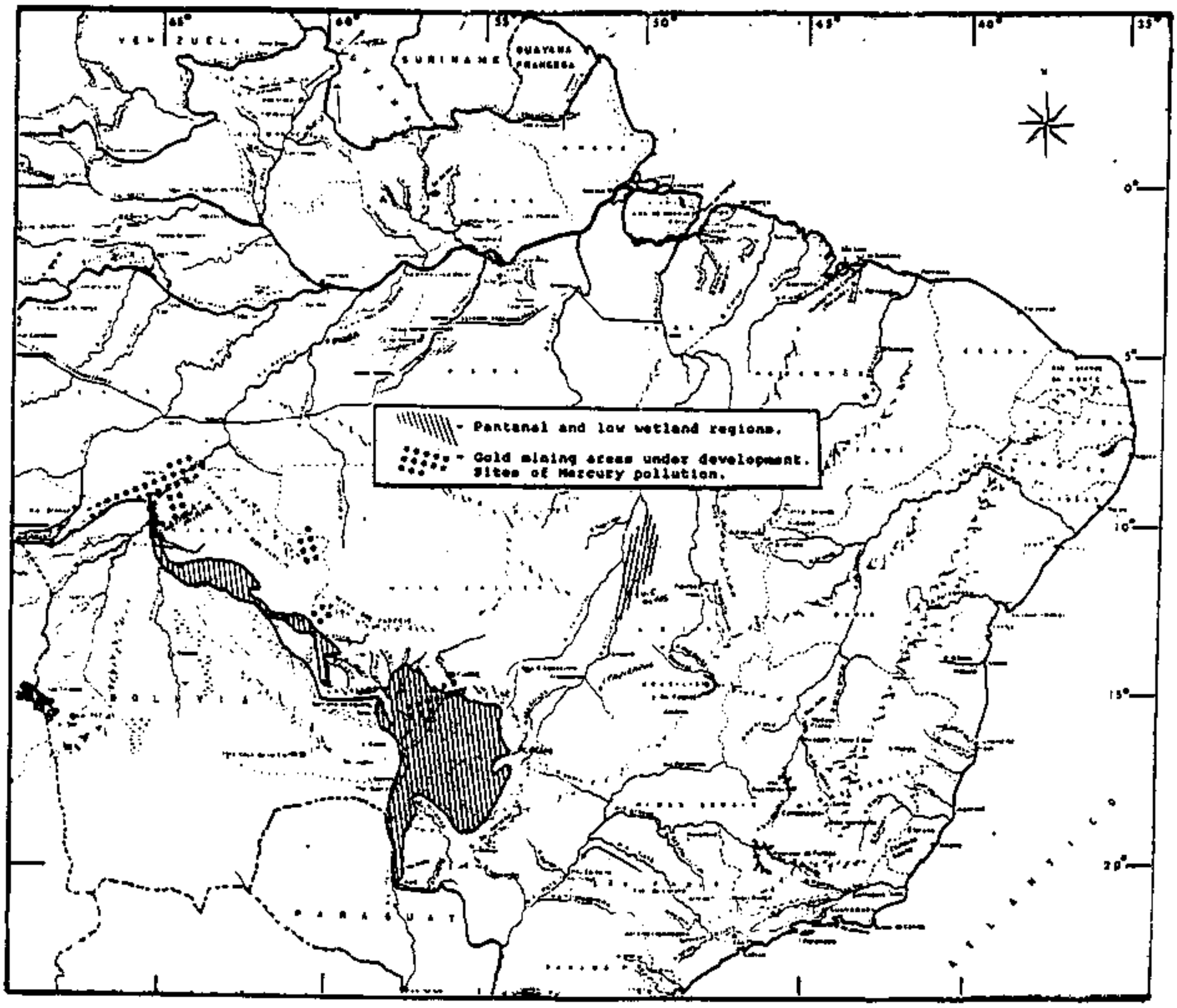


Figure 8 . Indicates the regions of intensive gold mining and the dumping of waste mercury into the environment. There are many other sites. Shaded area indicates Pantanal, and primary <u>Caiman yacare</u> habitat.

GROWTH CURVE ANALYSES AND THEIR APPLICATION TO THE CONSERVATION AND CAPTIVE MANAGEMENT OF CROCODILIANS

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Abstract. The analysis of growth is an important component of many studies of crocodilians both in the wild and captivity. Although reptilian growth has often been considered to be indeterminate, this is most likely an artifact of abbreviated longevity under natural conditions. In captivity, many reptiles including crocodilians, may live long enough for growth to eventually approach an upper asymptote. The 4-parameter Richards model describes sigmoid asymptotic growth and was fit to data from the literature for Alligator mississippiensis. Growth in alligator body weight could not be analyzed with the Richards model because of a lack of adequate data for larger individuals. The Richards model did however provide an adequate description of growth in total body length. Both the Richards and the widely-used von Bertalanffy sigmoid model described the growth of captive male and female alligators equally well. In the case of wild alligators, however, the Richards model explained significantly more variation than did the von Bertalanffy model. In these analyses, values for the Richards curve shape parameter were lower than that predicted by the von Bertalanffy model and suggested more accelerated growth shortly after hatching under wild conditions. Thus, the description of alligator growth with fixed-shape sigmoid models, such as the logistic, Gompertz or von Bertalanffy curves, may not be warranted because of the failure of the assumption of constant curve shape to hold across treatment groups. Although analysis with a flexibly-shape sigmoid model offers many advantages over the use of simpler growth models, many growth data sets do not possess the characteristics required for use of these more complex methods. This is particularly true with regard to the need for measurements from older known-aged animals as they approach final asymptotic body size or weight.

Introduction

The process of growth is of basic importance to the survival and later successful reproduction of all crocodilians in the wild state as well as to applied interests that are directed towards the captive propagation and/or production of hides or meat as commercial products. Under all circumstances, vigorous growth is generally accepted to be a reliable indication of an individual's (or population's) state of health and well-being. Body sizes and weights are usually easy to quantify, even under field conditions, and growth data is therefore one of the first and most common forms of information collected in both field and/or laboratory studies of crocodilians. As a result, growth data has been frequently used to assess the importance of various experimental treatments in a variety of disciplines. Growth responses have been used for example, as criteria for evaluating the responses of crocodilians (and in some cases their populations) to differences due to sex (McIlhenny, 1934), nutrition (Arvelo and Robinson, 1986; Staton et al., in press), captive-rearing techniques (Joanen and McNease, 1977; Joanen et al., 1981), microhabitat variation in both the wild (Murphy, 1981) and captivity (Joanen et al., 1987), and annual climatic variation (Fogarty, 1974).

A major drawback to the analysis of growth however has been a lack of appreciation of the data requirements associated with the use of available methods for the statistical testing of hypotheses from raw data. Time-series data such as that describing body weights or sizes at specific ages are often particularly prone to artifacts which may be introduced as a result of the use of inappropriate methods for statistical analysis and/or inadequate experimental design (White and Brisbin, 1980.). As pointed out by these authors for example, the size or weight of a given individual organism at time t, is not independent of its corresponding size or weight at time t-*1*). Under these conditions, standard regression techniques may result in the calculation of derived growth parameters (e.g., asymptote, slope of a linear regression etc.) with confidence intervals that are unwarrantedly narrow. As a result, there would be a tendency to claim significant differences in growth between treatments more often than would be justified.

This report is designed to survey and describe the major forms of growth analysis that either have or could be used for crocodilians. In making this survey, an emphasis will be placed upon methods that generate parameters that could be useful for testing hypotheses of the types that may be of interest in studies of crocodilian biology. In particular, recently developed techniques based on the use of the flexibly-shaped Richards sigmoid model (Richards, 1959; White and Brisbin 1980; Brisbin et al., 1986a; Brisbin et al., 1986c; Brisbin et al., 1986d; Brisbin et al. 1987) will be used to analyze published data for the growth of both wild and captive Alligator mississippiensis. This represents the first time that these procedures have been applied to the growth of a reptile.

Materials and Methods

The division of growth into determinate vs. indeterminate patterns is of fundamental importance to understanding the role of the growth process in the life history of individual organisms and it also provides a basic means of classifying the methods available for growth analysis. Nowhere among the higher vertebrates however, is the need for clearly delineating the characteristics of these two subdivisions more important than in the case of reptiles. While it is generally accepted that mammals and birds, almost without exception, reach a defined asymptotic size and thereafter cease to grow, this is seldom assumed to be the case for reptiles. Rather, it has frequently been contended that most amphibians and reptiles, like many of the lower vertebrates, continue to grow throughout their lives (e.g., Pope, 1961; Duelman and Trueb, 1985.). It is important to consider however, that while many reptiles may indeed continue to grow throughout a period of time equal to or exceeding their normal lifespan in the wild, these same individuals, when maintained in captivity, may live much longer, show a decrease in growth rate and approach an upper asymptotic limit of body size and/or weight at ages which would normally be well beyond their ecological life span (Bellairs, 1969; Halliday and Verrell, 1988). Thus, in many cases, the designation of reptilian growth into determinate vs. indeterminate categories may be an artifact of lifespan realization and particularly may vary according to whether free-living wild or captive-reared individuals are considered.

It is important to realize that even growth which approaches an asymptote will continue, by definition, to show increases, albeit to on increasingly small degree, throughout the individual's lifetime. For purposes for this report however, growth data sets which can be satisfactorily described with asymptotic models will be classified as determinate growth as opposed to clearly indeterminate growth as described for example, by linear and logarithmic models.

Given the above distinction between determinate and indeterminate growth, the methods which either have or potentially could be used to analyze the growth of crocodilians can be grouped into three general categories: (1) direct measurements of size-at-age or age-at-size, (2) indeterminate linear or log-linear regression analyses, and (3) determinate non-linear, in particular sigmoid, analyses. Each of these categories requires varying degrees of data set completeness and sophistication and concomitantly requires varying degrees of assumptions to be made about the nature of the underlying growth processes which produced the data set being analyzed.

Direct measurements of or size-at-age or age-at-size, are the most simple of the available methods of growth analysis. They make the lowest demands in terms of data set complexity and require the fewest assumptions to be made concerning the underlying growth processes. On the other hand, these methods also provide the least amount of information for testing hypotheses concerning factors affecting growth. These methods are widely used by agriculturists and most commonly involve the direct measurement of the sizes of all individuals when they attain a specific age. Often this age is chosen to represent the time at which the animals are harvested and/or sent to market. As such, these measurements have proven particularly applicable to the evaluation of alternative means of captive production of animals for meat, hides or other products (e.g., Joanen and McNease, 1977; Joanen et al., 1981; Staton et al., in press). A variation of these procedures consists of measuring the ages at which a given size is attained. Again, particularly meaningful sizes may be selected--e.g., the size at which reproduction first occurs.

Because the data generated by these methods are measured empirically, they may be compared with simple parametric statistics with no assumptions being required concerning the nature of the growth process which brought the individual to the observed size or weight within the observed period of time. On the other hand, since observations are recorded only once for each individual, no information is provided concerning the path or trajectory by which the growth process reached the observed point, and potentially important information may therefore be lost. As pointed out by Pasternak and Shalev (1983) for example, poultry which attain a given body weight in a specified time by a concave-upward shape of growth curve, are more efficient and consume less total feed than other birds which attain exactly the same weight in the same amount of time, but do so with by a less concave or more convex-upward growth trajectory. Such differences in efficiency would be of obvious importance to the economics of the production of crocodilian products for market and emphasize the importance of obtaining the most complete information on growth that is available.

Linear, log-linear and non-linear growth analyses, unlike the direct observations described above, require body sizes or weights to be determined at more than one period of time for each individual or treatment group. As explained in detail by Brisbin et al. (1987) such growth data sets may be either longitudinal, cross-sectional or mixed, depending on whether the same individuals are measured more than once over time. Differences between these types of data sets place important constraints on the types of analyses which can be used.

Of the three forms of regression analysis, the linear and log-linear forms are based on the assumption of indeterminate (non-asymptotic) growth during the time period over which data has been collected. While this is almost certainly an erroneous assumption over time periods approaching the lifespan of the animal, as discussed above, reptilian growth data collected over shorter time periods may show significant fits to either linear or log-linear regression models (e.g., Arvelo and Robinson, 1986). The shorter the time period over which growth is measured, the more likely a linear model will be able to successfully approximate the data.

Non-linear asymptotic models, although more demanding in terms of data set requirements, provide the greatest amount of information concerning the growth of an organism throughout its total growing period. As mentioned above, the application of such models often suffer from a lack of sufficient data points later in the growing period as asymptote is approached. In addition, the more formidable mathematics and statistical procedures associated with the analysis of such data have often prevented the use of these procedures by many investigators. However, recent advances in the development of personal computing devices and the increasing availability of user-friendly statistical packages for the analysis of nonlinear data (e.g., procedure NLIN of SAS, 1982) have now made procedures for the analysis of such data more generally available. Of all forms of asymptotic non-linear data analysis, sigmoid models have proved the most relevant to the growth of vertebrates and have been used to describe the growth of a variety of reptiles (Schoener and Schoener, 1978; Frazer and Ehrhardt, 1985; Bjorndal and Bolten,

1988) including alligators (Chabreck and Joanen, 1979). Sigmoid growth analyses will thus form the focus for the remainder of this report.

Sigmoid Growth Models

Until recently, most all sigmoid analyses of growth were based on one or more of a series of fixed-shaped mathematical models. Ricklefs (1967) described a graphical method for selecting the particular fixed-shape model which best approximated the data to be analyzed. Nearly a decade earlier however, Richards (1959) described a single sigmoid growth model which could, through variation in the value of a "shape parameter" (m), generate most all of the commonly-used fixed-shape sigmoid models. Thus for example, when the value of Richards $m = 0$, 0.667 or 2.00, the Richards model becomes the monomolecular, von Bertalanffy or logistic growth models respectively, and when m approaches a value of 1.00 the Richards model becomes the Gompertz model (Richards, 1959). As the numerical value of m changes, the shape of the sigmoid model is altered, with the point of inflection (the time of most rapid growth) occurring progressively later in the growing period as m increases (Figure 1). When $m = 0$ (the monomolecular model), the point of inflection occurs at the time of birth or hatching, and growth rate decreases exponentially throughout the entire period of postnatal growth (Figure 1). Later modifications in the formulation of the Richards model (Brisbin et al., 1986c) and the development of procedures using this model to statistically test hypotheses concerning growth (White and Brisbin, 1980) have addressed several problems that had hithertofore been associated with its use (Davies and Ku, 1977; Zach, 1988). In particular, the rate-parameter (K) has been replaced in the growth equation with the parameter T, the inverse of the proportional weighted mean growth rate, which, as expressed by Richards (1959), "...probably represents the period of development as well as any other figure derivable from an asymptotic function." This transformation has improved convergence characteristics of the model and has provided biological reality and meaning to the interpretation of the parameters derived from the analysis (Brisbin et al., 1986a; Brisbin et al., 1986c; Brisbin et al., 1986d; Brisbin et al., 1987).

As demonstrated by White and Brisbin (1980), the most realistic estimation of confidence intervals associated with parameters derived from use of the Richards model, are obtained through the use of the process error form (i.e., growth in size or weight ($^{dw}/dt$) is expressed as a function of increasing body size or weight). However, such studies require longitudinal growth data sets in which the same individual is measured and/or weighed repeatedly until final asymptote is attained--often a period of several decades in the case of most crocodilians. A survey of the published growth data available for the American alligator (Brisbin et al., 1986b) revealed that insufficient data of this kind was available for this species, particularly in the wild state, and as a result, data was analyzed in the present study using the integrated form of the Richards model, as modified by Brisbin et al. (1986c):

$$W_t = \left[A^{(1-m)} - \left(A^{(1-m)} - W_o^{(1-m)}\right) exp\left(\frac{-2t}{T}\left(m+1\right)\right)\right]^{\frac{1}{1-m}} \qquad (1)$$

where: W_t and W_o represent measured body weight or length at time t and at time t = 0 (i.e., hatching) respectively, A equals final asymptotic weight or size, and T and m respectively represent the length of the total growing period and the Richards curve shape parameter, as described by Richards (1959) and discussed above.

Equation (1) was fit to growth data, entered as measured alligator body weights and/or total lengths at known ages, using procedure NLIN of the Statistical Analysis System (SAS, 198?). In conducting this procedure, W_o was entered as an observed value--being calculated as the average of all published values surveyed for body weight and/or total body length at hatching ($\bar{x}$ weight = 0.590 kg; n = 39; Arthur, 1928; McIlhenny, 1934) ($\bar{x}$ length = 0.296 m; n = 42; Arthur, 1928; McIlhenny, 1934; Ditmars, 1936; Duffy, 1963; Fogarty, 1974). The parameters A, T and m in Equation (1) were allowed to vary and values which minimized residual sums of squares were recorded as indicating final asymptotic length or weight (A), the time required to approximate asymptote (T) and the path or trajectory (m) taken by the growth curve in attaining asymptote (A) in T years.

The above procedure was considered to represent the "complete" model and was then repeated with the constraint m = 0.667 (the "reduced" model). By setting m = 0.667 in Equation (1), the Richards model is transformed into the von Bertalanffy model as used previously for many analyses of reptilian growth (e.g., Fabens, 1965; Schoener and Schoener, 1978; Frazer and Ehrhart, 1985; Halliday and Verrell, 1988). The increase in residual sums of squares resulting from use of the reduced vs. the complete models to analyze the same data set was then evaluated with an F-test as described by White and Brisbin (1980). A significant F-ratio in this test was taken to indicate that the parameters (A, T, m) generated by the Richards model described the growth data better than those of the von Bertalanffy model. This procedure was repeated for each of the four male-female/wild-captive alligator growth data sets.

Alligator Growth Data

The Richards growth model analysis was applied to a data base of published values describing growth of the American alligator, as obtained from a review of the published literature on this species (Brisbin et all, 1986b). The references used included 4 and 18 reference sources providing data on the growth of free-living wild and captive-raised alligators, respectively, as follows (numbers following hyphens indicate the number of individual data points contributed to the analysis from each source): wild growth data: McIlhenny (1934)-101, Duffy (1963)-7, Fogarty (1974)-4 (total = 112 data points); captive growth data: Anon. [N.D.]-1, Ditmars (1907)-2, Ditmars (1910)-2, Boulenger (1914)-2, Schmidt (1919)-1, Arthur (1928)-14, Barbour (1928)-2, Ditmars (1936)-5, Angel (1942)-1, Cook (1942)-1, Bothe (1948)-9, Brandt (1948)-2, Palmer (1952)-3, Austin (1962)-2, Dowling and Brazaitis (1966)-11, Neill (1971)-2, Coulson et al. (1973)-2, Joanen et al. (1981)-10 (total = 72 data points). Each data point used consisted of either total body length (m) and/or total body weight (kg) measured at a known age (expressed as the nearest 0.01 year). In addition, because of a lack of actual measured data points for older alligators in the wild, 2 additional data points were added, consisting of the estimates made by Chabreck and Joanen (1979) for the predicted total body lengths which would be attained by wild male and female alligators in Louisiana at the times that they predicted, on the basis of the von Bertalanffy model, that asymptotic sizes would be obtained (80 years and 45 years for males and females, respectively).

Literature data was classified according to sex, with the designation "unknown" being used for all cases where the literature source did not specifically the sex of the animal measured and/or the animal was too young to be reliably sexed by external characteristics. Data for immature animals of unknown sex were included in the analyses of both sexes. Animals with body lengths greater than 3.1 m that were not identified as to sex were classified as males because of the low probability that any female alligator would exceed that length.

Results

The results of fitting alligator growth data to both the Richards and von Bertalanffy sigmoid models are summarized in Table 1. Data for growth in body weight failed to converge to both the Richards and von Bertalanffy models more often than did data for growth in body length, which showed convergence in all 8 of the cases tested.

Even in those cases where body weight did converge, biologically unrealistic parameter values were often produced, particularly in the case of the Richards model where the only convergence of body weight data produced an unrealistically high estimate of an asymptotic body weight of 399 kg being attained by captive males in only 3.45 years! Even if these estimates had not been so obviously unrealistic, the inappropriateness of this data set for such a sigmoid analysis would have been further indicated by an unrealistically high m value of 18.9. As explained by Fletcher (1975) large changes in the value of m above the range of 4.0-5.0 will result from relatively minor shifts in the actual shape of the resulting sigmoid curve--specifically the amount of final asymptotic size which has been achieved when the curve's point of infection occurs. Thus, these larger values of m can serve as "red flags," warning of analyses which are inappropriate for the data set being used. It is interesting to note that analysis of this same data set for captive male body weight, with the von Bertalanffy model, produced biologically realistic parameters indicating the attainment of a body weight asymptote of 118 kg in 20.2 years. The meaningfulness of the results produced by this von Bertalanffy analysis must be questioned however, in light of questions concerning the adequacy of the data set for such sigmoid analysis as indicated by the failure of the Richards model to show convergence. The parameter estimates produced by the von Bertalanffy model for captive females must be viewed in the same light and were even less biologically realistic (Table 1).

F-tests comparing analyses with reduced vs. complete models indicated that in the case of body lengths of wild male and female alligators, the use of the Richards model resulted in a highly significant reduction ($p<0.001$) in the residual sums of squares vs. the use of the von Bertalanffy model to analyze the same data sets

(Table 1). There were no such significant differences, however, in the case of either captive males or captive females. The values for the curve shape parameters produced by the Richards analysis of the captive alligators ($m = 0.498$ and 0.318 for males and females respectively; Table 1) were much closer to the set von Bertalanffy value of $m = 0.667$ than were the comparable values for wild alligators ($m = 0.150$ and 0.047 for males and females, respectively; Table 1). The lower m values for the wild growth curves indicated that in comparison to the improved fit with the Richards, the von Bertalanffy model tended to underestimate the growth in length of wild alligators between hatching and above 6 years of age, and then tended to overestimate growth at older ages as asymptote was approached between 8-18 years of age (Figure 2). However, no such differences occurred in the case of the growth of captive alligators (Figure 3).

Discussion

The analyses reported here indicate clearly that growth in total body length of American alligators, and by implication other species of crocodilians as well, can be described by non-linear asymptotic sigmoid models. The failure of data for growth in body weight to converge and produce biologically realistic parameters in most cases, was probably related to the lack of sufficient data for whole body weights of known-age older adults near asymptote. In the case of wild males for example, no data are available for body weights of animals older than 19 years of age, even though substantial increases in body weight were still occurring at that age (Figure 4). This was probably the result of two factors. First, alligators cease to grow in body length long before they stop increasing in body weight, and secondly, the practical measurement of body weight is much more difficult on larger individuals than is the measurement of total body length, again contributing to a lack of sufficient asymptotic data for the former.

The greater reduction in residual variance by the Richards vs. the von Bertalanffy model was not unexpected. In every case where the same data set is analyzed with a fixed-shape model which is part of a "nested" series of models within a parent curve, the parent curve (in this case the Richards model) will always produce a residual variance that is either less than or equal to that of the fixed-shape model. This is a mathematical necessity as long as both models converge to normal solutions. The fixed-shape and Richards models will only perform equally in reducing residual variance when the value of the curve shape parameter produced by the Richards model exactly equals that of the fixed-shape model. In the case of the present data for example, the residual variances of the Richards and von Bertalanffy models did not differ statistically (although that of the Richards was always lower) in the case of the captive animals whose shape parameter values were closer to that assumed by the von Bertalanffy, than was the case for the wild animals. In the latter case significant differences were indeed found between the two models. Thus, the more the value of the shape parameter of a Richards analysis differs from that assumed by a specific fixed-shape model, the more likely it will be that the Richards model will provide a statistically significant reduction in residual variance. In making these comparisons, however, it is not a question as to whether the Richards or von Bertalanffy (or any other fixed-shape model) is "best" at reducing residual variance. Although the Richards model will always be the "best" in that regard, it will, whenever the data set is appropriate, actually <u>become</u> the fixed-shape model as its shape parameter value approaches that assumed by the latter. The von Bertalanffy model, for example, <u>is</u> a Richards model with a shape parameter of 0.667.

Several previous studies using fixed-shape models of reptilian growth have compared the fits of more than one of these models to their data. They thus have undertaken in a preliminary way, the same type of evaluation which was performed more thoroughly here with a single analysis using the flexibly shaped Richards model. Comparing the fits to one or more fixed-shape models limits the choices of "best fit" to only those particular models chosen for study, while use of the Richards model allows for the selection of any shape of sigmoid curve-including those which may be intermediate in shape between the various fixed-shape models. An m value of 0.25 for example, would indicate a curve shape intermediate between that of the monomollecular (m = 0) and von Bertalanffy (m = 0.667) models, and no fixed-shape model is currently available to describe such a pattern of growth.

Attempts to compare the fits of several fixed-shape models to reptilian growth data have produced conflicting results and confirm the findings reported here that the assumption of a single constant shape of sigmoid growth curve across species and/or experimental treatment groups is almost certainly unwarranted. Schoener and Schoener (1978) for example, found that the logistic model (m = 2) described data for growth in size of Anolis lizards better than the von Bertalanffy model. Frazer and Ehrhart (1985) and Bjorndal and Bolten (1988), however, found that the von Bertalanffy model described the growth several of body size parameters of sea turtles (Caretta caretta and Chelonia mydas) better than did the logistic model. The results of these latter studies are therefore more similar to those reported here for alligators and suggest that there may be a tendency for reptiles with larger body sizes to show growth curves with shapes defined by lower m values (0.050-0.667) than smaller species. Nevertheless, the results reported here would caution against the assumption of any single curve shape as typifying growth within a species since the growth curve of the alligator alone varies in shape from m values of 0.050 to 0.0667, depending on whether wild or captive growth is being considered.

The tendency of captive alligators to show body length growth curves with lower m values than those of their free-living wild counterparts suggests that early growth of the captive animals is somewhat delayed in comparison to that of free-living individuals. The findings of Brisbin et al. (1986a; 1986b; 1987) have suggested that in such cases, the higher m values of the captive growth curves may be the result of suboptimal conditions or stress during the early part of the growing period, as compared to free-living wild conditions. This may not be unreasonable when it is considered that the majority of captive growth data used in this study were collected in the early 1900s (e.g., Ditmars, 1907; Ditmars, 1910; Ditmars, 1936) when the technology for captive propagation was not nearly as advanced as is presently the case. It would be important to now repeat these analyses when complete growth data sets become available for alligators raised under more advanced conditions of housing, feeding and general captive management (Joanen and McNease, 1977; Arvelo and Robinson, 1986; Staton et al., in press). It is important to note, however, that despite a slower start in growth, captive male alligators actually approached their final asymptotic size in less time than wild males (T = 14.0 vs. 21.4 years respectively; Table 1). The wild males, however, eventually grew to a larger asymptotic size (4.15 vs. 3.10 m respectively; Table 1). The asymptotic length of captive males, which was actually lower than that estimated for captive females, is probably another indicator of inadequate conditions for expression of maximum growth potential under captive conditions. Practical problems and risks associated with the restraint and measurement of the larger males probably also contributed to the lack of sufficient data to accurately estimate asymptote (no data was available for males over 24 years of age in this treatment group).

Several factors combine to suggest that quantitative comparisons of individual growth parameters between treatment groups (White and Brisbin, 1980) would not be warranted here. Comparisons between male and female growth parameters for example are compromised by the fact that the same data for juveniles of unknown sex were included in both male and female analyses. Despite this fact, however, the curve-shaped parameters for male and female growth curves differed by as much as three-fold (0.150 vs. 0.047; Table 2) within the wild treatment group alone. This indicates the strong influence that later growth can exert upon the determination of the overall growth curve shape--even when early growth patterns are otherwise identical.

The use of body length estimates from Chabreck and Joanen (1979) for wild male and female alligators at ages of 45 and 80 years respectively, undoubtedly improved the ability of the Richards model to estimate asymptotic sizes in these analyses. Although these two estimates had been obtained by these authors through the use of a von Bertalanffy analysis, any bias that may therefore have been introduced must have been minimal since it was precisely these analyses of wild growth data that differed the most from the von Bertalanffy curve shape (Table 1). The parameters A and T, as produced here by the Richards model however still closely approximate the findings of Chabreck and Joanen (1979), who report that wild male alligators, "grow fairly rapidly for 20 years"--an age which closely approximates the projected length of the total growing period for wild males in this study (T = 21.4 years; Table 1). Similarly, these authors found that the growth of wild females declines considerably after age 10, again closely approximating the results reported here by the Richards model (T = 12.3 years; Table 1).

When the Richards model is used however, further comparisons between treatment groups can also be made with respect to the age at which the growth curve's point of inflection (time of most rapid growth) occurs. (When the von Bertalanffy model is used, the point of inflection must always occur when body weight = 29.6% of asymptote and is not free to vary.) In the case of the Richards analyses presented in Table 1, growth curve inflection points all occurred early in the growing period at ages ranging from at or slightly before hatching (wild-females) to 1.45 years (captive males). In both sexes, the effect of captive-rearing was to delay the age at point of inflection by about one year for each of the sexes.

Because variable curve shapes are permitted, the Richards model can also allow the detection and quantification of differences in the ages at which particular subasymptotic sizes are attained, even when the data sets in question attain the same asymptotic sizes in the same lengths of time. This is because, in the reparameterized Richards model used here, m (curve shape) is free to vary even if A (asymptote) and T (growing period) remain constant (Brisbin et al., 1986c; Brisbin et al., 1987). The rate at which such subasymptotic sizes are attained may often be of more biological and/or economic importance than the attainment of asymptotes per se. As in the case of other domestic livestock and poultry marketing operations for example, few crocodilians on commercial farms are ever kept until asymptote is achieved. Rather they are usually marketed at some smaller body size, depending on various economic factors. Similarly, the population dynamics of wild crocodilians are much more influenced by the age at which first reproduction occurs than by the attainment of asymptote and in actual fact, probably few wild crocodilians ever live to reach final asymptotic size. The accurate assessment of growth curve shape is particularly important in these assessments since in many cases, age at first breeding seems to be more closely related to the attainment of a minimal body size than it is to a specific chronological age. In the case of the American alligator for example, females seem to become reproductive when they attain a body length of about 1.8 m (Bellairs, 1969). The Richards analysis for wild females (Table 1) would predict the attainment of this size at about 6.4 years of age, about 0.5 year later than would be predicted from the von Bertalanffy analysis of the same data. Although these estimates do not differ strikingly, it is possible that various factors could stress growth and thereby further alter growth curve shape (e.g., Brisbin et al. 1986a;

Brisbin et al., 1987), and only analyses with the Richards model could detect such changes.

Finally, no assessment of the use of the Richards or any other sigmoid model to analyze growth should fail to mention the demands that such analyses must make on the quality and characteristics of the data sets to be analyzed. As pointed out by Brisbin et al. (1987) and Leberg et al. (in press), many data sets do not warrant analysis with such complex models because of inadequate coverage of the entire growing period (e.g., Figure 4) or because of biases in ways in which the data has been collected. As has been pointed out for the analysis of growth in body weight by wild male alligators in the present study for example, an analysis using a fixed-shape sigmoid model converged to seemingly realistic parameter values even though an analysis with the more demanding Richards model (Table 1) indicated that the data set was probably inadequate to justify such an estimation procedure (unless of course there were an a priori reason to presume a specific value for curve shape, which would seldom if ever be the case). Under such conditions where the use of the Richards and/or other non-linear sigmoid models cannot be justified by the quality of the data base available, simpler methods of analysis such as linear or log-linear regression and/or parametric analysis of directly observed size-at-age values should be used. Within the limitations described above, such simpler methods of growth data analysis can often permit more meaningful conclusions to be drawn concerning the process of growth than would be the case with the application of models with unwarrantedly great complexity.

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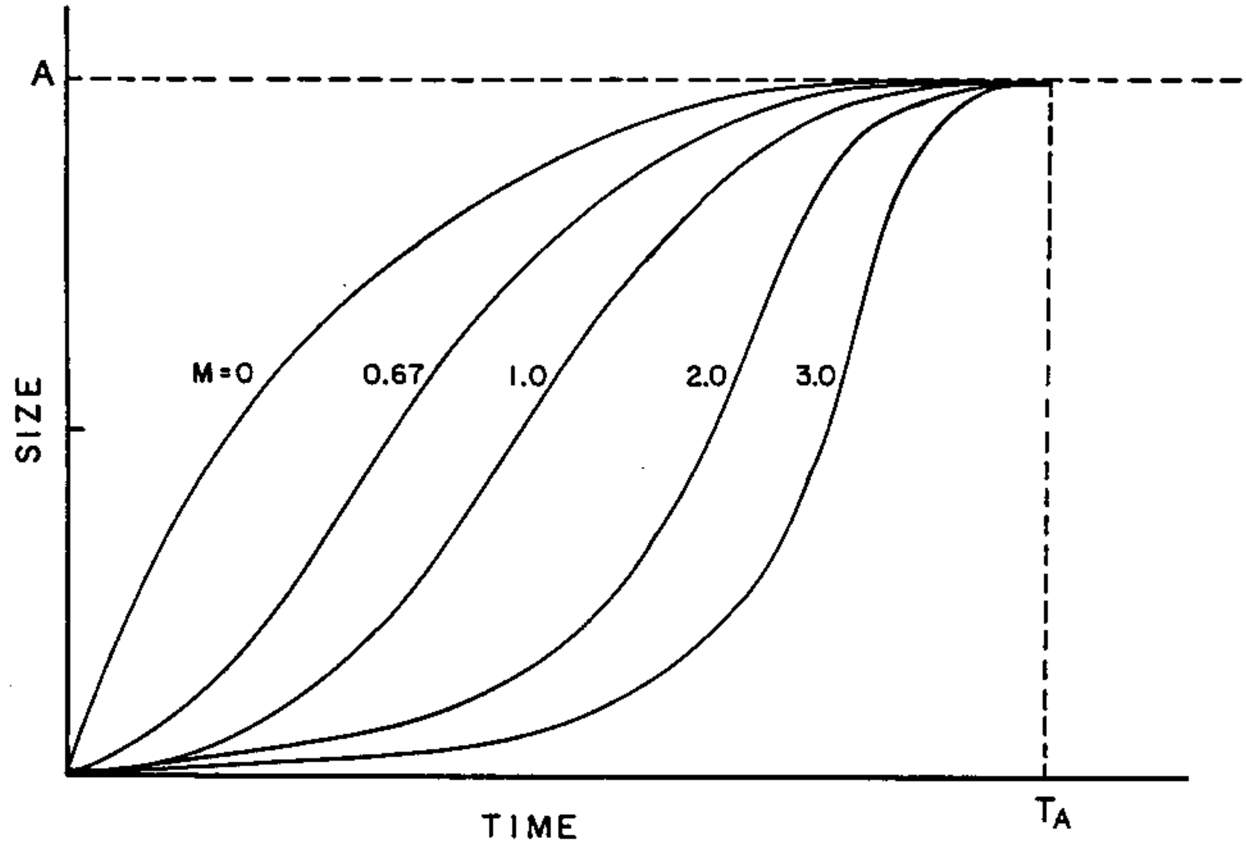

Figure 1. Diagrammatic representation of a family of sigmoid growth curves such as would be generated from the Richards growth model by varying the value of the Richards curve shape parameter (m) across the values indicated. When m = 0, 0.67, or 2.0 the curves are the monomollecular, von Bertalanffy and logistic sigmoid models, respectively, and when m approaches 1.0, the Gompertz model is produced. A and T_A represent the parameters quantifying asymptote and the time required to reach asymptote (A and T from Equation (1)) respectively.

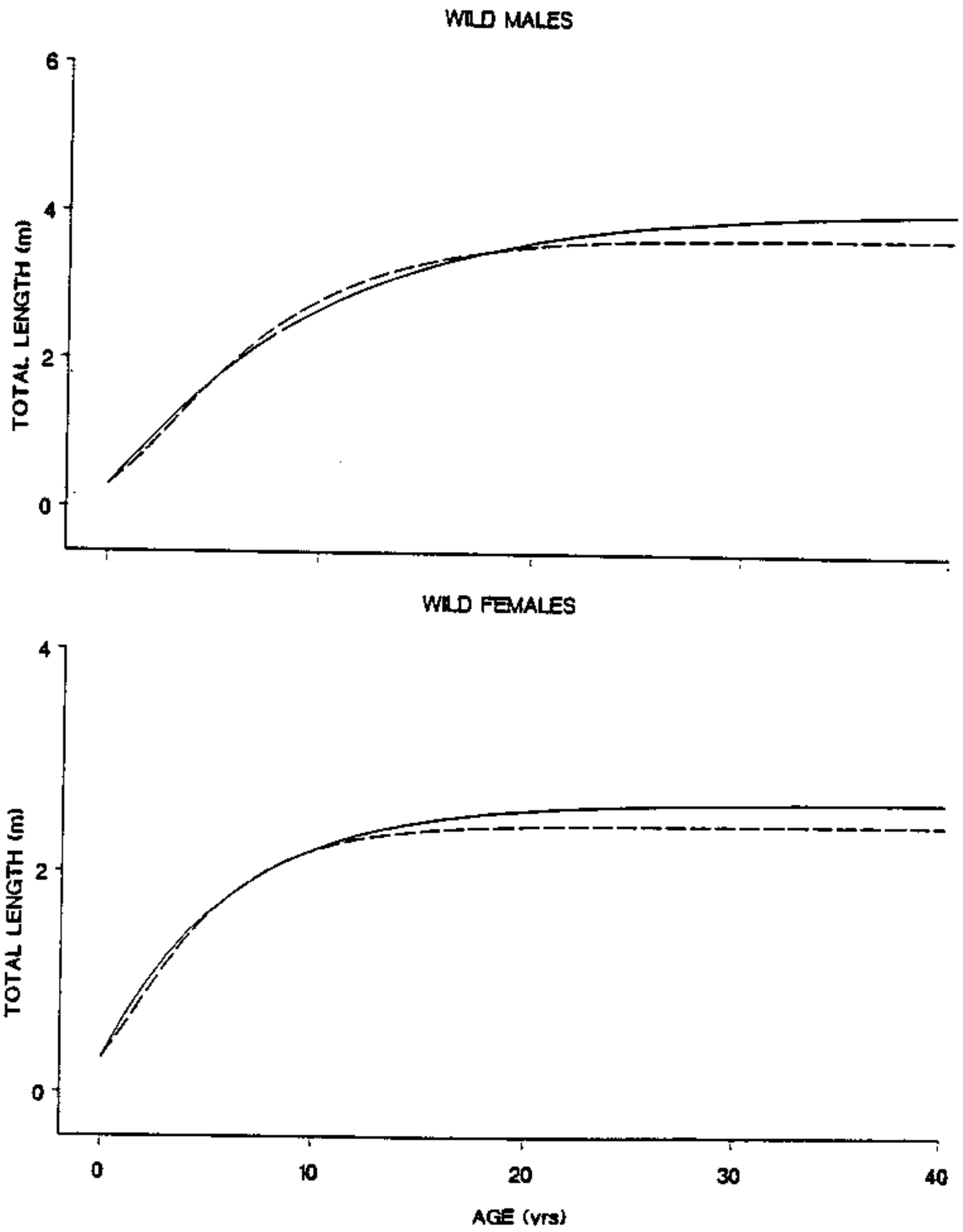

Figure 2. Growth curves for wild free-living male and female American alligators, as described by the Richards (solid line) and von Bertalanffy (dashed line) sigmoid models. Growth curves were generated by substituting parameter values for A, T and m, as given in Table 1, into Equation (1).

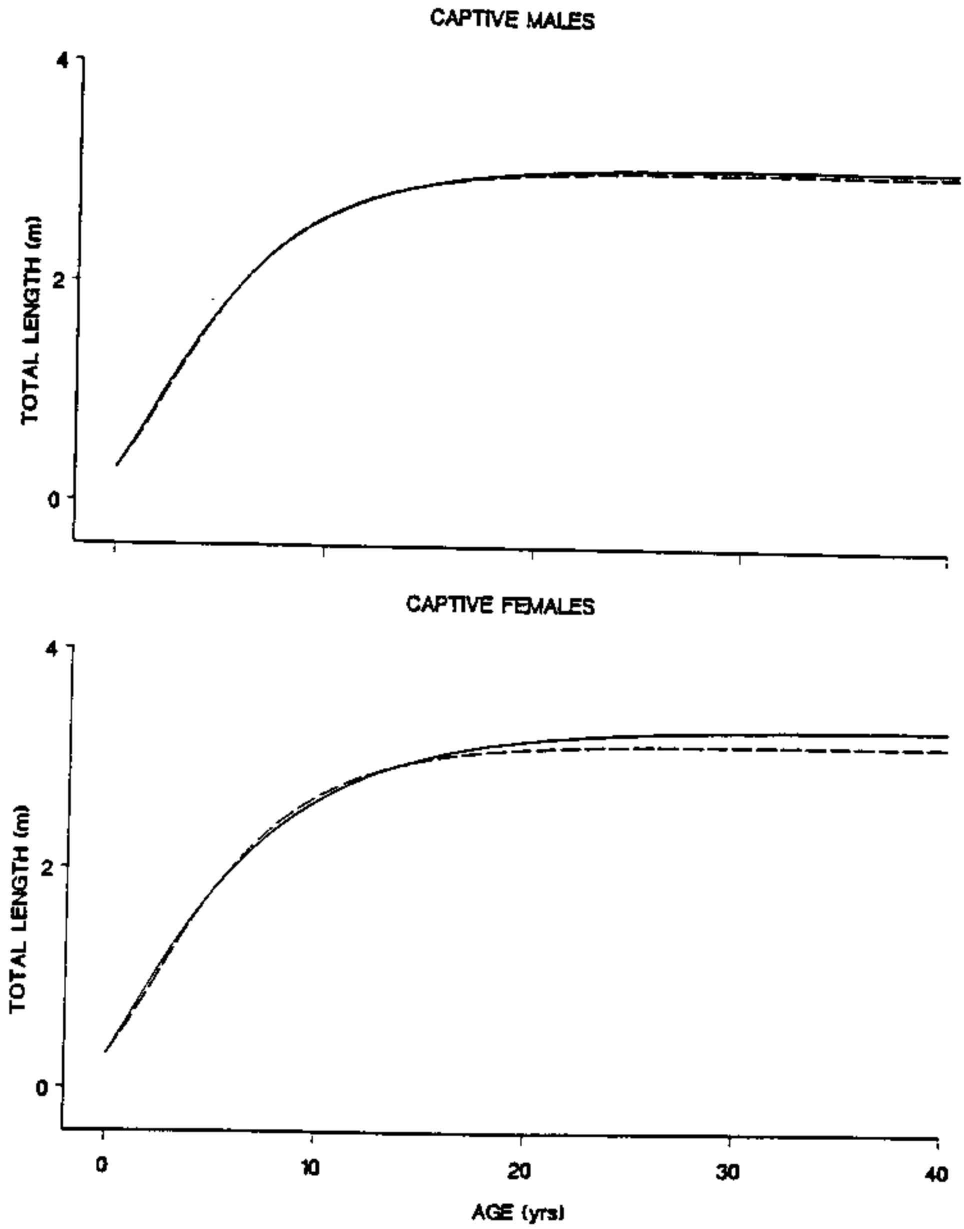

Figure 3. Growth curves for captive-raised male and female American alligators, as described by the Richards (solid line) and von Bertalanffy (dashed line) sigmoid models. Growth curves were generated by substituting parameter values for A, T and m, as given in Table 1, into Equation (1).

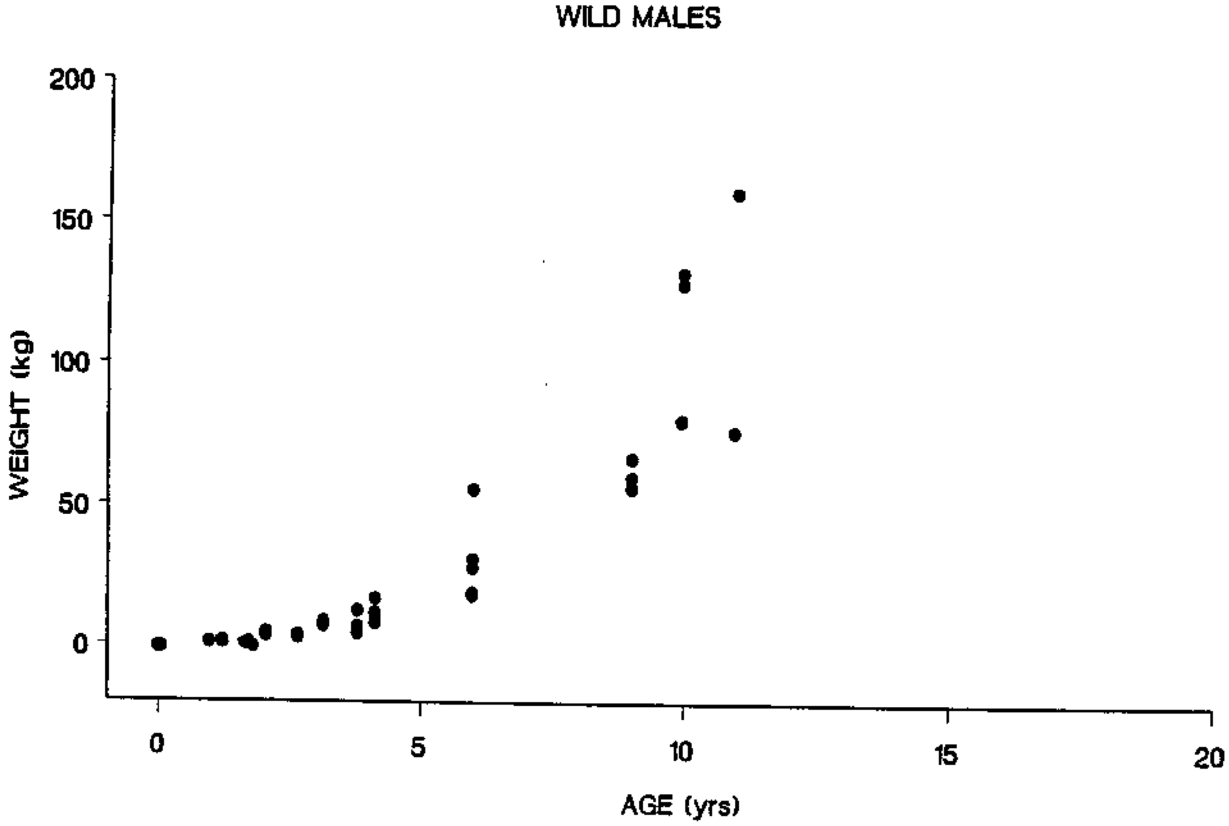

Figure 4. Body weight data for free-living wild male American alligators as a function of increasing age. Attempts to describe this data, with nonlinear sigmoid models, failed to produce convergence to biologically meaningful parameter values (Table 1).

Table 1. Results of fitting the Richards[a] and von Bertalanffy[b] sigmoid models to published data[c] for the growth of wild and captive American alligators.

	Males		Females	
	Richards Model	von Bertalanffy Model	Richards Model	von Bertalanffy Model
Body Weight				
Asymptote (kg)[d]	DNC[e]/399[f]	DNC/118	DNC/DNC	DNC/388
Growing period (years)[g]	DNC/3.45	DNC/20.2	DNC/DNC	DNC/46.4
Shape parameter[h]	DNC/18.9	DNC/0.667[i]	DNC/DNC	DNC/0.667[i]
Residual Sums of Squares	DNC/41140	DNC/36880	DNC/DNC	DNC/980.6
Residual df	87,88/33,34		84,85/24,25	
Total Length:				
Asymptote (m)[d]	4.15/3.10	3.74/3.06	2.64/3.31	2.43/3.16
Growing Period (years)[g]	21.4/14.0	17.9/13.9	12.3/15.3	11.5/14.4
Shape parameter[h]	0.150/0.498	0.667[i]/0.667[i]	0.047/0.318	0.667[i]/0.667[i]
Residual Sums of Squares	1.546*[j]/16.95	2.059/16.99	1.235*/11.24	1.405/11.35
Residual df	100,101/59,60		97,98/47,48	

[a] Richards (1959) as modified by Brisbin et al. (1986a).
[b] Obtained by setting m = 0.667 in the Richards model as defined above.
[c] See text for literature sources.
[d] A from Equation (1).
[e] DNC = did not converge to a solution.
[f] Wild/Captive.
[g] T from Equation (1).
[h] m from Equation (1).
[i] Shape parameter value set = 0.667 and not alowed to vary.
[j] Asterisks indicate significant reductions in residual sums of squares as a result of using the Richards model ($P<0.0001$).

HANDLING PROGRAM FOR THE CAYMAN. _Caiman crocodilus._ IN VENEZUELA. DEVELOPMENT AND PERSPECTIVES.

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INTRODUCTION.

Of the crocodilians found in Venezuela, the Cayman, *Caiman crocodilus*, is the species with the widest distribution and the greatest abundance.

In principle, two subspecies that inhabit the country are recognized: *C.c. crocodilus* and *C.c. fuscus*. The first one is widespread in the Mid-Western and Eastern Llanos and in the lowlands of Guayana. The second one is restricted to the Lago de Maracaibo Basin and the Yaracuy River (Meden, 1982, cit. in Seijas, 1986a) (fig.1). Nevertheless, some authors consider that the populations of Cayman in the Guayana Region correspond to a subspecies different from the preceding ones (Gorzula, 1982; I Taller sobre Conservacion de la Baba en Venezuela).

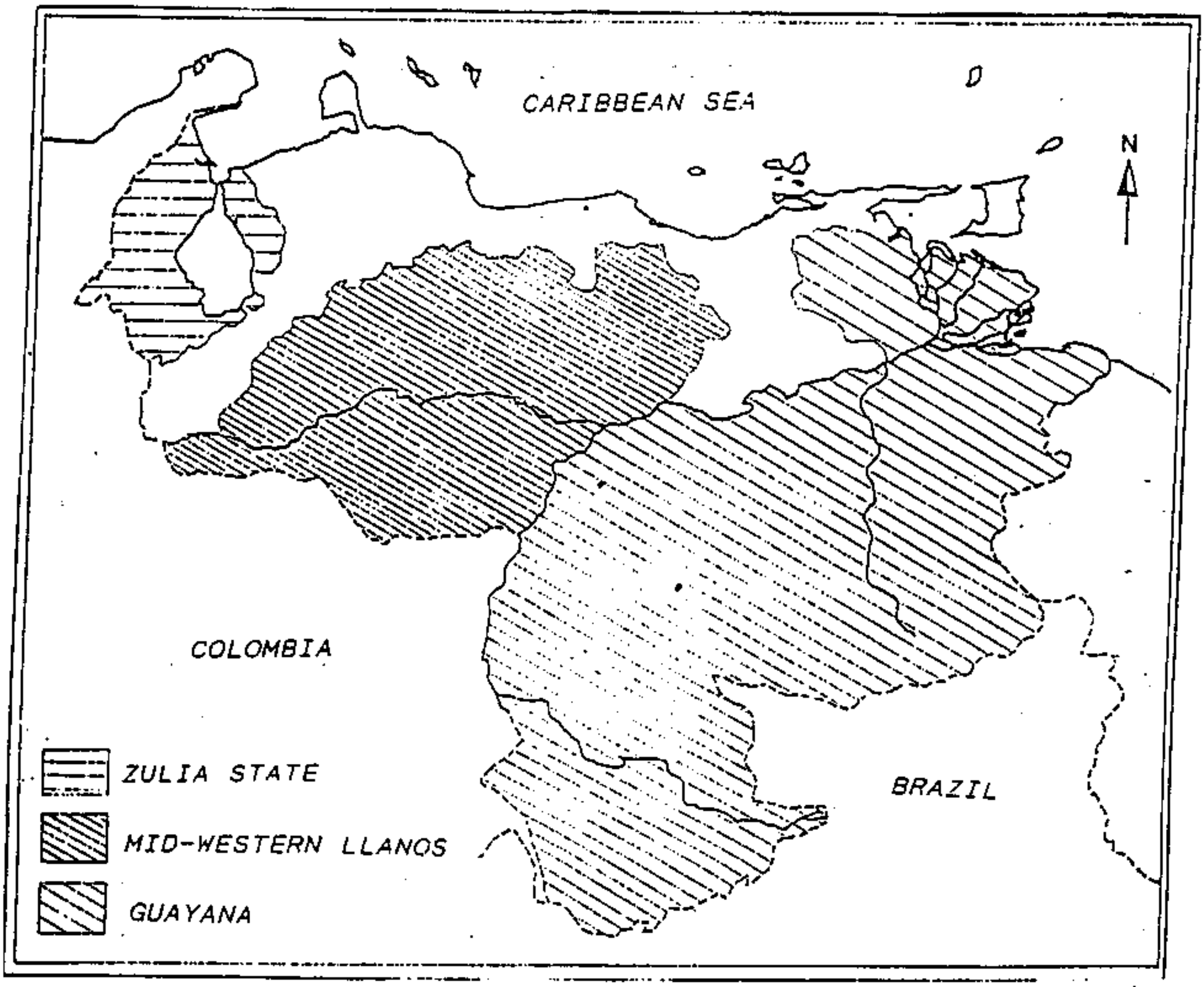
In any case, the population of the Mid-Western Llanos Region is the one which has suffered intense hunting pressure since the sixties. This pressure has apparently been significantly greater than the one the population in Guayana, referred to by some authors (Gorzula and Paolillo, 1986) might have suffered, although no evaluation of the magnitude of this pressure exists. Nevertheless, everything points to the fact that extraction has occured, not only in Guayana but in the South of Lago de Maracaibo as well. The most likely destinations of the skins would be Trinidad and Colombia, respectively. Thus, as an example, during 1979 and 1980, 30,155 and 44,322 cayman skins from Venezuela were registered in the international market (Hemley and Caldwell, 1986). This, in spite of the closed season declared at the beginning of the seventies and which was extended until 1983, when the Venezuelan State, through the Ministry of the Environment and Renewable Natural Resources (MARNR, for its Spanish abbreviation), decided to declare an Experimental Season for the Management of the Cayman on private properties in the Llanos states of Apure, Barinas, Portuguesa and Cojedes, and in the Guayana Region of Bolivar state.

Such decision was based on different evaluations undertaken by the MARNR on the state of the wild populations of the Cayman. These indicate that said populations could be rationally exploited. And what is even more important: at that time, sufficient scientific and technical information existed, which was basic for the elaboration of a Management Program of the resource.

The studies come not only from other distribution areas of the *Caiman* Genus (Webb et al., 1982, for example), or from Alligator *mississipiensis* (Murphy, 1977, for example) which could be partially extrapolated to the new Program, but there is also research on *Caiman crocodilus* in the Llanos Region basically, and in Guayana, about:

- Mathematical models of population dynamics oriented towards commercial utilization programs (D'Andria, 1980);
- Reproductive Biology (Rivero Blanco, 1974; Staton and Dixon, 1977; Gorzula, 1978);
- Movements and use of habitat in terms of size classes (Gorzula, op.cit.) and in terms of sex and season (Staton and Dixon, op.cit.);
- Feeding habits in terms of size classes and season (Staton and Dixon, 1975); and
- Ecological bases of food preference (Gorzula, op.cit; Seijas and Ramos, 1980), among others.

Additionally, in view of the almost total disappearance of species with a high commercial value such as Crocodylus acutus and C. intermedius, along with advances in the techniques of skin tanning, the species of the Caiman Genus acquired greater demand (Groombridge, 1982). This phenomenon can guide and justify the conservation of these species and the ecosystems they occupy (Palmisano et al., 1973).


CARIBBEAN SEA
N
COLOMBIA
BRAZIL
ZULIA STATE
MID-WESTERN LLANOS
GUAYANA

EVOLUTION OF THE PROGRAM.

The decision of the Government in 1982 allowing the commercial utilization of the Cayman is particularly important since it implies the acknowledgement that:
1) The closed season declared during the previous decade was a convenient measure, since there are indications that the populations recovered, reaching levels of significant abundance; but the closed season was not sufficient in order to avoid continued indiscriminate hunting and traffic of by-products, basically skins.
2) There are no reasons to continue the closed season. and the growing commercial value of the skin justifies a rational management of the resource.

A comparative analysis of the Resolutions which ruled the utilization seasons of 1982-1983; 1987-1988, and the one that rules the 1988-1989 season, in their fundamental aspects and with the implications on the System (Resource and environment, users, researchers, general public) permit the knowledge and evaluation of the degree of development of the "Cayman Program" in Venezuela.

RESOLUTION No. 445 (December 14, 1982):

1) Establishes the experimental character of this season.
2) The management takes place on private property in four Llanos states and in the state of Bolivar.
3) The granting of licenses remains conditional on the results from technical Reports made by officers of the MARNR.
The reports include: population census for each body of water, general characteristics of the habitat, practices adopted for the promotion and conservation of the species and other general data of legal character, such as property boundaries, geographical location, etc.
4) The Utilization Quota (Q) will oscillate between 7% and 12% of the estimated population for each property.
5) The utilization is based on the harvest of individuals whose total length is equal or greater than 1.8 m which corresponds to adult males (Class IV sensu Ayarzagüena, 1980), although 10 % of the total harvest can be animals whose total length is between 1.2 m and 1.7 m.
6) The mobilization of the by-products of the harvest requires direct authorization on the part of the MARNR, as well as the tanning of the skins.
7) The export of raw or semi-raw skins is prohibited.

Without disclaiming the merits of this first official regulation, it presents serious theoretical and practical limitations.
(1) Given that the technical reports are of exclusive responsibility of the MARNR, for lack of sufficient human and logistic

resources, it is not possible to attend such an extensive and complicated area as the one covered by the Program. Added to this is the fact that the Resolution is published in December and the utilization activity goes from January 1st to April 30th. Thus, there is not enough time for the elaboration and evaluation of the reports. These reasons lead to an underutilization of the resource and to the obtaining of low-quality products.

(2) As to the technical report in itself, note that the only variable on population which is evaluated is the abundance. In spite of only the capture of individuals in state IV being permitted, the characterization of populations according to their relative composition is not demanded or carried out. This omission can be translated into the granting of licenses on properties where, for example, the relative abundance of these individuals is inferior to the value of "Q" assigned. The situation thus described leads to illegal killings by some unscrupulous users in order to complete the utilization quota.

(3) The use of the Total Length as variable to guarantee the exclusive extraction of adult males through the subsequent inspection of the obtained skins, is not practical due to the high percentage of animals with amputations of the tail (up to 83% of the population, Cartaya, 1987). Therefore, it is more realistic to make reference to the Body Length (muzzle-cloaca).

(4) In the Cayman population of Guayana the individuals with a state of development IV reach smaller body sizes than their equivalents in the Llanos region, for which adult males in Bolívar could not be legally harvested.

These differences pose serious problems for the Management Model based on "size classes".

How to guarantee the source of skins of small sizes?

How to avoid, in other words, that individuals in a state of development III be harvested in the Llanos, and that the skins obtained be traded in Guayana for subsequent presentation as products obtained in the Region?

As a consequence of administrative and inspection voids such as those presented, the MARNR is lead to exclude Bolívar State from the Cayman Management Area. This situation still persists.

RESOLUTION No. 73 (December 29, 1987):

In this resolution important elements of control are added, such as the obligation of transporting the skins derived from the harvest on each property to a Center for Storage and Supervision of the MARNR. In these Centers the Mobilization Clearance Certificates are granted, in order to enter the skins in the tanneries.

Requisites are reiterated, such as the verification of the ownership of the land and auxiliary elements are demanded, such as maps elaborated by National Cartography, in 1:25.000 scale, where boundaries, roads and bodies of water in the ranch are indicated.

Unfortunately, much of the national cartographic information was registered at least 25 years ago, which renders it obsolete.

On the other hand, in the Resolution there are no major conceptual changes or modifications in terms of the Handling Model: besides, the faults already mentioned for Resolution No. 445 in points (1),(2) and (3), not only are in effect during the 87-88 season, but they also become accentuated by the ever growing number of applicants for Management Licenses.

Therefore, the MARNR, because of the impossibility of carrying out the field evaluations and technical Reports, and to avoid declaring a Closed Season, has opted for assigning utilization Quotas through population density estimates in terms of water area, calculated by interpretation and analysis of the 1:25.000 charts.

Once more, an untested empirical quota of 150.000 animals in state IV development in the Llanos States of Apure, Barinas, Cojedes and Portuguesa, is fixed by administrative means. Each private estate has a special quota not greater than 7% of the estimated population, as was previously indicated.

In Table I the variables of greater interest which synthesize the tendencies of the Cayman Program from 1982 until 1988, are shown.

TABLE 1

The Venezuelan Management
Program of *Caiman crocodilus* since 1983. (few variables).

Year:	1983	1984	1985	1987	1988
Variables:					
1. Geographic area	Bolivar Apure Cojedes Portuguesa Barinas	Bolivar state is excluded	idem	idem	idem
2. Licenses requested Licenses authorized	56 50	115 55	339 178	358 197	703 304
3. Number of Cayman authorized (x 1000)	13.97	85.23	235.69	105.31	153.03
4. Quota allocation (%)	7-12	7	4-7	2-3	7
5. Income (Bs/cayman) to Venez. State	2	2	2	20	40
6. Harvesting Cost (Bs/cayman)	?	?	75	125	150
7. Hunters' Income (Bs/cayman)	?	30	60	60	150
8. Price on the ranch (Bs/cayman)	?	100	200	300	1200
9. Mobilized salted skins. Meat units	2,214 1,856	72,612 28,780	232,063 110,357	102,689 64,456	152,045 ?
10. Minimal Net Incomes (Thousands Bs)					
a. Landowners	?	?	28,125	39,375	1,425,000
b. Local Hunters	?	2,400	13,500	10,800	22,500
c. State	24	160	4,500	3,600	6,000

TABLE 2

Some recent research undertaken in Venezuela about Cayman. (1983 - 1988)

Subject	Author
Cayman as a source of food a) For Humans b) For Animals	 Gutierrez (1984) Belda (1984)
Reproductive Biology in the Mid-Western Llanos	Romero (1984) Rodríguez (1984) Cartaya (1987) ASOBABA (In press)
Growth of hatchlings in captivity as a function of density and diet	Rodríguez (1984) Cartaya (1987) ASOBABA (In press)
Population status in: a) Guayana Area b) Northern Coast Area	 Gorzula and Paolillo (1986) Seijas (1986a)
Census methods	Rivero Blanco (1985) Davis and Fitzgerald (n.p.) Cartaya (1987, 1988)
Population Dynamics	Fitzgerald (1987, 1988) Cartaya (1987, 1988)
Structure of the Llanos populations	Woodward and Davis (1985) Seijas (1986b) Fitzgerald (1987, 1988) Cartaya (1987, 1988)
Feeding ecology in the Llanos	Fitzgerald (1988)
Evaluation of harvesting season	Rivero Blanco (1985) Cartaya (1987)

THE NEW STAGE OF THE PROGRAM

The philosophical, political and administrative changes that the Cayman Management Program has undergone since 1988 are manifested in:

I. The organization of all sectors linked to the resource. This has been achieved in principle through the establishment of two associations, one of industrialists (AVECUR), and another one for the breeding and conservation of the Cayman (ASOBABA), both non-profit organizations. These associations promote and sponsor the Foundation for Research, Handling and Management of Wildlife (FUNDAFAUNA, for its Spanish abbreviation), in which the principal conservationist associations of Venezuela converge (AUDUBON, BIOMA, FUDENA, SVCN and LA SALLE) and the MARNR, as permanent special guest.

II. The realization of the I WORKSHOP ON CONSERVATION AND HANDLING OF THE CAYMAN IN VENEZUELA (July 1988), and the effective follow up of its decisions and recommendations.

The most relevant recommendations and conclusions are:

1) To evaluate the potential of other areas. having in mind their eventual incorporation in the Program, provided that they satisfy the scientific, technical and administrative requirements established by the MARNR.

2) To demand as requisite to opt for a License, that they present an Annual Technical Report, with integral information on the cayman and its habitat. These reports will be undertaken by capable professionals, following a reliable and standard methodology.

3) To demand as requisite to opt for a License, the presentation of a HANDLING PLAN for the resource, of exact fulfillment during five (5) years.

4) To initiate a plan for the evaluation, follow up and control of the execution of the Management Program.

5) To define the utilization quotas in terms of the relative abundance of Group IV.

6) To continue the utilization of the resource based on the harvest of wild populations; and while a regulation for cayman hatcheries -which are being developed since 1987- is defined, these will have an experimental and repopulation character.

7) To design a RESEARCH PROGRAM to review and establish uniform criteria for field estimates, and to develop activities for the improvement of the habitat.

8) The MARNR must study the possibility of creating a NATIONAL COUNSIL ON WILDLIFE, formed by representatives of recognized institutions in the subject, and which will be the scientific authority for Venezuela before CITES. This way the MARNR would only be the administrative authority.

9) The industrial sector must try to achieve an optimum utilization of all by-products.
10) The implementation of formation and permanent training programs on technical aspects, as well as a Seminar for officials about CITES.

III. Resolution No. 60 (September 12) which regulates the 1988-1989 Utilization Season.

It is truly significant that all recommendations formulated in the I Workshop remain formally established in the Resolution (Recommendations 1 through 6) and the other recommendations on the implementing of courses, etc., have been accepted and are being worked on for their execution. For example, the first courses on technical formation training.

Such changes result from the coincidence of the following events:
1. SCIENTIFIC.
A better knowledge of Cayman, specially in the Llanos. Possibly as a result of the growing interest in Cayman, much research is taking place (Table 2), which feed the Management Program.

2. CONSERVATIONIST AND CULTURAL.
The decided participation of the conservationist societies of Venezuela in the proposal and/or acceptance of the conservation model based on the rational management -no longer "protectionist"- of the wildlife resources.

3. SOCIOECONOMIC.
a) The transformation of the national economic model, which has a tendency to diversify, with an accentuated independence from traditional sources of income, such as oil, basic industry, etc. The economic and alimentary potential of wildlife is recognized. It is estimated between 66,000 and 128,000 Metric Tons of annual animal meat for the year 2,000, which is equivalent to 5-9% of estimated domestic consumption for the same year (MARNR, 1987).

b) The realization of the profitability of Cayman management, on the part of landowners and industrialists. This implies changes of attitude in regard to the resource: (i) From casual, circumstantial user he becomes permanent user-manager, in analogy with the cattle activity; (ii) The income obtained from a proper handling of the cayman will not be marginal but significant, sustained and permanent.

4. POLITICAL.
The internal reorganization of the MARNR which leads to the creation of the NATIONAL FAUNA OFFICE. Relationships become more intense and the exchange of information on handling policies, etc. with the conservationist societies, with the industrialist linked to the resource, with cattle and agricultural producers, with scientists and the general public, intensifies.

Although it is true that there will always be obstacles in the perfect development of any program, it is also true that the Management Program of the Cayman Caiman crocodilus in Venezuela deserves the confidence from our country and the international scientific community.

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CROCODILE MANAGEMENT IN INDONESIA: PROBLEMS, POLICIES AND PROGRESS

A paper prepared for presentation at

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CROCODILE MANAGEMENT IN INDONESIA:

PROBLEMS, POLICIES AND PROGRESS

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CROCODILE MANAGEMENT IN INDONESIA:

PROBLEMS, POLICIES AND PROGRESS

1. INTRODUCTION

Efforts to manage the crocodile resource in Indonesia are being focused in the far eastern province of Irian Jaya (western half of the island of New Guinea), where the great majority of the country's crocodile stocks exist. Of the four species which occur in Indonesia, the two commercially important ones are found in Irian Jaya: Crocodylus novaeguineae, the endemic New Guinea freshwater crocodile, and C. porosus, the saltwater or estuarine crocodile. The latter species is widespread throughout other islands of the Indonesian archipelago, although evidently extirpated over much of its range. Best stocks remain in Irian Jaya, and to a far lesser extent, in the adjacent Maluku islands.

Tomistoma schlegelii, the Malayan False Gharial, appears to survive in protected areas of Sumatra and Kalimantan (McKinnon, 1982), although apparently in low numbers. Because of ventral osteoderms the species is economically unsuitable for rearing and breeding. Nonetheless, over-hunting for skins (at approximately 40% of value compared to C. porosus [J. Jong, pers comm]), along with habitat conversion, appears to have caused decline in abundance and distribution of this elusive species.

C. siamensis, the Siamese crocodile, may persist in freshwater swamps of Kalimantan (Groombridge, 1982), but this remains to be confirmed.

Over vast areas of swamp and lowland river systems in Irian Jaya, crocodiles represent the only immediately available resource for economic development. Need and potential is greatest in the most remote lowlands, where remaining strongholds of crocodile populations can be found, and the benefits of development least felt. In addition to the fundamental aspect of sustainable utilization, there similarly exists much potential for socio-political benefits such as village income generation, earnings management -- even enhanced political stability of some communities. Consequently, the project has taken on a wide scope, and with the funding resources at hand, a timely and unique opportunity is afforded to integrate conservation and development over a considerable part of the province.

The Directorate General of Forest Protection and Nature Conservation (PHPA) - Government of Indonesia (GOI) and the Food and Agriculture Organization (FAO), through a trust fund grant provided by the Japanese government, have cooperated since October, 1986 in the joint project entitled "Crocodile Industry Development on a Sustainable Basis". Matching inputs from GOI are being contributed through a complimentary project "Breeding of Endangered Species of Crocodiles in Irian Jaya". Important preparatory surveys and project proposals resulted from an FAO consultancy (Lever, 1980) and a World Wildlife Fund - PHPA study (Whitaker, Sukran and Hartono, 1985). The current FAO-PHPA project runs for three years, but the need for at least a two year extension is widely recognized, and has recently been approved in principle by the cooperating parties.

2. MANAGEMENT AIMS AND POLICIES

2.1 FAO-PHPA Project Objectives

Based upon the agreement between FAO and PHPA as presented in the Plan of Operations, principle objectives of the project are to:

A) Establish a crocodile ranching and farming industry in Irian Jaya, primarily consisting of a network of holding pens and ranches at the village level, to supply young crocodiles to commercial farms where they can be economically reared to desired culling size.

B) Provide technical expertise relating to crocodile husbandry, including, where feasible, the promotion of breeding ventures.

C) Regularly monitor wild populations of the two crocodilians, results of which are to be used (e.g. setting harvest quotas) to assure that the resource is being developed on a sustained yield basis.

D) Promote rural development by ensuring that village-level crocodile producers receive a fair share of industry profits; in order that these proceeds are effectively managed to the benefit of local communities, village cooperatives are to be established.

E) Revise legislation regulating crocodile skin trade and ranching/farming operations.

F) Assist the development of processing and marketing of industry products to obtain maximum economic benefit.

G) Train and deploy a team of Indonesian counterparts in the skills of crocodile husbandry, monitoring techniques, enforcement of trade regulations and protected areas management.

2.2 Government Policy and Guidelines

2.2.1 Pola PIR

Development of the crocodile resource in Indonesia is envisioned along the lines of Pola PIR, loosely translated as "Pattern of People-Emphasized Rearing", or a people's enterprise system, derived from forest plantation management in Java (IPB, 1986). As Figure 2.2.1 illustrates, the industry is to center around establishment of rearing and breeding farms known as 'nuclei', which have sole rights of export. Nuclei are supplied with crocodiles from sub-units termed 'plasmas', which are also expected to rear and breed crocodiles. The third and most basic level is a network of 'collectors' to catch crocodiles for forwarding to plasmas and nuclei.

Plasmas are intended to supply collectors with tools such as torches, batteries, outboard motors, fuel and pen construction equipment, in addition to acting as a principle force behind establishment of village cooperatives. Minimum prices paid to collectors are to be fixed by the government. Although not yet formalized, Rp. 100 (USD .06) /cm total length is becoming the de facto minimum.

The Pola PIR development pattern resembles industry structure in Papua New Guinea. Nuclei are represented by commercial rearing and breeding facilities. Plasma units are similar in concept to midi-ranches (see Hollands, 1985), and collectors perform an identical role as village holding pen operators. There is, however, much more emphasis placed on rearing and breeding at the village level than in PNG. Some of the greatest drawbacks and difficulties related to industry development (e.g. feed supplies, water availability and management practices) are being encountered at this level.

2.2.2 Licensing

Industry development along the lines of Pola PIR is regulated by a system of six permits:

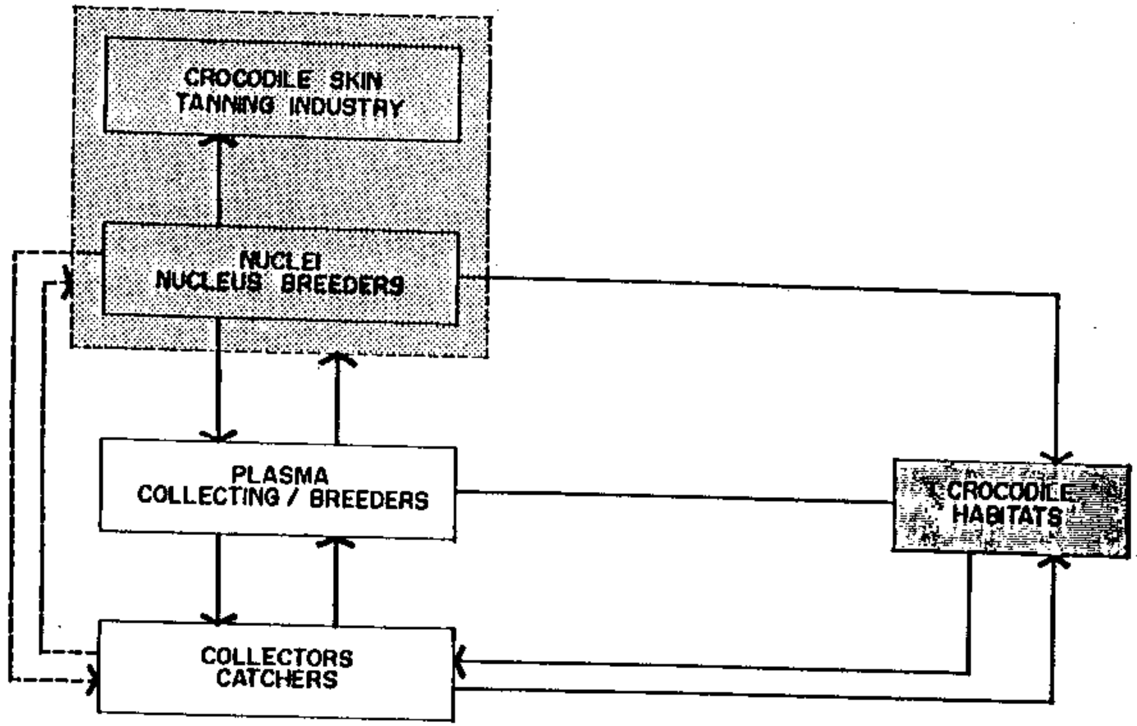
1) Rearing and Breeding

2) Capture of Live Crocodiles

3) Transport of Live Crocdiles

4) Culling

FIGURE ·2·2·1· POLA PIR STRUCTURAL FLOW CHART



SOURCE : Adapted from Figure 14 "Crocodile Breeding System and Habitat Development", of Feasibility Study of the Crocodile Skin Industry in Irian Jaya

5) Transport of Skins

6) Export

Each of these permits is issued through the office of the Directorate General - PHPA. Those related to local regulation (e.g. transport of live crocodiles) are often delegated to regional and provincial PHPA (Balai and Sub-Balai) or regional forestry (Kakanwil) offices, ostensibly in order to expedite processing. There appears to be scope for further streamlining of licensing procedures and format, as well as possible decentralization. In this regard a review is scheduled before the end of 1988. Further computerization of a licensing records system and trade data collection/analysis will also be studied.

3. MONITORING RESULTS

The results of previous and project-conducted monitoring surveys of crocodile populations in Irian Jaya are discussed in a separate paper (Frazier, 1988). A summary of the conclusions is included here.

Surficial crocodile monitoring surveys have been concentrated in three main regions of Irian Jaya: 1) the Mamberamo-Rouffaer river system; 2) associated lakes and tidal rivers in the west and south of Kimaam Island; and, 3) along the shoreline and inflowing rivers of Bintuni Bay. The Mamberamo-Rouffaer complex is a primary stronghold of C. novaeguineae while Kimaam Island can be regarded similarly for C. porosus. All of these regions, as well as others not yet thoroughly researched, have been and are moderate-to-heavily hunted. C. porosus populations within Bintuni Bay appear to have undergone some of the most severe depletion. Of foremost concern with regard to crocodile exploitation throughout Irian Jaya is the heavy pressure on the breeding component of the populations of both crocodilian species. This is especially so considering that development of the crocodile industry in Irian Jaya depends, for the foreseeable future, on large numbers of young supplied from wild populations.

3.1 Mamberamo-Rouffaer System

A variety of freshwater habitats have been night-surveyed in the Mamberamo-Rouffaer region. Unfortunately, detailed maps or aerial photos are lacking for many survey locales and this has complicated interpretation of observation data. However, aerial nesting surveys, trade records and examination of confiscated skins have helped to fortify monitoring data in this area.

There are strong indications that C. porosus populations have been seriously diminished throughout the region. Whereas live capture data showed C. porosus to constitute approximately 10% of pen stock in one area, nest surveys, night surveys and inspections of seized skins, point to a lower region-wide population proportion closer to 5 percent.

Initial night counts and aerial surveys have been conducted in the Mamberamo delta, where expanses of intact crocodile habitat exist. Much of this is thought to comprise primary C. porosus habitat, but indications from both survey regimes are that populations have been severly depleted. This tentative finding is supported by qualitative assessments from delta hunters and other residents.

C. novaeguineae populations are heavily exploited by both legal concerns and hide-smugglers within the region. Some areas exhibit very low population levels (e.g. the largest tributary of the Rouffaer and two of its associated tributaries have yielded only 3 observations on each of two occasions during several hours of survey). Still other locales appear relatively untouched by heavy exploitation (e.g. another major tributary of the Rouffaer yielded a density of 3.2 crocodiles/km over an estimated course of 26.5 kilometres). Aerial nest surveys in a four-zone area of the Mamberamo-Rouffaer region have indicated that nesting population levels within some areas are on a par with healthy levels observed in the ecologically similar Sepik region of neighboring Papua New Guinea. It is likely that sizeable crocodile populations remain in remote and as yet unexploited swamps and headwaters of rivers. However, in the absence of calculable densities, interpretation of existing observation data from many survey locations, especially scroll and oxbow lakes, will have to rely on a future site-by-site historical comparison.

Of particular concern though, are regional crocodile skin data indicating that mean size of wild hides of both species has been dropping in recent years. This is coupled with the observation that the harvest percentage of breeding-size hides has remained substantial yet also is in decline. Records indicate that in a 1978/1979 sample of 10,926 skins (5.4% C. porosus), average size of C. porosus hides was 18 center bellywidth inches (CBWI) while C. novaeguineae skins measured on average 17 CBWI (Lever 1980). Thus a high level of breeding size crocodiles were being harvested. A recent sample of 425 confiscated skins (4.7% C. porosus) averaged 12.4 CBWI for C. porosus and 13.6 CBWI for C. novaeguineae, while the proportion of breeding size skins was 15 and 20%, respectively.

3.2 Kimaam Island

The current project's entire set of Kimaam crocodile population data was derived from an intense riverine survey of tidal rivers on the west and south of the island during July and August 1988 (S. Frazier, M. Silvius, in prep). Night-surveys covering an estimated 306 km (some replicated) and daylight travel yielded 426 and 15 crocodile sightings, respectively, of which 159 were identified as C. porosus. No wild C. novaeguineae were recognized during the survey but this species has been observed in sizeable numbers in holding pens at several locations over the east and south of the island (S. Frazier, unpubl data). It is likely that C. novaeguineae populations are concentrated in interior freshwater swamps.

Calculated density values (based on estimated survey route length) ranged from 0.18 to 4.7 crocodiles/km (from courses of 22.6 and 3.4/6.6 km, respectively). However almost 66 percent of the total kilometres (by survey), over the variety of river sizes, yielded crocodile density ratings of less than 2.0/km. High densities (>3.0 crocodiles/km) occurred over only approximately 8.4 percent of the survey kilometres. Age-structure observations indicated that at least 43 percent of the crocodiles were hatchlings. Yearlings, juveniles and adults (1) accounted for 12.7, 1.4 and 0.23 percent of the sightings, respectively (although 3 additional adults were seen during daylight travel). The remaining 42.4 percent of observations were classified as "eyes-only" (EO) crocodiles. The relatively high percentage of EO crocodiles was often artificially high, stemming from sub-optimal survey conditions or operations under time constraints, but likely in part due to hunting pressure. The overall impression though was of a depleted adult component of the population. Nash, Nash and Irwanto (1984) reached a similar conclusion.

There was evidence of heavy pressure on the breeding segment of the crocodile population at Pulau Kimaam. Frequently observed at the mouths of tributary rivers, even in areas remote from human settlement, were poles which local informants said were used to set baited hooks for catching crocodiles. This method selects for larger size (i.e. breeding size) individuals. Several semi-permanent hunting camps were sighted along mangrove-lined river courses. An inspection of two such sites revealed scores of crocodile bones. Several skulls from breeding size animals were measured ranging in length up to 55 cm. There are no wild skin data from this region to analyze according to age-composition.

3.3 Bintuni Bay

Most of the monitoring data for Bintuni Bay comes from a recent survey regime conducted during September 1988 (R. Whitaker, in prep). Approximately 428 km of river courses and bay shoreline were night-surveyed. A total of 183 crocodiles (including 68 C. porosus and 59 C. novaeguineae) were sighted.

This survey regime indicated seriously depleted numbers of C. porosus throughout large expanses of Bintuni Bay. Several very lengthy segments revealed extremely low crocodile densities (e.g. 85 km : 0.012 crocodiles/km; 58 km : 0.017 crocodiles/km; 60 km : 0.050 crocodiles/km). With the exception of one 3 km survey that included a small oxbow lake, all of the assays produced crocodile densities under 2.0/km. Whitaker, Sukran and Hartono (1985) observed 42 crocodiles during 5 sessions covering 102 km in a previous survey of Bintuni Bay. That results in an overall density rating of 0.41 crocodiles/km. If the current set of data is regarded in this fashion, then the outcome is very similar (0.43 crocodiles/km).

Regardless of how the data are interpreted though, C. porosus has apparently suffered serious impoverishment in Bintuni Bay. This diminution of the population has even occurred in areas where large tracts of otherwise undisturbed and ideal habitat still exist (R. Whitaker, pers comm). Although habitat loss is certainly ongoing in Bintuni Bay, the immediate cause of a depletion in crocodile numbers is more likely attributable to over-hunting. During the recent survey local informants revealed that illegal skin trade continues to engage local people on a wide scale. In fact, most canoes observed were armed with harpoons. Some local hunters seem reluctant to acknowledge the obvious scarcity of crocodiles, insisting that numbers are high even in the face of many unsuccessful hunting attempts. Hunters will probably continue to operate on an opportunistic basis in the absence of other economic incentives. Poles for anchoring baited crocodile hooks were frequently encountered during the surveys (R. Whitaker, pers comm).

3.4 Other Areas

Limited crocodile surveys have been conducted in other areas of Irian Jaya. Night counts in four "Bird's Head" rivers and two large lakes along the lower Mamberamo River were carried out in early 1988. Water levels were seasonally high and sightings were predictably low under these sub-optimal conditions. Plans exist to return to these areas to collect more definitive data in the near future.

A 20-25km night survey during May 1988 of a river segment in the Asmat region of southern Irian Jaya, said to be one of the last remaining waterways in the lower reaches where crocodiles could still be encountered, did not yield a single crocodile observation (Rumbarar, 1988). This reinforced reports that the area has endured heavy hunting.

During August 1988, an estimated 190km of the Maro River was surveyed in three consecutive night-time sessions. This river is heavily trafficked and has suffered considerable human disturbance along its banks. A total of 16 crocodiles (7 identified C. novaeguineae) were observed during the survey (S. Frazier, M. Silvius, unpubl data). This yielded a very low density value of 0.084 crocodiles/km. Over such a long span, tidal conditions were ever changing, which certainly influenced (lowered) the number and quality of observations. Nevertheless, this river appears to have undergone serious depletion of its crocodilian populations. Furthermore, it would appear that C. porosus has been all but extirpated in the river based on these observations and local accounts (e.g. the survey guide predicted that no C. porosus would be observed). There were no sightings made in the last several hours of survey travel when the river became increasingly tidal in character.

4. THE ILLEGAL SKIN TRADE

The main obstacle to development of a sustainable crocodile industry continues to be the thriving illegal trade in crocodile skins from Irian Jaya to other nations. This is destabilizing supplies of young for rearing and breeding ventures, depleting local populations, creating social discontent, undermining resource management ability, and denying the country full export value of its resource.

4.1 Deduced Level and Seriousness

Compilation and interpretation of crocodile skin trade data deduced to originate from Indonesia is reported by Frazier (1988). Varying skin data measures and the nature of clandestine trade render accurate analysis an exceedingly complex task. Minimum annual trade from Indonesia (and by extension the great majority from Irian Jaya) is estimated at some 15-20,000 skins, most of which appears destined (at least until recently) for markets in Japan and Singapore. It is entirely possible that sizeable unreported trade also exists with additional countries, particularly non-Party CITES states in the Asia-Pacific region.

Initially considered, a level not much in excess of 20,000 skins per annum is not very worrisome. After all, neighboring Papua New Guinea, which features the same crocodilian species, similar habitat and approximate stocks as Irian Jaya, has in recent years exported some 25,000 wild-harvested skins per annum (J. Wilmot unpbl data). However, Papua New Guinea is effectively protecting the critical breeding component of its populations (Hollands, 1985; Hollands and Wilmot, 1985), while the illegal trade from Irian Jaya remains characterised by >20% of skins from breeding age animals. Reduction of this percentage would likely go far towards reversing the apparent trend of depletion. Furthermore, while approximately 90% of current composite trade (i.e. 1,500-2,000 legal skins vs 15-20,000 illegal ones) is unable to be adequately monitored, resource management ability remains severely hindered.

4.2 Control Measures

4.2.1 Culling of Non-serious Enterprises

Both control of illegal trade and development of and committed crocodile enterprises would appear to be facilitated by suspension or cancellation of licenses held by firms showing little or no interest in crocodile rearing, particularly ones which appear to be fronts for illegal skin trading. Such traders could likely be more easily kept out of the field, as their cover of capture and rearing licenses would be removed. Serious rearing concerns would, in turn, likely benefit from more stable crocodile stocks and supply of young.

4.2.2 Auctions of Confiscated Skins

Recent experiences with seizures of illegal crocodile skins in Irian Jaya indicate that development of the crocodile industry and enforcement effectiveness in the province would be significantly promoted by amendments to current policy.

Bureacratic processing delays have often led to skin spoilage, thus depriving Indonesia of full resource value. Expeditious processing would improve this situation, but much greater benefits would result if confiscated skins could be sold by international auction. Such government sanctioned sales, which would include the accurate cataloguing and grading of skins, would generate higher profits than recent winning bids, in addition to creating a significant additional source of revenue. If a portion of auction proceeds could be awarded to apprehending Forest Police or other enforcement officers, this would likely serve as an important incentive for these low-salaried staff to effectively perform the duties envisiged by establishment of their posts.

4.2.3 Canine Enforcement Assistance

Enforcement of crocodile laws is in large part made difficult by the vastness of the crocodile producing area in Irian Jaya, an even wider smuggling complex, and legislation (e.g. Inpres Number 4 [1985]) which prohibits inspection of inner island cargo without evidence of contraband. This decree serves to speed bureacratic processing of consignments, but preempts much needed spot checking operations.

Nonetheless, air and sea cargoes may be efficiently examined by trained sniffer dogs. It has been proposed that a small team of dogs be trained, if necessary utilizing project funds, to assist project enforcement operations in suspected centers of crocodile skin smuggling. Still to be worked out are acquisition costs, training and care requirements, and counterpart attachment. If found to be reasonably economical, canine assistance could add a new dimension to efforts aimed at controlling illegal trade.

4.2.4 Enforcement Operations

Following an initiative by the PHPA Directorate General in consultation with law enforcement officials, joint field operations (Forestry/ Provincial Police/ Military) were launched in late March to arrest persons involved in organized hunting and skin buying schemes, and to seize stocks of skins, supplies and equipment related to crocodile hunting.

Initial efforts were focused on the Mamberamo River system, scene of intensive project field work, and where an alarming increase in hunter activity has been noted since 1986. Particularly disturbing was a disastrous scheme to purchase some 15,000 "existing stock", mostly breeding size, crocodile skins, which were alleged to be the result of either village rearing efforts or traditional subsistence activity (i.e. meat for local consumption). Field surveys and interviews with a variety of local officials and villagers showed unequivocally that no such stock existed.

It was further apparent from the placement of large quantities of salt, batteries and camping equipment by certain unsanctioned enterprises that the scheme was a thinly disguised hunting effort, the scale of which would seriously deplete area crocodile populations. The Directorate General's refusal to endorse the scheme and appeal to provincial authorities for assistance has been instrumental in dealing firmly and swiftly with the crisis. The resulting field enforcement operation was initiated none too soon, and major damage to remaining Mamberamo crocodile stocks has been averted. Although some illegal skin buyers remain active in the river system, many have retreated from the field. The effectiveness of recent operations has been bolstered by a clampdown on the unauthorized use of non-civilian aircraft in the transporting of skin buyers, supplies and crocodile skins.

Enforcement operations were extended in June, 1988 to the Sumo-Siru village area south of the main cordillera in Jayawijaya regency. It is hoped that during the second half of the year additional operations can be organized for other suspected centers of illegal trade.

4.2.5 Controlled Hunting

Enforcement operations may provide immediate improvement with the illegal trade problem, but to assure that the crocodile resource is conserved on a long term basis, there is a growing realization that controlled crocodile hunting would act as a complement to existing policy and provide a variety of much needed benefits, specifically:

1) Displace illegal traders by paying substantially higher prices to local hunters. Illegal skin buyers would tend to be outcompeted because prices received from Singaporean middlemen are 20-40% lower than full-value markets in Japan, Europe and the USA.

2) Loss of the majority of trade which Singapore currently enjoys would encourage that country to reconsider its CITES reservations on *C. porosus* and *C. novaeguineae*, and possibly promote responsible trading and investment in the Indonesian crocodile industry.

3) Legalized exports can be taxed to generate revenue for the government, part of which might be plowed back into PHPA for regulatory and monitoring activities.

4) By controlling a significant share of its crocodile exports, Indonesia would have enhanced price negotiating power on world markets.

5) Higher prices to local producers (hunters) would in turn increase the value of the resource to rural people, and the likelihood that they will more carefully utilize crocodiles for long term benefit ("value-added conservation"). Local people would welcome higher prices for skins, accessibility to crocodile meat, and the opportunity to derive benefit from their hunting skill. By realizing that the government is more responsive to their needs and hunter-gatherer lifestyle, they should be more receptive to abiding by conservation-oriented restrictions (e.g. protection of breeding size crocodiles). This would be reinforced by project staff, who will emphasize and demonstrate that the

new policy is designed to directly benefit local people. With true support and mutual trust, villagers could be effectively involved as guardians of the crocodile resource, a role which PHPA or the project alone cannot practically perform over such a vast and difficult area as the lowlands of Irian Jaya.

6) Carefully controlled hunting is an entirely acceptable management strategy to the CITES Secretariat, whose principle concern is sustainable utilization. If successfully implemented, this would support Indonesia's proposal for relaxed international trade restrictions, which in turn would allow the country greater flexibilty in managing its crocodile resource.

4.2.6 Inhutani II Skin Purchase Plan

A feasibilty study of the potential to buy wild-harvested crocodile skins directly from local hunters was completed at the end of April 1988. A recent forestry graduate and employee of the state owned forestry enterprise Inhutani II accompanied FAO and Forestry Department counterparts to most villages in the Mamberamo River region. This area is the most appropriate location in the province for experimental skin purchasing, as geographically it is nearly a 'closed system', thus facilitating control over origin and movement of crocodile skins.

Meetings were held with villagers to: 1) elucidate the aims and advantages of the buying plan, and 2) solicit local reaction to the required consensus regarding conservation-oriented restrictions. These have been developed into four categories:

1) **Acceptance of a harvest quota,** which would be determined by the FAO-PHPA project, based on apparent crocodile population status, quality and availability of habitat, and minimal needs of local people;

2) **Assurance that illegal skin buyers will not be received.** Villagers must agree to refuse such buyers and to report their presence to local authorities or project personnel;

3) **Only skins measuring 10 inches (25.4 cm) to 18 inches (45.7 cm) will be harvested,** in order to promote protection of breeding stock in the wild and reserve young for rearing ventures and population recruitment. Incidental extra-limital catches (e.g. in fishing nets; hunter errors) must be surrendered to enforcement personnel.

4) **Agree that no hooks will be used to hunt crocodiles.** Hooks select for medium-sized and large

crocodiles, and thus pose a significant threat to conservation of crocodile stocks.

In addition, it may be appropriate to attach requirements which support the collection and/or rearing of young (e.g. Pola PIR participation). However, immediate benefits from skin purchasing should motivate villagers to further support project aims (e.g. constructing collection pens where apprpriate, and, as deemed feasible, attempt rearing ventures).

Penalties for non-compliance with these restrictions have been discussed. Moratoria appear the most effective means to demonstrate the seriousness of reneging on the agreement, while retaining opportunity for future participation in the buying scheme. Violators of the above conditions would be subject to suspension of hunting privileges for a (suggested) period of not less than 6 months. Ad interim project enforcement operations would be focused on offending villages as yet an additional incentive to support the controlled purchase scheme.

During the course of the feasibility study, a detailed estimation of the logistics and operating costs involved with such a venture was achieved. Indications are that an overall quota for the Mamberamo system should be set at some 4,000 - 5,000 skins per annum. This level would almost certainly be sustainable, and if carefully distributed locally, the attached conservation-oriented restrictions could even induce recovery of stocks in depleted areas.

Assuming current international market prices remain steady, and that the harvest would consist of an approximate 50/30/20/mix of Grade 1/2/3 skins, a minimum average price of Rp. 5,000 - 6,000 per bellywidth inch could be paid to local hunters. Moreover, three-tiered purchasing to include standard downgrading for Grades 2 and 3 would induce hunters to more carefully hunt, prepare and preserve their skins, thus significantly improving the value of the harvest.

Efficiently implemented, the controlled purchase scheme would likely yield considerable profit for Inhutani II. If much of this profit can be cycled into government management needs (e. g. enforcement activities, crocodile population monitoring, village extension patrols), then the significant costs of project operations could be adequately funded once FAO assistance is phased out. Simultaneously, fair prices paid to local villagers would result in an enormous increase in earnings from skin sales, and may well mean that fewer crocodiles than at present would need to be hunted. Moreover, fair prices make possible the creation of village cooperatives, another important stated objective of the FAO-PHPA project. This would represent a vast improvement over the very low current prices and unfair barter agreements by smugglers and their middlemen, which often result in negligible benefit to local villagers and widespread social discontent.

The proposed limited harvest was well received by villagers throughout the Mamberamo. The essential need for restrictions appears understood, and villagers aquiesced in their willingness to follow.

Joint project/police operations during March and April paved the way for trial purchasing. A pressing need was seeen to initiate the plan, owing to the onset of the June-October dry season when hunting pressure on crocodile stocks is greatest. Paradoxically, hunting is most amenable to control during these low water months. Medium-sized crocodiles are directly encountered by hunters and can be selectively speared, or sometimes even trapped by hand. This is in sharp contrast to later in the year when crocodiles disperse with rising flood waters into adjacent swamp forests, where indiscriminate setting of hooks is virtually the only efficient hunting method. This practice is very destructive of crocodile stocks because it selects for medium-sized and large crocodiles, thus depleting important breeding cohorts.

Concern was expressed regarding the fairness of parastatal purchasing. The major misgivings cited were that a monopolistic situation would be created whereby private enterprises are excluded from the scheme, and that purchase prices might be unfairly set.

These fears should be allayed for several reasons. Inhutani II maintains an excellent management 'track record'; moreover, their intention for involvement has been clearly expressed from the start. Rather than an interest in maximizing profits from such a venture, their stated primary aim is to stabilize the current seriously disturbed situation, with particular emphasis applied to sustained resource use, and a fair share of benefits received by local producers.

Most important, Inhutani II executives are amenable to close monitoring of their purchasing activities. The value of this willingness cannot be overemphasized. The more accurate our data on number, sizes, species, and local origin of crocodile skins, the better the statistical feedback on the structure of local crocodile populations and trends in their utilization. This is an integral aspect of effectively monitoring the crocodile resource, which is also one of the most fundamental and pressing needs of the project, and a major expectation of Indonesia as a CITES signatory.

4.2.7 Private Enterprise Purchasing

Following an obstructed start to controlled purchasing by Inhutani II, it was decided that a more politically acceptable solution would be to open the crocodile skin trade throughout Irian Jaya to private enterprise purchasing. Two additional skin purchase licences have been issued to established crocodile enterprises, with one of the Jayapura commercial enterprises also allowed to purchase skins in northern Irian Jaya in addition to Inhutani II. This essentially divides the activity into three spheres: 1) the western Bird's Head region and southern coast as far east as the Asmat area; 2) southern Irian Jaya from the Asmat region south; and, 3) the Mamberamo, north Irian coast and east coast of Cendrawasih Bay.

So that the scheme is fair, all existing crocodile rearing enterprises will be eligible to collect and purchase skins in the field. However, skins must be sold to each sphere's licensed exporter. Skin purchase restrictions will follow those outlined for Inhutani II, especially size limits, but may allow for an initial purchase size tolerance of 10% and clearing of stocks. In conjunction with Forestry Department offices and the provincial government, and with advice from project staff, an association of buyers and exporters will be formed to set operational guidelines, penalties and reporting procedures.

Due to the wide area of operation and ease of illegal purchasing on the side, a supervisory network is already apparent as one of the most pressing needs. Self-policing by association members may assist in this regard, but also under consideration is an association funded pool to sponsor supervisory personnel. These could also report on the benefit of skin sales to local communities. Villagers in remote swamps of Irian Jaya are largely unsophisticated and easily influenced, and have difficulty counting money and accurately measuring skins, not to mention calculating their due return from skin sales. Thus, they are particularly vulnerable to being taken advantage of.

The new skin purchase scheme does carry the risk that concurrent smuggling of over- and undersized skins may continue unabated (or possibly be exacerbated) by easier skin buyer access to crocodile producing areas. However, an association of members acting together to stabilize trade for long-term benefit, and even enhancing profits by greater international bargaining power and reputation, may well eventuate as the workable solution in the Indonesian context to the industry-threatening problem of uncontrolled exploitation. Lacking any foreseeable alternative at this stage, the scheme deserves every chance to succeed.

4.2.8 Diplomatic Efforts

Diplomatic initiatives need to be directed to governments of those countries maintaining CITES reservations on Indonesian crocodilian species to withdraw them. Non-Party regional states, for which indications exist that Indonesian skins are being imported (e.g. Taiwan), should either honor GOI trade restrictions or accede to CITES without reservations on Indonesian crocodilian species, in order to eliminate markets for smuggled goods.

Most notable among the Parties is the Republic of Singapore, holding CITES reservations on both C. porosus and C. novaeguineae, and which, according to strong circumstantial evidence, is the major initial destination of illegally traded crocodile skins from Indonesia. Some of these skins appear to be processed in Singapore, but the bulk are ostensibly re-exported.

By withdrawing its reservations, the country would likely loose most middleman profits, but these appear to be on the order of only USD 1-2.5 million per annum. It is difficult to understand why, in the interest of ASEAN cooperation and with increasing awareness of the manifold detrimental effects stemming from the illegal skin trade, Singapore, with economic policies geared towards advanced technology and service industry development, continues to protect such a controversial and negligible business interest, especially one which appears to hold little long-term future if allowed to remain uncontrolled.

5. RESOURCE UTILIZATION AND DEVELOPMENT

Prospects for sustained development of the crocodile resource in Irian Jaya are bolstered by several advantages, chief of which are: significant remaining wild populations, inexpensive construction and labour costs, and evolving management potential and technical expertise. However, the profitability of a smoothly running industry is still in doubt for many aspiring enterprises, as a cheap and regular supply of feed is either limited or unavailable. As well, constraints on supplies of freshwater and young crocodiles in some locations must also be overcome. Add to this the apparent continuing decline of wild crocodile stocks plus interference by illegal traders and their supporters, and prospects become more uncertain.

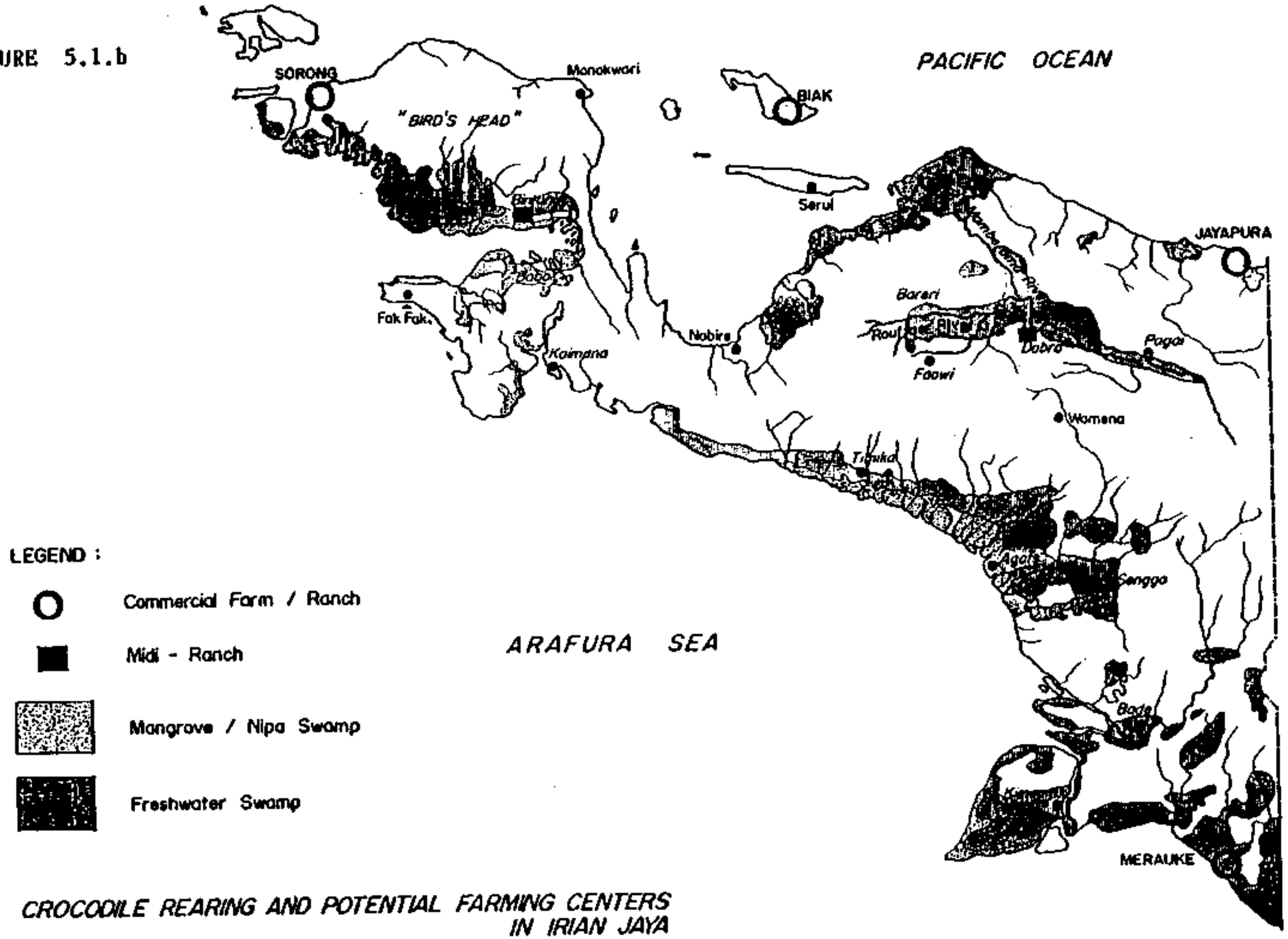
5.1 Rearing Ventures

Figure 5.1.a shows locations of existing and potential centers of crocodile rearing and breeding in the province. Table 5.1.b details approximate stocks as of 01 September 1988. A description and assessment of commercial enterprises, including major constraints and middle-term prospects, is presented on a regional basis in sections 5.1.1- 5.1.3.

Table 5.1.b Captive Crocodile Stocks in Irian Jaya

Enterprise	Location	# C. p.	# C. n.	Total
C.V. Bintang Mas	Jayapura	1,107	3,642	4,749
C.V. Sinar Asahan	''	~80	~240	~320
C.V. Sikoway Jaya	''	0	459	459
P.T. Sentani Valley	''	1	5	6
P.T. Bintang Diai	Dabra	297	4,121	4,418
C.V. Ridha	Nabire	~120	~400	~520
C.V. Ramli	Biak	2	15	17
C.V. Nikmat	Merauke	432	386	818
C.V. Jaya Abadi	``	162	260	422
C.V. Trinaga Kreasi	``	2	1	3
C.V. Modan Baru	Sorong	~250	1	~251
P.T. Alam Murni Bahana	``	~300	~450	~750
Forestry Dept./PHPA	``	120	463	583
TOTALS		~2,873	~10,443	~13,316

FIGURE 5.1.b



CROCODILE REARING AND POTENTIAL FARMING CENTERS IN IRIAN JAYA

5.1.1 Jayapura Area

C.V. Bintang Mas continues to show good progress with its rearing operations. A cull of 960 crocodiles was commenced in April but postponed after about 300 in order for the company's tanning partner to evaluate the quality of initial skin processing.

Trash fish feed from the company's off-shore prawning operations appears insufficient for rearing of >5,000 head. Feed acquisition should improve with the expected purchase of additional trawlers. As well, difficulties in obtaining an ample supply of young crocodiles from the wild are being experienced. This is variously related to disturbance of collecting centers by illegal hunting activities, logistical constraints, and competition from other purchasers of young. The quality of harvested young also needs improvement. Project personnel will be assisting in this regard by emphasizing through extension services the importance of capture by hand instead of spearing.

Bintang Mas has constructed a separate facility to rear the smallest of its crocodiles (<1.2m total length [TL]). In addition, the managers plan to build a hatchery and controlled environment pens to rear hatchlings produced from the envisaged Pagai area trial egg harvest (see Section 5.4). A project consultant in commercial aspects of crocodile rearing has advised the company regarding current 'state of the art' design.

Long-established C.V. Sinar Asahan (now known as C.V. Sinar Asahan Raya) has shown some interest in expanding its rearing pens, and to organize fixed sources of young crocodiles. Although this is a noteworthy improvement, economic prospects for the company are not favourable while their cost of obtainable feed hovers around Rupiah 1,000-1,500 (USD 0.62- 0.93) per kilogram.

C.V. Reptilindo Eka Pratama (formerly C.V. Bintang Diai) is experiencing difficulties with sufficient water and feed for its crocodile stocks. In remote outstations such as Batom and Merauke, pens are no longer in use. By contrast, management has improved considerably at Dabra, Mamberamo Hulu, the company's main rearing station. However, prospects are limited due to lack of sufficient feed for more than ~3,000 head. Moreover, the cost of fish from the Mamberamo and nearby lakes and lagoons (the only source of supply) appears too expensive and irregular for a large-scale rearing concern. Prices paid to area villagers for young crocodiles are low compared to Bintang Mas (e.g. Rp. 5,000 [USD 3] versus Rp. 6-10,000 [USD 3.5-6] per 60 cm total length); however, this is understandably attributable for the most part to higher overhead. Prices for live medium-sized crocodiles (>10 inch belly width) are

Rp. 5,000-10,000 per inch - best along the Mamberamo. Considering the situational difficulties of centering its operations in a remote outstation such as Dabra, C.V. Reptilindo has made admirable progress over the course of the last year.

It has been suggested that shifting main rearing operations to Nabire or Jayapura might enhance the company's economic prospects. Unfortunately, neither location features a readily available source of cheap feed, thus necessitating an independent fleet of small boats to supply adequate amounts in order to operate commercially. Even then, profitability would not be assured.

C.V. Reptilindo Eka Pertama may, however, find that the frozen fish factory and cannery at Biak can provide sufficient quantities of cheap feed, if not at present, then in the near future when expanded production is anticipated. A thorough feasibility study is needed, including assessment of freshwater sources and potential for a guaranteed supply of trash fish. As a hub for flights to the interior of northern Irian Jaya, Biak offers a convenient location to receive and rear young crocodiles from a network of village holding pens.

5.1.2 Sorong Area Private Enterprises

P.T. Alam Murni Bahana continues to expand their facility and improve rearing techniques. A cull of third and fourth year animals was begun in late February. By the end of May about 400 mostly *C. novaeguineae* of bellywidths ranging from 12-20 inches were skinned, with some 400-500 cullable animals said to remain in the pens.

C.V. Modan Baru has completed additional rearing pens at its site outside Sorong, but is experiencing an extended delay in obtaining a capture license to provide additional stock. Management at the facility is of adequate standard, although improved flushing of pens and removal of uneaten food would likely enhance growth. The enterprise currently rears some 250 *C. porosus* and 3 *C. novaeguineae*, mostly juveniles and sub-adults. In addition, a relatively large area has been enclosed for attempted breeding.

5.1.3 Sorong Government Farm

5.1.3.1 Rearing Efforts

Progress continues at the Forestry Department crocodile farm in Sorong, although at a slower pace than expected. Previous funding was apparently insufficient to complete the rearing pens and auxillary facilities. Provision within this and next year's budget is needed to cement pen bottoms, connect electricity, upgrade the water supply and acquire additional stock.

In May, much of the current stock was caught, numbered by standard dorsal scute clipping pattern, and shifted to completed pens in two operations. It was observed that a ectoparasitic nematode infestation is etching belly skins of some crocodiles in one of the pens, and is likely contributing to excessive mortality and inferior growth rates. This problem should be remedied by transfer of stock to pens with cement bottoms and a frequent (daily, if possible) routine of flushing and scrubbing. A sample of parasites has been collected for identification and study.

This year's counterpart budget provides for additional purchase of 750 young crocodiles. As supply sources in the Bird's Head region appear uncertain alternative collection sites on Serui Island and Bareri/Faowi village areas are being arranged. Should the envisaged development by the Sorong Catholic Mission to establish collecting pens in the Babo area of Bintuni Bay proceed on schedule, a further source of young could be available by the end of the year.

Aquisition of additional stock should allow feed to be provided at lower cost, since some 2,000 or more crocodiles make possible bulk feed contracting with local fishermen. Better yet would be formation of a businessventure to utilize side catch of the Sorong area fisheries industry. These possibilities are being investigated.

Temporary cool storage of crocodile feed is also urgently needed. At present, fish must be purchased from local markets in the early mornings. As farm stock prefer to feed in late afernoons and evenings, fish feed tends to attract flies and stimulate bacterial growth if apportioned just after purchase. To alleviate this problem, a small freezer has been purchased and placed from Jayapura. Once town electricity is supplied to the premises and its true KWh costs known, larger feed demands may be handled economically with construction of a walk-in type freezer or cool room. This would allow even greater bulk purchasing (hence, probable cheaper costs), as well as the ability to stockpile substantial quantities during seasonal gluts when feed prices decrease markedly..

5.1.3.2 Husbandry Research

Completion of existing pens and acquisition of additional stock will also permit important feed trials to be conducted. A potentially abundant source of crocodile feed may exist in the form of shark carcasses, which continue to be cast away by shark fin fishermen along the Irian coasts. Little is known of the nutritional value, storage suitability and supply costs. These factors merit immediate investigation.

Also of much value would be investigation of differential growth (C. porosus versus C. novaeguineae) not only with shark, but trash fish as well, and including indepedant experiments on various age groups of farm stock. Depending upon the availability and economics of supplying prawns, trials may also be carried out on hatchlings. Studies in various countries have demonstrated superior growth and increased survivorship with this feed source. Initiation of a research program, emphasizing effective training of counterpart staff is scheduled for the latter half of 1988. Should qualified Associate Professional Officers (APOs) be identified (as intended in the Plan of Operations) and approved by GOI for attachment to the project, priority posting will be given to Sorong.

With its government status and enthusiastic staff including a university graduate in biology, the Sorong government farm is singularly suited as a research facility. The results of crocodile husbandry research would be expected to contribute significantly to the profitability and advancement of the industry as a whole in Irian Jaya.

5.1.4 Southern Irian Jaya

Three crocodile rearing ventures are nearly operational, two of which have large-scale (>10,000 head) targets. Prospects in the Merauke area appear least favourable of main towns in Irian Jaya, due primarily to lack of freshwater and uncertainty of ample amounts of cheap protein on a regular basis. Drawbacks are also compounded by widespread illegal skin trade in the area.

C.V. Nikmat has constructed seven new rearing pens incorporating improved design, and rebuilt most of their existing pens. Although further improvements in husbandry techniques would assist the prospects of this enterprise, management is now of adequate standard. Current capacity is about 2,000 head, with plans to double that in the near future. An additional well should help to solve water shortages during the dry season, but this problem, along with acquisition of feed, are limiting factors. The enterprise reportedly culled 323 crocodiles in January 1988, but relates considerable loss of value due to spoilage before the skins could be exported.

C.V. Trinaga Kreasi has completed 44 rearing pens at their large farm site, and await capture and transport licenses to begin operations. Current capacity is 15-20,000 crocodiles. The pens are well-designed, but there remains considerable uncertainty that sufficient water and feed can be supplied to the farm.

C.V. Jaya Abadi is the other aspiring commercial crocodile enterprise in Merauke. Adequately designed pens to rear some 5,000 crocodiles have been constructed, with plans to expand to 20,000. Even attainment of current capacity will require surmounting limited water and feed supplies which similarly affect all three concerns in Merauke.

5.2 Breeding

Breeding remains an important goal of industry development, but its attainment is complicated by a number of technical and economic factors over and above those associated with successful rearing. For the near future it would seem most appropriate to continue concentrating efforts on ensuring the profitablity of rearing operations, while preparing the groundwork for breeding. This may best be promoted by amending restocking policy to reduce, or delay in full, return of 10% of reared stock to the wild. Restocking is currently infeasible in many areas because, notwithstanding the costs and difficulties of transporting medium-sized and large animals to suitable habitat, the security of releases cannot yet be guaranteed. If say, five per cent of cullable stock can be reserved for breeding, this would act as an incentive for enterprises to select their healthiest and fastest growing stock, and therefore genetically promote future production from breeding efforts.

C.V. Nikmat in Merauke improved upon last year's initial C. porosus success with seven hatchlings this February. These were produced from a breeding pair which have been maintained at the location for ten years. Should the pair again mate next year, further improvement can be realized if ample nesting material is provided.

Several other enterprises have acquired small numbers of evidently sexually mature C. porosus to investigate breeding suitability, but as yet no activity has been noted.

5.3 Village Level Demonstration Holding Pens

The remote upper reaches of the Mamberamo (Idenburg) River around Pagai village appear to harbor one of the most intact C. novaeguineae populations in the province. Very little hunting and no live harvests were said to occurred since 1979. With a further important advantage of proximity to Jayapura via missionary Cessna flights, the village was chosen as the initial site for construction of project sponsored crocodile holding pens. Initially operational since December 1987, the pens were completed during early 1988. The site now features two joined pens, one for 50-69 cm young and the other for 70-100 cm individuals. Young crocodiles were collected by the villagers in April when river levels fell unexpectedly. In only six nights along the Mamberamo and adjacent tributaries, some 280 crocodiles (13% C. porosus) were collected, sorted by size into the two pens, and then sent by air to a Jayapura commercial farm two weeks later.

In keeping with project aims, a cooperative has been established with assistance from the resident Gereja Kristian Indonesia (GKI) missionary. Future shipments of live crocodiles can be 'front loaded' with store goods from Jayapura in order to save on transport costs. As of September 1988, more than 900 young crocodiles have been shipped to Jayapura, for a net profit to Pagai villagers of >Rp. 16,500,000 (USD 9,800).

It is envisaged that the Pagai model of village-level utilization be replicated at other remote sites in the Mamberamo system, and eventually throughout major crocodile producing areas of Irian Jaya. Two additional plots have been constructed, at Bareri on the Rouffaer River and Faowi on the Van Daalen. Bareri is one of the largest villages (~350 inhabitants) along the Rouffaer. Even though disturbed by illegal hunting operations, this river system appears to hold considerable stocks of crocodiles. Faowi, on the other hand, is a much smaller village amongst more limited crocodile habitat, and little affected by outside hunters and skin buyers. Although the area is remote and few of the residents speak Indonesian, there is a team of recently posted teachers and an SIL translator who enthusiastically support the plan, and will likely play an important role in coordinating collection and onforwarding activities.

It is intended that initial shipments of crocodiles from both demonstration plots will be forwarded to the Forestry Department rearing facility in Sorong. Top prices may be maintained for local collectors by taking advantage of very reasonably priced cargo transport via Wamena and Biak, else shipments via Jayapura utilizing missionary and Garuda aircraft are adequately economical to maintain good returns to village collectors.

5.4 Trial Egg Harvest

Field surveys in the Pagai village vicinity of the Upper Mamberamo have demonstrated the potential for a conservation-oriented crocodile egg harvest. Freshwater crocodile populations remain fairly abundant in this area, notwithstanding a tradition of egg gathering for local consumption. The proposed scheme would be particularly suited to conservation objectives as emphasis is placed upon the most expendable portion of crocodile `populations'. It is likely that the number of nests currently exploited can be reduced, while achieving a measure of middle-term commercial production.

Local interest in the egg harvest has been stimulated by Bintang Mas crocodile farm in Jayapura, which has acquired converted poultry incubators and is constructing hatching pens. The company plans to offer Rp. 2,000 per live egg plus double exchange of chicken eggs. This more than balances the dietary yield from crocodile egg gathering and simultaneously provides a financial incentive to abide by conservation-oriented restrictions. Pagai villagers have agreed to a limited harvest and strict protection of remaining active nests. The harvest would be conducted along the lines of those in Papua New Guinea which have proven very successful (see Hollands, 1986; Cox, Wilmot and Gowep, 1987; Genolagani, 1988) which also serves to reinforce breeding female protection. Depending on the number of active nests in each nesting location, as many as 30% may be harvested, with emphasis placed on those nests most likely to fail if left in the wild.

With completion of the project work center at Pagai, appropriate nesting areas can be reconnoitered in September and October, the harvest adequately supervised in November, and follow-up nest inspections (to assure protected nests are allowed to hatch) conducted in late November and December.

5.5 Skin Processing and Marketing

Recent decrees by the Ministry of Trade require that all crocodile skins exported from Indonesia be semi-processed (i.e. wet blue or crust stage). By 1989 exporters will be further required to attain the finished (polished) level. Only one enterprise (C.V. Bintang Mas) is currently producing wet blue and crust skins of export quality, but equipment is in place and training under way to produce finished skins in the near future. Other exporters have been granted temporary dispensations, and this will apparently apply to most exports of wild harvested skins.

5.6 By-product Potential

Significant added value of the crocodile resource can be realized if by-products of rearing and farming operations could be legally and efficiently marketed. Potential is already at hand for domestic marketing of fresh and frozen meat. Restaurant provisioners in Jakarta will pay Rp. 6,000 (USD 3.50) or more CIF per kilogram to Irian suppliers. Even higher prices would be obtainable in markets such as Taiwan, Hong Kong and Singapore. However, until these countries either join CITES or drop reservations on