IUCN PUBLICATIONS NEW SERIES Supplementary Paper No 32

CROCODILES

Proceedings of the First Working Meeting of Crocodile Specialists:
Sponsored by the New York Zoological Society and organized
by the Survival Service Commission, IUCN, at the Bronx Zoo,
New York 15—17 March, 1971

Volume I

Published with the financial assistance of UNESCO

International Union
for Conservation of Nature and Natural Resources
1110 Morges, Switzerland

2-88032-008-9

The International Union for Conservation of Nature and Natural Resources (IUCN) was founded in 1948 and has its headquarters in Morges, 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 at man's modification of the natural environment through the rapidity of urban and industrial development and the excessive exploitation of the earth's natural resources, upon which rest the foundations of his survival. IUCN's main purpose is to promote or support action which will ensure the perpetuation of wild nature and natural resources on a world-wide basis, not only for their intrinsic cultural or scientific values but also for the long-term economic and social welfare of mankind.

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

The World Wildlife Fund (WWF) is an international charitable foundation for saving the world's wildlife and wild places. It was established in 1961 under Swiss law and has headquarters near those of the International Union for Conservation of Nature and Natural Resources (IUCN). Its aim is to support the conservation of nature in all its forms (landscape, soil, water, flora and fauna) by raising funds and allocating them to projects, by publicity and by education of the general public and young people in particular. For all these activities it takes scientific and technical advice from IUCN.

Although WWF may occasionally conduct its own field operations, it tries as much as possible to work through competent specialists or local organizations.

Among WWF projects financial support for IUCN and for the International Council for Bird Preservation (ICBP) have highest priority, in order to enable these bodies to build up the vital scientific and technical basis for world conservation and specific projects. Other projects cover a very wide range, from education, ecological studies and surveys to the establishment and management of areas as national parks and reserves and emergency programmes for the safeguarding of animal and plant species threatened with extinction.

WWF's fund-raising and publicity activities are mainly carried out by National Appeals in a number of countries, and its international governing body is made up of prominent personalities in many fields.

FIRST WORKING MEETING OF CROCODILE SPECIALISTS

VOLUME 1

CONTENTS

PARTICIPANTS IN THE FIRST WORKING MEETING
OF CROCODILE SPECIALISTS

Professor Angus d'A. Bellairs
Department of Anatomy
St Mary's Hospital Medical School
University of London
Paddington
London W2
England

Mrs Deborah Besch (Secretary)
Department of Herpetology
New York Zoological Society
Bronx, N.Y. 10460
USA

Dr Robert H. Bustard
Research School of Biological Sciences
Australian National University
P.O. Box 475
Canberra City, A.C.T. 2601
Australia

Dr Robert H. Chabreck
Louisiana Cooperative Wildlife
Research Unit
L.S.U. School of Forestry & Wildlife
Baton Rouge, Louisiana 70803
USA

Dr Hugh B. Cott
Denebanks
Netherbury
Bridport
Dorset
England

Mr Max C. Downes
Senior Ecologist
Wildlife Laboratory
D.A.S.
Konedobu
Papua and New Guinea

Mrs Claire Hagen (Observer)
Representative Reptile Products
Association
120 Cabrini Boulevard
New York, N.Y. 10033
USA

Mr Fred Hauptfuhrer (Observer)
Director of Planning & Development
World Wildlife Fund, Inc.
910, 17th Street N.W.
Washington, D.C. 20006
USA

Mr René E. Honegger
Assistant
Zürich Zoo
Zürichbergstrasse 221
8044 Zürich
Switzerland

Dr F. Wayne King
Curator of Herpetology
New York Zoological Society
Bronx, N.Y. 10460
USA

Mr Kongsiri (Interpreter)
Interpreter
Thailand Mission
United Nations
New York
USA

Professor Federico Medem
Instituto Roberto Franco
Apartado Aereo 2261
Villavicencio (Meta)
Colombia

Dr James A. Oliver (Observer)
American Museum of Natural History
15th West 77th Street
New York, N.Y. 10024
USA

Mr Antony Pooley
Ndumu Game Reserve
P.O. Ndumu
Zululand
Rep. South Africa

Mr James H. Powell
1110 Kokomo Street
Plainview, Texas 79072
USA

Miss Moira A.G. Warland
Executive Officer SSC
IUCN
1110 Morges
Switzerland

Mr Utai Yangprapakorn
Crocodile Farm Samut Prakan
Samut Prakan
Thailand

OTHERS WHO SUBMITTED PAPERS

Dr Gerardo Budowski
Director General
IUCN
1110 Morges
Switzerland

Mr C.M. Chapman
Priorsfield
51 Malthouse Lane
Kenilworth
Warwickshire
England

Mr U. Srisomboon
Ministry of Agriculture
Department of Livestock
Development
Bangkok
Thailand

Dr Paul R. Wycherley
President
Malayan Nature Society
P.O. Box 150
Kuala Lumpur
Malaysia

INTRODUCTION

Gerardo Budowski
Director General IUCN

I must first and foremost express my earnest regret at not being able to participate in this first important meeting of the Crocodile Specialist Group.

The supporting papers alone indicate that the opportunities for conservation action in relation to the crocodilians are quite outstanding. They contain many elements which, properly channelled, could become effective action programmes. And it is earnestly hoped that this working meeting will result in constructive and long-term conservation activity.

We have witnessed over the past years an escalating deterioration in habitats and pressure on natural areas, including increasing difficulties in controlling poachers who work for ever more lucrative ends. These factors and others have taken a heavy toll of the world's crocodilian resources and you are gathered in New York expressly to consider ways and means of ensuring the continued existence of the world's crocodile species.

There are many encouraging signs which should be fully exploited. Suddenly environmental concern is 'in' and the words 'ecology' and 'conservation' are on everyone's lips.

In IUCN we are getting a direct feeling of this trend from many different sources, some of them we had never suspected before. Perhaps the most significant change has been the attitude displayed by the machinery of the United Nations and its different agencies. Being legally bound to execute the wishes of its member countries, it is hardly to be expected that the UN can be at the forefront of ecological thinking or that it will point out new trends and new ways of taking the necessary action to deal with those trends. Besides, we all know that the traditional tendency for governmental delegates is to consider first the interest of countries which they represent, and not so much to look at problems that require global approaches and global solutions, such as the biosphere and its functioning -- its health, as we like to call it. National interests prevail over global interests. Yet it is precisely in the United Nations system that some of the greatest changes are presently taking place.

UNESCO's programme of Man and the Biosphere, containing a substantial conservation ingredient, has finally taken shape and IUCN will play an important role in implementing it.

Four weeks ago the Preparatory Committee meetings of the 1972 United Nations Conference on the Human Environment took place in Geneva, and again conservation of nature and natural resources was at the root of many discussions. IUCN was represented in the working groups that were formed in order to decide on the different types of activities to be carried out for the 1972 Conference; and again it was quite clear that a considerable input was expected from our organization. I hasten to say that we have somewhat mixed feelings about this since we can hardly cope with the additional work load that is increasingly demanded from us on world conservation matters.

FAO also has many projects already under way containing strong conservation elements: they recently sent a one-man mission to Peru to look into the utilization of hides and skins of wild animals, including Caiman sclerops and Melanosuchus niger. Total protection for the latter was recommended as a result.

I could mention the changing role of a few other intergovernmental organizations in dealing more intensively with conservation matters. These tendencies show up in multiple manifestations throughout the world, many of which affect IUCN in some way or another; for instance there is the much closer, friendlier and much more productive co-operation between the World Wildlife Fund and IUCN, there is the increased demand for IUCN to inject conservation into a multitude of meetings to which, unfortunately, we can only respond to a minimal degree, and many other activities which I shall not enumerate here.

I have mentioned these developments because they directly or indirectly affect any potential crocodile programme either because of the new or increasing interest from different organizations throughout the world in conservation programmes or because they make it possible for IUCN to move in this field with better co-operation and financial backing. To meet this challenge, however, IUCN itself had to undergo a very significant change. This process is presently in full swing.

Some of you have known our organization for years and while it was always staffed by a small group of extremely dedicated conservationists, it was so poorly financed that it could hardly pretend to do the job for which it had been created. In fact it is amazing to see how many publications were produced and how much good will generated with so little financial support. We have now 18 professional members on our staff, 16 of whom are located at Morges; and the number of field projects is now around 50, a good part of them operational. Every one of the six IUCN Commissions (except, at present, that on Environmental Policy, Law and Administration) is now staffed with an Executive Officer responsible for servicing the Commission and its different specialist groups and co-ordinating these activities with those of other Commissions or with other types of scientific activity not directly connected with the Commissions. IUCN's 'new look' as we like to call it

also includes a section on Research and Planning with a major input by Dr Raymond Dasmann, our Senior Ecologist.

True enough, we are now flooded with papers as we have never been before; but at the same time, we never have felt so much, in the life of IUCN or in our individual lives, the impact of being "in the middle of where the action is". In place of the romantic period when conservation, particularly that of animals and plants, was the realm of a few enlightened people, we now suddenly feel that a large sector of mankind, including youth, industrial workers and lately even Government officials, have acquired a deep interest in the matter.

In such a situation, where the interest generated is certainly exploding, there are naturally several different appreciations as to what action should receive the top priority. We are aware of this but at the same time pledged to base our actions on the best possible appraisal as to where priorities lie. And for IUCN those priorities will always be based primarily on the best possible scientific understanding of a world situation. Naturally economic and even political considerations also influence our decisions; and naturally too, the principal obstacle we meet in getting more action under way is lack of additional funds since, without increasing staff, at least to our headquarters in Morges, we could immediately undertake many more projects if the financial support were forthcoming.

Such action projects constitute the essence of our programme and certainly we hope to develop a certain number related to crocodiles. I propose in my concluding paragraphs to review some of these projects, with particular reference to those which have a bearing on crocodilian conservation.

A very important part of the programme involves several projects on monitoring of species populations and biotic communities throughout the world. These include of course our current appraisals of vanishing species and will now also include depleting species. The fact that crocodilians lend themselves well to such monitoring may generate a series of useful correlated projects involving other biological variables.

Conservation of coastal areas and estuarine regions will also be given much impetus through a series of projects with major inputs from some staff members and several of our expert working groups.

We are also working on a series of ecological guidelines designed to form the basis of solutions to problems involved in economic development. Not only should this make possible the inclusion of a holistic long-term approach where land and sea use planning is being undertaken, but eventually we expect to generate much greater awareness amongst countries of the possibilities open to them to request assistance from intergovernmental agencies. Thus we would hope that, ultimately, funds from the United Nations Development

Programme can be channelled into programmes that include, for example, the conservation of crocodiles and other reptilians.

I have on purpose mentioned to you some of our current thinking and our desire to ride on the present wave of environmental concern. I insist that this is quite relevant to crocodiles -- may I say 'ecologically linked' -- and it was my purpose to inform you how IUCN operates so you can give us the best effective advice to link your field of competence to our own activities -- and, what is perhaps more important, to lead our thinking into operational programmes, Action programmes as we like to call them. We sincerely feel that IUCN is in a particularly favourable position to make everyone understand that crocodiles have a very important role to play in the complex environmental balance and that any money invested to capitalize on the present knowledge, to promote action or to extend research as a basis for action, will indeed be very well invested and should produce multiple benefits. As an international non-governmental organization, we can loudly proclaim what failure to take action implies and we should, of course, explain equally frankly how the benefits of taking action will involve a series of advantages for mankind. Not only should we emphasize the economic aspects, which are self-evident, but we can also bring out eloquently the educational, aesthetic and cultural advantages that a sound programme of crocodile conservation, including wise utilization, can yield, within a co-ordinated effort towards a balanced relationship between man and his environment. With the help of our sister organization, the World Wildlife Fund, we believe we can get the message across.

I therefore hope very much, and I do not mind repeating it over again, that by the time this meeting adjourns, you will have provided new and effective advice and additional arguments for a series of action-oriented projects which should make a decisive impact on crocodile conservation.

I cannot end without extending IUCN's warm and heartfelt appreciation to the New York Zoological Society for hosting the meeting and enabling it to take place. The Society is already well-known for its intensive activities in the conservation and educational fields and many members of its staff are widely known for the great contribution they have already made to the cause of conservation in general and to the conservation of crocodilians in particular. May their and your further efforts in this field meet with every success.

SUMMARY OF THE MEETING

Part 1. THE SCOPE OF THE DISCUSSIONS: THE WORLDWIDE SITUATION OF CROCODILIANS

H. Robert Bustard
Secretary, IUCN Crocodile Specialist Group

Introduction

A working meeting of crocodile specialists, organized by the Survival Service Commission of the International Union for Conservation of Nature and Natural Resources, was held at the New York Zoological Society, Bronx Park, New York, on 15-17 March 1971. The Chairman was Dr Wayne King, Curator of Herpetology of the New York Zoological Society, which financed the meeting. Ten delegates and three observers, all actively engaged in the study and conservation of crocodiles, attended the meeting, the Minutes of which follow as Part 2 of this Summary of the Proceedings. The aims of the meeting were to review available knowledge and to devise a high priority action programme for halting the accelerating decline of world crocodile populations and for preventing certain species of crocodile, now critically endangered, from becoming extinct.

The order Crocodylia is represented by three families with living representatives, namely the Crocodylidae, the Alligatoridae and the Gavialidae, containing, respectively, the crocodiles; alligators and caimans; and the unique gavial Gavialis gangeticus. Currently 13 species of crocodiles, two alligators and five caimans are recognized.

All crocodilians are hunted for their skins so it is not useful for conservation purposes to try to list them in order of economic importance. With the exception of several species which enter saltwater, and special cases such as the Nile crocodile C. niloticus distributed over most of Africa except for desert regions or the extreme south, most crocodilians have fairly restricted ranges. This results in people exploiting their local species even although species with more valuable hides occur elsewhere. Since prices for crocodilian hides on the world market have risen steeply in recent decades, skins which fetch only half the top prices still bring in enormous financial rewards to people with a low standard of living – a situation which unfortunately occurs in many parts of the world. This is a basic problem in crocodile conservation.

The living crocodilians are distributed as follows: Africa - three species, the Nile crocodile C. niloticus, the African slender-snouted C. cataphractus and the West African dwarf Osteolaemus tetraspis. The last-named divides into two well separated subspecies, tetraspis and osborni, which further investigation may show to be distinct species. In Asia there are six species - the saltwater C. porosus, Siamese freshwater C. siamensis, the mugger C. palustris, the false gavial Tomistoma schlegelii, the gavial Gavialis gangeticus and the Chinese alligator A. sinensis. The Australian region has three species. These are the Asian saltwater C. porosus, the Australian freshwater C. johnsoni and the New Guinea freshwater C. novaeguineae, a subspecies of which, mindorensis, occurs in the Philippines. Two species occur in the United States - the American alligator A. mississipiensis and the American crocodile C. acutus. The latter has a wide range from Central America southwards to Ecuador and northwards to western Mexico; it also occurs in the larger West Indian islands. The Central America-West Indies area has two endemic crocodiles, C. rhombifer, the Cuban freshwater, and C. moreletii from Mexico and other countries of Central America. The remaining six species are endemic to South America - the Orinoco crocodile C. intermedius and five species of caiman: the spectacled caiman Caiman crocodilus, which separates into a number of well differentiated subspecies, the Brazilian spectacled caiman C. latirostris, the black caiman Melanosuchus niger, the dwarf caiman Paleosuchus palpebrosus and the smooth-fronted caiman P. trigonatus.

Although crocodiles are eaten in certain parts of the world and their eggs are often relished, there is no question that it is the commercial demand for their skins which has brought some species to the brink of extinction and has caused a catastrophic decline in numbers of all species for which information is available. The members of the specialist group know of no species (other than the American alligator) which is anything like as abundant as it was even a decade ago. The preferred habitat of crocodilians is such that in most parts of the world it has saved them from direct competition with mankind for 'a place to live'.

National Situation and Requirements

For this inaugural meeting of the Group some of the delegates had agreed to accept responsibility for representing areas additional to their own, so as to ensure a better world coverage of the subject. Thus, at present, of the Group's membership, Mr Utai Yangprapakorn is the only Asian representative and Professor Medem the only one from South America. Clearly IUCN and the specialist group must stimulate research on crocodilians in these important areas of the world, so that we can recruit the leading workers to group membership. A similar situation also applies to most of

Africa despite the detailed research of the Chairman of the Group, Dr Hugh B. Cott, in East Africa and the important conservation research being carried out by Mr Tony Pooley in Natal.

As the Group is presently constituted, Dr Cott and Mr Pooley can speak authoritatively for their respective areas of Africa, Mr Downes for the Territory of Papua and New Guinea, Professor Medem for Colombia (South America), Mr Yangprapakorn for Thailand, Dr Bustard for Australia and Dr King for the United States. In addition, Mr Powell has accumulated a vast amount of detailed data for Central America and the West Indies as well as for the whole of the 'alligator belt' of the United States; Mr Honegger, in his capacity as Compiler for the Red Data Book, Volume 3, has some data for most parts of the world, as does the group secretary; and many members are knowledgeable about areas other than those where they work and which they represented at the meeting. The large gaps in data do not detract from any statements about the overall trend in world crocodile stocks since the world trend is obvious -- everywhere there is a huge decline in numbers. The Group can document over and over again the virtual extirpation of enormous populations of crocodilians over very short periods of time, often only a few years, after hunters equipped with modern firearms have moved into virgin areas in all crocodile-bearing continents.

The existing situations and requirements for the areas represented by the delegates may be summarized as follows:

Africa. The Nile crocodile is being rapidly depleted everywhere at a rate that causes intense alarm. This species appears to be one that would lend itself to management and it is tragic that this is not happening but that a valuable resource is being wiped out. Information on the African slender-snouted crocodile and the African dwarf crocodile is extremely sparse. A survey of these two species was given a high priority rating by the meeting (see Vol. 2 of these Proceedings).

Asia (except Thailand). It is impossible to summarize the situation in this huge region in a few lines but the trend of massive decline and disappearance of crocodiles is abundantly clear. C. porosus has such a wide range that it is not currently endangered, nor, due to successful captive breeding, is siamensis (see under Thailand); information on the Chinese alligator is lacking, but the mugger is rapidly becoming critically depleted; major concern centres on the false gavial Tomistoma and the unique gavial Gavialis, both of which urgently need detailed surveys (see Paper No 4).

Australia. Neither species is currently threatened. The freshwater crocodile has been totally protected in Western Australia and the Northern Territory for many years, but Queensland continues to provide an outlet for poached skins; the saltwater species has been accorded total protection by Western Australia for a period of ten years with effect from 1 January 1970.

Central America and the West Indies. The two species endemic to the region -- Morelet's and the cuban crocodile -- are both considered to be on the verge of extinction in the wild state. The Group felt that creation of captive breeding studs under ideal conditions was a matter of the greatest urgency (see Paper No 7).

South America. Professor Medem (Paper No 6) expressed particular concern for the future survival of the Orinoco crocodile, the black caiman and the very distinctive race of the Spectacled caiman, C. crocodilus (sclerops) apoporiensis, found only in the Apoporis River in Colombia. All species, however, are currently being depleted at a much faster rate than they can reproduce themselves.

Territory of Papua and New Guinea. Mr Downes (Paper No 3) explained that there was no future for crocodiles in Papua-New Guinea unless they could be commercially exploited. His section was working on crocodile management. The saltwater species C. porosus had been largely wiped out as far as populations of sizeable adults were concerned and management faced the task of re-establishing it. The freshwater C. novaeguineae was still fairly abundant in many areas.

Thailand. Mr U. Yangprapakorn (Papers Nos 8 and 10) explained that crocodiles in the wild state were almost extinct in Thailand, there being probably less than forty individuals each of siamensis and porosus and perhaps half this number of false gavials in the extreme south of Thailand. He had foreseen this situation more than 20 years ago and had established a crocodile farm which currently held more than 11,000 porosus and siamensis. When the Thai Government created properly patrolled National Parks he would make crocodiles available to restock the parks. It was stressed that all hides were produced from young hatched from eggs laid in the farm by a captive breeding stud. Excellent breeding success and captive growth rates were reported for both species. The delegates felt this was exceptionally good news.

United States. Mr Powell (Paper No 7) had provided the further good news that the American alligator is certainly responding to management and that it should be possible to maintain suitable habitats for it by allowing closely controlled cropping of the populations and thus a financial incentive to land-owners. Alligator farms are still in an experimental stage but Dr Chabreck (Paper No 13) felt they would prove themselves in the near future.

International Conservation and Research Requirements

Surveys. There is an urgent conservation need for greatly increased pure research and survey work on crocodiles in many parts of the world. The Group were unanimously agreed that the highest priority should be given to status surveys of species thought to be critically endangered and that the personnel undertaking this work should be charged with collecting several pairs to form the basis of a captive breeding stud.

Management. Undoubtedly the future for wild populations of crocodiles lies in managing them as a resource croppable at a measured rate. Unfortunately, immediate political problems are involved and basic biological data on many species are not yet available. Research workers should be encouraged to enter this field, which is an attractive one due to its basic scientific promise combined with immediate economic and conservation application.

Farming. The Group discussed crocodile farming in some detail in view of the detailed report given by Mr Yangprapakorn (Paper No 10). Ranch-type farming in which natural-laid eggs or wild hatchlings were collected for rearing to an economic size, was unanimously condemned, but farms which, like the Thai one, operate independently from natural populations, could, it was felt, eventually make a valuable conservation contribution, by reducing the pressure on wild populations. Farm-reared animals produced excellent skins of uniform size and quality and were much in demand.

A crocodile foundation. Mr Utai Yangprapakorn offered to maintain breeding populations of any species which the Group felt was sufficiently endangered in the wild state to merit a captive breeding programme. Thailand has an ideal climate for this type of work and the experience and success of the Samut Prakan crocodile farm made the delegates enthusiastic to accept this offer. Here was an immediate action project requiring international co-operation and IUCN backing with a view to the capture of very small numbers (ideally four females, and two males) of threatened species and arrangements for their transportation to Bangkok. Both the IUCN Secretariat and the Survival Service Commission have already given their approval to such a project.

Legislation and fauna reserves. It was felt that considerable gains could be achieved by international co-operation and help in drafting suitable conservation legislation, as well as advice on the setting up and locating of fauna reserves and on practical problems such as poaching.

The delegates were in favour of publicity for the plight of the world's crocodilians. They were unanimous that, unless urgent action was taken, many species would disappear before the end of the century. They felt their

proposed action programme -- urgent status surveys and creation of captive breeding studs for the most threatened species, combined with greatly increased management studies and farming investigations (under proper scientific control at a non-commercial level until techniques had been properly worked out) -- would go a long way to solving the problem in time. There was some difference of opinion among the delegates about what should be done in the short-term. Clearly, all agreed that depleting species would soon become endangered unless their rate of exploitation could be reduced to levels which the natural population could meet by breeding success. However, suggestions for a complete ban on the sale of crocodilian products (as has in effect happened in the United States, as a result of the Mason Act) met with a mixed reception. Since all delegates were interested first and foremost in the continued existence of crocodilians as species it was clear this divergence resulted from different local conditions and that there is probably not a single universal solution. Certain species can no doubt be saved by a properly enforced ban on hunting; on the other hand, the long-term survival of others depends on their efficient utilization, rather like some of the African game parks and their foreign exchange earnings from tourists. Most delegates agreed, however, that the type of legislation which enables supplies of crocodile skins to be temporarily cut off, would allow a breathing space during which rational exploitation schemes could perhaps be devised. The hope was generally expressed that the Mason Act would help to achieve this result.

Part 2. MINUTES AND RECOMMENDATIONS

1. Mr William Conway, Chairman of the New York Zoological Society, opened the proceedings by welcoming participants on behalf of the President and Trustees of his Society, which was sponsoring the meeting.

2. The opening address by Dr Gerardo Budowski, Director General of IUCN (reproduced as the Introduction to these Proceedings) was read in his absence by Miss Moira Warland, Executive Officer of the Survival Service Commission.

3. Dr Wayne King was elected Chairman. Dr Angus Bellairs, Mrs Deborah Besch and Miss Warland were elected Rapporteurs.

4. The agenda was adopted with amendments.

5. Dr Hugh Cott reminded participants of the objectives of the Survival

Service Commission and defined the terms of reference of the Crocodile Group (Paper No 1 of these Proceedings).

6. It was decided that an ad hoc subcommittee should be formed to consider the formulation of the decisions and recommendations of the meeting. Dr Robert Bustard and Dr King formed this committee with Mr Max Downes as Chairman. Recommendations are annexed to these Minutes.

Regional Reports

7. Australia

Dr Bustard presented his report on the status of crocodiles in Australia (Paper No 2). The Group gave its support to the need for partial protection of the Estuarine crocodile Crocodylus porosus in the Northern Territory, by deciding to adopt Recommendation 1 (see Annex).

8. Africa

Dr Cott and Mr Tony Pooley presented the results of their questionnaire survey to all African states (see Volume 2 of these Proceedings: IUCN Supplementary Paper No 33). In summary, it emerged that both the Slender-snouted crocodile Crocodylus cataphractus and the Dwarf crocodile Osteolaemus tetraspis were severely endangered throughout their range and that the Nile crocodile Crocodylus niloticus was suffering serious depletion.

It was decided that IUCN should formally congratulate the Natal Parks, Game and Fish Preservation Board on their very successful restocking programme for the Nile crocodile and call attention to the need for extending the work to O. tetraspis and C. cataphractus; that steps should be taken to have O. tetraspis and C. cataphractus included in U.S. list of endangered species; and that the Governments of Botswana, Rhodesia and Mozambique be formally invited to draft and enforce unified protective legislation for the crocodile, so that the legislation existing in South Africa can be rendered more effective in conserving crocodilian stocks.

9. Papua - New Guinea

Mr Downes reported (Paper No 3) that, as a result of selective hunting of the saltwater crocodile Crocodylus porosus in New Guinea, numbers were greatly reduced in the late 1950's; demands of the

leather trade now fall mainly on the New Guinea freshwater crocodile C. novaeguineae. Mr Downes recommended that efforts should be increased to establish a viable crocodile industry in Papua - New Guinea on a sustained yield basis. This would ensure greater chances of survival for the species than a total prohibition.

10. Parts of Asia

Mr René Honegger presented data on the threatened species of Asia (Paper No 4). The precarious status of the Marsh crocodile C. palustris palustris and the gavial Gavialis gangeticus was underlined.

Attention was also drawn to statistics on the trade in crocodile skins in West Malaysia kindly provided by Dr Paul Wycherley, Chairman of the Malayan Nature Society (Paper No 5).

11. South America

Professor Federico Medem outlined the status of crocodiles in Brazil, Colombia and Peru (Paper No 6). Several of the species occurring in these countries are greatly diminished or virtually extinct. Legislation that exists is not enforced.

It was decided to adopt Recommendation 2 (see Annex). The Group also noted that the extensive export of baby caimans is prohibited by law in at least one country and that the trade in the US therefore is in violation of the US Lacey Act; it was decided this should be brought to the attention of the US authorities.

The Group requested Professor Medem and Dr King to prepare a document on Melanosuchus niger with a view to advising its inclusion in the US list of endangered species.

12. United States, Central America and West Indies

Of the five species of crocodilians in the New World north of South America, Crocodylus moreletii and C. rhombifer are considered critically endangered, and C. acutus potentially endangered, according to Mr James Powell Jr., who summarized the status of the five species (Paper No 7). He recommended captive breeding projects for moreletii and rhombifer.

It was decided to approach Dr Howard Campbell for a report on the possible hybridization between Crocodylus rhombifer and C. acutus in a captive breeding project in Cuba.

13. Thailand

The status report on crocodiles in Thailand by Mr Utai Yangprapakorn (Paper No 8) indicated that the three species occurring in that country, Tomistoma schlegelii, Crocodylus siamensis and C. porosus, would probably become extinct in the wild within the next few years. The crocodile farm, where the majority of Thailand's crocodiles are concentrated, is dealt with in paragraph 15 below.

Controlled Breeding

14. Zoo breeding and crocodile bank

After considering Mr Honegger's paper (No 9) the Group decided to adopt Recommendations 3, 4 and 5 (see Annex).

15. Crocodile farming

Mr U. Yangprapakorn described the history and work of the Samut Prakan Crocodile Farm (Paper No 10). He made a formal offer to the Group to conduct captive breeding projects for rare species.

16. Crocodile rearing and restocking

Mr Pooley circulated a document describing suitable rearing techniques for the Nile crocodile, evolved over some years at the experimental crocodile rearing and restocking station in northern Zululand. The conservation recommendations from this document, which is being published elsewhere, are contained in Paper No 11. He warned of poor husbandry methods and low profit margins in some ventures set up elsewhere. Discussion resulted in the Group deciding to adopt Recommendation 6 (see Annex).

17. Exploitation, preservation, farming

Discussion on the above topic, led by Dr Bustard, resulted in the Group deciding to inform all governments with crocodile resources that the Group is available to advise on the taking of eggs from the wild, on conditions that should obtain in crocodile rearing projects, and on repopulation of natural habitats.

The Group also decided to adopt the following definitions:

Crocodile farm: an establishment whose products are ultimately obtained from eggs laid on the farm.

Rearing station: an establishment which collects eggs and/or hatchlings and raises them for a period of time after which they are slaughtered.

Restocking station: a rearing station that raises crocodilians for restocking purposes.

18. Management of crocodile industry

In presenting his report (Paper No 12) Mr Downes stressed that the future of the crocodile in Papua - New Guinea and other developing nations lay in managed rearing stations run on a cottage industry basis. Success in managing wild crocodile populations lay in controlling the skin commerce; in Papua - New Guinea, trade in skins greater than 20 inches belly-width was prohibited.

The Group decided to congratulate the Government of Papua - New Guinea for the action taken so far in managing its crocodile industry, but regretted the removal of these restrictions from three districts of New Guinea.

19. Management of the American alligator

Dr Robert Chabreck (Paper No 13) confirmed Mr Powell's report that numbers of the American alligator are increasing thanks to protection and better management.

Other Conservation Measures

20. Legislation and National Parks

The usefulness of appropriate legislation and the need for sanctuary areas were discussed, on the basis of a report by Dr Bustard (Paper No 14). The Group considered that legislation should concentrate on controlling the economic outlets and that more stringent penal measures should be exacted for infractions of laws that do exist.

21. The US Endangered Species Act was applauded as a valuable contribution by an importing country towards controlling world trade in certain species, but the Group considered that the list did not include all the endangered species of Crocodilia.

It was decided that Group members should provide Dr Bustard with full supporting documentation on species that should be included in

in the US list of endangered species (already on the list: Caiman crocodilus yacare, Crocodylus intermedius, C. moreletii, C. niloticus, C. rhombifer and Gavialis gangeticus).

It was further decided to adopt Recommendation 7 (see Annex).

22. Skin identification

Dr King showed the Group a film on the identification of crocodile hides and referred to his forthcoming publication on the subject (King, F.W. & P. Brazaitis, 1971. Species Identification of Commercial Crocodilian Skins. Zoologica, Vol. 56, No 2). He stressed that large numbers of skins were required to sustain a viable industry and that it would therefore be many years before crocodile farms could hope to relieve the pressure on wild populations.

23. Crocodile Foundation

The Group decided to endorse the Samut Prakan Farm, Thailand, and the Ndumu Crocodile Rearing Station, Zululand, as IUCN recognized breeding stations for endangered species.

The Group further decided to launch captive breeding projects in Thailand for the following species, specimens to be procured and arrangements made for shipping to Thailand by those named in brackets: Crocodylus moreletii (King); C. rhombifer (King with Howard Campbell); C. intermedius (King and Medem); Caiman crocodilus apaporiensis (Medem); Gavialis gangeticus (Bustard).

The Group also decided that captive breeding projects should be extended to Osteolaemus tetraspis and Crocodylus cataphractus in Zululand. Mr Pooley agreed to undertake these.

It was stressed that, where possible, specimens already in captivity should be used for these projects.

The primary function of this 'Crocodile Foundation' would be to act as a gene bank, but the possibility of using the captive nuclei for research purposes should also be considered.

24. Public Relations

Mr Powell Jr. (Paper No 15) suggested capitalizing on the current wave of public interest in crocodilians. He proposed a book on living crocodilians to be prepared jointly by the members of the Group; this proposal was not adopted owing to the fact that a similar book by Dr Allan Greer of Harvard University was already under way. Attention was drawn to other pertinent books already in print and to

plans of the New York Zoological Society to boost popular magazine articles on the subject.

25. Bibliography

Mr Downes presented the Group with his extensive Bibliography of the recent Crocodilians, which gathers together 2400 references. He stated that he still required six months of full-time work in the British Museum and the American Museum of Natural History to complete the task. All members were asked to comment on the author-indices and to provide any references that were not included.

The Group decided to congratulate Mr Downes for his past two years extensive work on this draft bibliography of the recent Crocodilians and considered its completion and publication would be of great scientific value.

The Group was warned, however, that the work could not be considered of a high priority, where it competed for scarce IUCN-controlled conservation funds.

26. Species synopses

The Group decided to give a high priority also to the compilation of synopses of crocodilian species which were rapidly declining, containing details of population status etc. IUCN would undertake their publication in monograph form and it was hoped to have two or three in press by the next meeting. Dr Bustard had drawn up a paper for the guidance of members showing the type of information that should be included and it was decided to delegate work as follows:

Alligator mississippiensis	Dr Chabreck
Caiman sclerops	Professor Medem
C. crocodilus apaporiensis	Professor Medem
Crocodylus intermedius	Professor Medem
C. niloticus	Dr Cott and Mr Pooley
C. novaeguineae	Mr Downes
C. siamensis	Mr U. Yangprapakorn

27. Red Data Book

The Group decided to appoint a sub-committee to examine the categories of the crocodilian species that were included in the Red Data Book, the membership of which would be Messrs Downes, Honegger and Pooley with Dr King as Chairman.

The Group was unanimous in its decision to transfer Alligator mississippiensis from category 1 -- critically endangered -- to category 5 -- recovered.

The Group further decided to recommend the following definition of an endangered species:

> A species is endangered when its numbers are consistently being depleted more rapidly than they can reproduce themselves. Absolute numbers may not be relevant to its threatened status since even large populations can be reduced catastrophically by adverse factors. In the case of Crocodilia, commercial exploitation is the key factor.

Crocodile Biology and Ecology

28. Papers were presented on the ecological isolation of crocodilians in Colombia and on the reproduction of Paleosuchus palpebrosus (Papers Nos 16 and 17) by Professor Medem, on parental care in the Crocodilia by Dr Cott (Paper No 18) and on the senses of crocodilians by Dr Bellairs (Paper No 19).

Crocodile Group and Action Programme

29. Projects requiring funding

The Group decided to accord the highest priority to the following projects:

A. Capture of two breeding nuclei each of Osteolaemus tetraspis and Crocodylus cataphractus for breeding programmes at the Samut Prakan Farm, Thailand, and the Ndumu Rearing Station, Zululand.

Action: Mr Pooley.

B. (i) Field survey on the status of Crocodylus intermedius and Caiman crocodilus apaporiensis.

(ii) Capture of breeding nuclei of the above two species for breeding in Thailand.

Action: Professor Medem.

C. Field survey on the status of Gavialis gangeticus.

Action: Dr Bustard and IUCN Secretariat.

30. Further information required

The Group agreed that further information should be sought for certain species. It was decided that Dr Bustard should investigate Alligator sinensis, Professor Medem Caiman latirostris, Dr Bustard and Dr King Tomistoma schlegelii.

It was further decided that Professor Medem would investigate the export of baby caimans from South America. Dr Cott and Mr Pooley would also investigate the feasibility of crocodile agreements between African countries.

31. Newsletter

It was decided that a Group Newsletter should be published and that Mr Pooley should act as Editor.

32. Group co-ordination

The Group considered the possibility of appointing a half-time administrative co-ordinator who would also work with the Turtle Group. However, the Group felt that the cost of this (estimated at $5000 per annum) would be much better spent on field work.

33. Next Meeting

It was recommended to IUCN that subsequent meetings of the Crocodile Group should last a minimum of four days and that more attention should be concentrated on specific problems. Mr U. Yangprapakorn graciously invited the Group to hold its second meeting at the Samut Prakan Farm in March 1973, and the Group unanimously decided to accept the offer. Mr Pooley suggested South Africa as an alternative in the event that it was not found possible to hold the meeting in Thailand.

34. Conclusion

The Crocodile Group decided to express their deep appreciation to the New York Zoological Society for making the meeting possible. The meeting was then closed.

ANNEX

INTERNATIONAL UNION FOR CONSERVATION
OF NATURE AND NATURAL RESOURCES

Survival Service Commission

CROCODILE GROUP

Recommendations

1. Noting with concern the accelerated decline of Crocodylus porosus in the north of Australia, the IUCN/SSC Crocodile Group meeting in New York in March 1971 requests the administration of the Northern Territory to consider a total closure of the hunting of this species in line with the action in Western Australia.

2. Regretting that the Amazonian countries lack a co-ordinated policy for the conservation of their crocodiles, the IUCN/SSC Crocodile Group recommends that the states of Brazil, Colombia (including the township of Leticia), Ecuador, Peru and Venezuela unify their crocodile legislation and establish a minimum size limit of 1.5 m for crocodiles taken.

3. The IUCN/SSC Crocodile Group recommends that zoos should aim at maintaining one species group in a unit suitable for breeding rather than individuals of several species.

4. The IUCN/SSC Crocodile Group recommends that no specimens should be taken from the wild for a zoo if they could in fact be obtained from another zoo.

5. Whereas individual specimens of many endangered species of crocodiles are now held in zoos throughout the world, the IUCN/SSC Crocodile Group recommends that a definite co-ordinated plan be worked out to bring together as many of these specimens as possible for breeding.

6. The IUCN/SSC Crocodile Group urges State Game Departments to assume responsibility for controlling crocodile rearing and restocking practices on their territory by issuing permits under strict conditions and by giving advice on techniques and return of hatchlings to the wild.

7. The IUCN/SSC Crocodile Group recommends that living specimens of endangered species of crocodilians should only be allowed into the United States for inclusion in definite breeding programmes.

March 1971.

Paper No 1

ADDRESS BY THE CHAIRMAN OF THE CROCODILE SPECIALIST GROUP OF IUCN'S SURVIVAL SERVICE COMMISSION

H.B. Cott

I feel it a great honour to serve in the capacity of Chairman of our Group. It is also a great pleasure to meet, in some cases for the first time, colleagues with similar research interests to my own. Members have come to this working meeting of the Crocodile Specialist Group from widely separated locations -- from Colombia and Texas in the New World, and from South Africa, Thailand, Australia, New Guinea and Europe in the Old.

Crocodilians are one of the most rapidly disappearing groups of animals. Twenty-five years ago they were still generally plentiful throughout most of their range. Their numbers have now almost everywhere been decimated; until today the survival of several species is threatened. The decline is due to two main causes, namely destruction of habitat and excessive exploitation in the wild.

The Survival Service Commission of IUCN has for some considerable time recognized the urgent need to promote the conservation of crocodiles as a unique resource; and at their meeting held in Bonn in the autumn of 1968 it was decided, in view of the serious world situation for the Crocodilia, to set up the Specialist Group which is today meeting for the first time.

May I remind you of the re-affirmation of the Commission's aims, which were issued from Morges in August last year:

> "The objective of the Commission is to prevent species extinction. The survival of plant and animal species in their natural environment is the Commission's main concern and it recognizes that this requires conservation of ecosystems in their entirety. Its activity is not confined to the protection of individual species in isolation. Captive breeding is therefore regarded as a last resort and an interim measure, with repopulation in the natural habitat as the ultimate objective. ... The Commission further recognizes that economic considerations and exploitation on principles of sustained yield may offer the only practical prospect for long-term conservation of certain species. In many cases it will therefore favour the quota system rather than total prohibition as the best means of achieving its objective of species survival."

The particular terms of reference of our Group are: to review existing information on the status of the various species (of crocodilians); to determine national and international research, conservation and management priorities; and to devise a mechanism for co-operation and co-ordination of effort in these fields.

A discussion was held in Cambridge, England, in the summer of last year (1970) between Professor Bellairs, Dr Bustard, Mr Fitter (Hon. Secretary of the Fauna Preservation Society and a member of the SSC) and myself, when the agenda of the present meeting were provisionally drawn up. Incidentally, one of the suggestions that we discussed was that Prof. Bellairs should investigate methods of identifying crocodilian species from prepared skins. However, in the event it was learned that Dr Wayne King had already explored this field and he will in fact be referring to this work under one of the items of our agenda.*

Members of the Group have been active in obtaining information on the national and regional situation of crocodilian species throughout the world. The results of these and related enquiries will be presented in the next item on the agenda.** They will provide a background for the revision, where necessary, of the Red Data Book sheets; and for management recommendations in relation to an exploitation rate that is compatible with safeguarding the future of the resource.

Having regard to the serious world situation for crocodiles and their rapidly changing status, may I suggest that the problems to be discussed are not concerned with what may happen in a hundred years' time: we are talking in terms of a decade or two. A major objective of the symposium must be to draw up a detailed action programme for crocodilian conservation now.

Following recent federal and state legislation in the US against the importation and sale of crocodile hides, a number of tanners and manufacturers have gone out of business owing to the import ban imposed by the State of New York. Because of this, Dr Wayne King has been approached by representatives of both the American and French dealers, urgently requesting a meeting of crocodilian ecologists and representatives of the hide industry which is seeking a repeal or revision of the laws. The purpose of the meeting would be to explore the status of crocodilian populations, the

---

* See under section 22 of the Summary of the Meeting, Part 2, Minutes on p. 25 above.

** Papers Nos 3 to 8 inclusive of these Proceedings.

needs of the industry, and the possibility of a regulatory agreement between conservationists and tanners. Rational exploitation of crocodile populations could be discussed along these lines.

In the light of this new development, the SSC has welcomed the change of venue of this meeting from Morges to New York, recognizing that the opportunity it affords to all interested parties to discuss questions of mutual concern could be of the utmost importance.

Finally, I should like to express our sincere thanks to Mr William Conway and the staff of the New York Zoological Society for their generous hospitality; for the excellent arrangements they have made for our meeting; and for receiving us with so friendly a welcome. Speaking for myself I can think of no better meeting place for zoologists than the Bronx Zoo.

Paper No 2

CROCODILES IN AUSTRALIA

H.R. Bustard
Research School of Biological Sciences, Canberra

National (Regional) Situation Report

General

The distribution and abundance of crocodiles in Australia has been drastically altered since the war by the effects of shooting. Indeed, in many areas the situation has changed so rapidly that only the most recent data are of value to conservation effort. Unfortunately, there have been few status surveys carried out in Australia. The only one in depth was that by Bustard in the Kimberley Division of Western Australia in late 1969.

There are two species of crocodile in Australia. The Australian endemic freshwater crocodile Crocodylus johnsoni and the widely distributed saltwater or estuarine crocodile Crocodylus porosus. In Australia both species are restricted to the northern parts of the continent, occurring in the State of Western Australia, the Northern Territory and the State of Queensland. In Western Australia crocodiles occur only in the far north of the State -- the area known as the Kimberley Division. However, in Queensland the range of the estuarine species, at least, extended much further south -- more than two-thirds of the way down the Queensland coast. Shooting has resulted in marked contraction of range for this species in Queensland as human population pressure extends along the coast from the south.

Australia must be considered an important habitat, biogeographically speaking, for the estuarine crocodile. Habitat is restricted in many parts of the Kimberleys due to the mountainous nature of the terrain which results in only narrow mangrove belts along the river courses and little area of swampland. However, in the Northern Territory and in Queensland there are enormous areas of coastal swampland ideally suited to the needs of this species. These particularly occur in the Gulf of Carpentaria, which must offer one of the best crocodile habitats in the world.

The crocodile conservation situation in Australia, although still far from ideal, is much more satisfactory than in most other crocodile-bearing countries. It does not seem that either species is in any danger of extinction.

The freshwater species is currently losing ground as a result of intensive poaching, mainly by expatriate shooters operating from Queensland. However, the Governments concerned are well aware of the problem (Bustard, 1969) and steps are being taken to remedy it.

The estuarine crocodile has been under pressure for some time. Its large size at first breeding makes it extremely vulnerable. However, it has been reduced to a level where commercial shooting is no longer profitable in most areas. Furthermore, there are Aboriginal Reserves where substancial populations still occur. Although the species will never be common again over most of its former range, there is no reason to think that adequate provision will not be made for it in National Parks and by legislation to control shooting.

Exploitation

The freshwater crocodile may only be exploited legally in the State of Queensland where exploitation was extremely heavy with the result that the species has been drastically reduced in numbers. Poaching occurs extensively in the Northern Territory and Western Australia (see Conservation).

The estuarine crocodile may be legally exploited in the Northern Territory and Queensland. Shooting has reduced the populations to a tiny fragment of those existing in 1950.

Conservation

Freshwater crocodile. This species has been totally protected in the State of Western Australia since 1962. On 1 January 1964 similar legislation was passed in the Northern Territory. Unfortunately, Queensland has still not agreed to any legislation to cover this species despite requests at the Australian Fauna Authorities Conferences extending over many years. This means that extensive poaching occurs even where it is completely protected (see National Requirements (Conservation)). Poaching has recently become so severe as to cause alarm. It is certain that even the present large populations cannot sustain the present level of poaching (Bustard, 1969).

Estuarine crocodile. Political attitudes to this species are coloured by the fact that the species is a known man-eater, is frequently alleged to attack stock, and has a first class commercial hide. Following advice from me the Government of Western Australia placed the estuarine crocodile on the totally protected list early in 1970. This action will be in force for an initial period of ten years when a further survey of crocodile stocks will be carried out. If

the species has regained ground then licences may be issued to allow the taking of some stock to start commercial farming enterprises (see National Requirements (General)). It is not envisaged that indiscriminate shooting will ever be allowed again.

The Northern Territory is considering similar action to Western Australia. It would appear likely that, as happened with the freshwater species almost a decade ago, the lead set by Western Australia will be followed by the Northern Territory. Unfortunately, it seems most unlikely that Queensland will apply protection to the estuarine crocodile. There have been a number of deaths involving Europeans in Queensland and the reptile is widely loathed. This means that a poaching problem will occur as currently exists for the freshwater crocodile.

Since Australia is an island continent, and crocodiles occur in only three of the seven political units, action by Queensland on the freshwater crocodile would protect the species throughout its range. Poaching would no longer be an important problem as the Commonwealth (Federal) Customs would prohibit export of skins or specimens, on the same way as applies at present to animals such as koala bears, the platypus and echidnas.

The estuarine crocodile poses more difficult problems. Whereas the freshwater species does not have a desirable skin and is quite innocuous to humans unless attacked, the estuarine is a prime commercial animal. Accordingly, although it is hoped that it will soon prove practicable to give total protection to the freshwater species in Queensland and hence throughout the Continent, rational exploitation techniques which can be enforced politically have to be worked out for the estuarine crocodile.

It is my belief that farming offers the best solution to the problem (see National Requirements (General)). Quite apart from providing a strong political case for preventing the extinction of the species (based on its potential commercial value in farms), such farms if properly organized and on a sufficiently large scale, could supply much of the world demand for hides and so reduce pressure on wild populations. There is no question that the main skin buyers would much prefer to be able to write long-term contracts to buy skins of specified quality and size, in place of the present haphazard situation which exists as a result of exploitation of dwindling natural stocks.

Education

As with all conservation problems education is a 'must'. Scope for education concerning crocodiles is extremely wide as the group enjoy a very low popularity status. Every effort is being made to provide factual information on Australian crocodiles and their right to continue to exist, by means of

newspaper releases, semi-popular articles in magazines, radio, TV and films. The farming ventures about to commence in the north under my guidance (see National Requirements (General)) have aroused very considerable interest in crocodiles.

Research

Extremely little work has been carried out at a research level on Australian crocodiles. Many years ago I intended to start a long-term field population ecology study of the freshwater species. However, it seemed that my time could be more gainfully employed on short-term, detailed survey work and providing advice and reports to Government.

However, in order to be able to age standing populations in the field, which is an exceptionally important requirement both in ecology and conservation, we have been working on skeletal age determination techniques. This would appear to have considerable promise, especially since, in species like C. johnsoni, age determinations can be readily made from scutes which can be removed from the living animal. In the course of this work it is hoped to be able to build up a substantial body of data on the range of sizes occurring in each age class for both Australian species.

I know of no other research on these species of relevance to this meeting.

National Requirements

Research

There is an urgent need for an Australia-wide survey of crocodile resources in order to determine the location of the larger population remnants of both species. In view of my recent work in Western Australia, efforts should be primarily directed at the Northern Territory and Queensland. The surveys would allow strategic siting of National Parks and provide a basis for future work both in Australia and overseas. I shall be carrying out survey work in the Northern Territory and Queensland later this year to determine where the best estuarine crocodile populations occur.

There is an urgent need for long-term population ecology studies on crocodilians. An ideal species in many ways would be the Australian freshwater crocodile. Its comparatively small size together with the billabong habitat (billabongs are pools which result when rivers stop flowing during the dry season) make it particularly amenable to work of this nature. Effective conservation requires information of many aspects of crocodiles' life tables

which are at present unknown. It is, however, only fair to point out that there are many difficulties in working with wild populations of crocodiles. The size of the animals concerned and the distances from centres of population usually make the work extremely costly -- well out of reach of an ordinary University department.

To my mind, one of the most important conservation-oriented fields of research with species like the estuarine crocodile is to pioneer crocodile farms -- at a pilot research level. I have felt for some years that a species such as C. porosus should be amenable to farming. I have seen penned individuals in northern Australia lay eggs in captivity in successive years in very small enclosures and also noted most favourable growth rates under such conditions. Accordingly, I sought funds from the Australian Federal Government to carry our pilot research crocodile farms in northern Australia. Funds were provided, initially for a three year period, by the Prime Minister's Department. Only C. porosus will be used in these farming experiments.

Since receiving funds I have visited the first-class crocodile farm owned by Mr Utai Yangprapakorn and seen the excellent growth rates obtained there. Details will be provided in a later paper (Paper No 10). There can now be no doubt that crocodile farming using species such as C. porosus or C. siamensis is a feasible proposition.

Conservation

This matter is best dealt with State by State:

Western Australia. Both species totally protected. Conservation problem centres around reducing poaching of hides to sell in Queensland (freshwater) or Queensland and Northern Territory (saltwater). Huge areas of crocodile habitat very difficult to police. Poor public image of crocodiles means that magistrates etc. do not always co-operate fully with Fauna Wardens. The Government of the State of Western Australia* takes a most enlightened attitude to conservation (reflected in the fact that both crocodiles are fully protected) and will take any reasonable measures possible to ensure their survival. A large Fauna Reserve (this State's terminology for what is known internationally as a National Park) is being created specifically for the estuarine crocodile at a location particularly recommended by me.

---

* Its Fisheries Department has long been a Member Organization of IUCN and was probably the first Australian one to become so. -- Ed.

It seems likely that the hunting closure of the estuarine species will reduce poaching of the freshwater. Until 1970, when it was still permissible to take estuarine crocodiles, possession of crocodile catching equipment could not be deemed unlawful as the shooter would say he was only taking the unprotected species. Now, with both species fully protected, clearly anyone in possession of gear is out to break the law.

Northern Territory. Total protection of freshwater species. It is hoped action will be taken as a matter of urgency to give total protection to the estuarine crocodile also and then to reduce poaching of both species.

Queensland. No conservation legislation exists for either crocodile at present. It is to be hoped that Queensland will move towards total protection of the freshwater species. There would then be no conservation problem for that species throughout Australia as poaching would no longer be profitable since (a) there would be no legal outlet for skins inside Australia and (b) export of skins would be forbidden by Federal Customs.

The estuarine species poses considerable problems in Queensland. Some legislation is essential but will be hard to bring about. At least one large National Park for the estuarine species is considered necessary. It appears likely that this can be declared. In Queensland the best remaining populations of the estuarine crocodile are inside aboriginal reserves which are supposedly inviolate by white Australians. These areas are under the control of the Department of Aboriginal and Island Affairs and unfortunately cannot be declared National Parks. However, the co-operation of the Department of Aboriginal and Island Affairs in safeguarding these crocodile populations is being sought, with the rationale that they can form the basis of crocodile farms run to aid aborigines.

Reference

Bustard, H. Robert 1969. "The current status of crocodiles in Western Australia with recommendations for conservation and managed exploitation". Report to Government of Western Australia, November, 1969.

APPENDIX

The status of Crocodylus porosus outside Australia, not including Papua, New Guinea and Thailand (covered by other delegates).

Having examined the available information together with that which I have been able to obtain through personal correspondence, I do not feel that it is profitable to attempt to discuss the status of the estuarine crocodile in the various areas it inhabits in Asia; information is too sparse to give a reliable picture. However, one obtains the impression of a species which is rapidly loosing ground both as a result of reduction in numbers in any given locality and as a result of range contraction. There is no doubt that porosus is extremely vulnerable to modern shooting methods. It is extremely difficult to judge the effectiveness of legislation even where it goes as far as to place a complete ban on the export of skins (as is the case in Ceylon and India).

Paper No 3

REGIONAL SITUATION REPORT -- PAPUA AND NEW GUINEA

M.C. Downes
Wildlife Laboratory, D.A.S., Konedobu

The two species of crocodile found in the Territory of Papua and New Guinea are the estuarine or saltwater crocodile Crocodylus porosus and the New Guinea freshwater crocodile C. novaeguineae.

The major areas of alluvial riverine plains, swamps and tidal swamps, forming very suitable habitat for crocodiles, probably total at least 40,000 square miles (see Figure 1 of Paper No 12 in these Proceedings, by the same author).

The major crocodile producing districts are the Fly River, the Gulf and the Sepik River, all within the lowlands of the main island.

The saltwater crocodile is found in greatest numbers in the estuaries and the lower reaches of the big rivers; but it occurs on all coasts and coastal rivers throughout the Territory. Inland it is usually limited to the larger, deeper rivers and connected water systems, but it can appear in any fresh-water swamp in occasional big flood years. It is regularly reported in the swift flowing rocky streams of the upper Fly River more than 600-700 miles inland, virtually in the foothills of the inland ranges, and similarly in the Sepik area.

Saltwater crocodiles not long hatched seem to be found through most of this range but are frequent only near the coast. Unused nests, said to be of this species, have been inspected in dry earth some 10-20 feet above the river in forest at Lake Murray, and similar nests are reported further inland at Kiunga.

A very big reduction in the numbers of saltwater crocodiles has occurred since commercial shooting started in the mid 1950s. In particular, the un-controlled shooting of crocodiles from upwards of 5 feet in length, in the period 1955-60, greatly reduced the adult population of saltwater crocodiles in accessible rivers and lakes. At the present time it is difficult to find this species in any of the water-ways accessible to boats.

The initial and rapid decline in saltwater crocodiles was followed by an increased hunting of freshwater crocodiles, which reached a peak in 1965-66. The freshwater crocodile, as far as is known, is restricted to the main

island of New Guinea. Suitable inland swamp habitat of any size does not occur east of about 148° E. longitude (east of Port Moresby) so that the freshwater species is found only from this longitude west into West Irian on both the north and south coasts. It is rarely taken in saltwater localities, and reaches its greatest numbers in the extensive swamps of the inland swampy plains.

Nests are located throughout the large grassy swamps and are still plentiful in the more remote and inaccessible areas. At coastal localities over 90% of skins for export are of the freshwater species, inland more than 99%.

The marked decline in export of skins after 1966 is due to a very obvious shortage of freshwater crocodiles in the areas easily hunted. There are moderate numbers still available in areas more difficult of access. In these areas due to rough terrain or to the indigenous people having had limited contacts with the outside world, the freshwater crocodile is only slowly being reduced in numbers.

However, these reservoirs of crocodile stocks are restricted in size compared with the original multitudes and are definitely threatened by the ever extending economic and cultural contacts. Although habitat changes have not yet reached significant proportions, there is definite potential danger from introduced fish (Tilapia in the Sepik) and mining exploration in the headwaters of the Sepik and Fly Rivers, with the considerable potential for pollution.

Prior to European contact, in the areas where crocodiles were plentiful, the native people hunted them for food, but it was the eggs and younger stages which were most heavily used. Naturally, such a large and dangerous animal was feared and revered, and played a dominant role in the folklore of traditional society. A clear distinction was made between the two species -- in appearance, breeding habits and danger to man. Until the time when the saltwater crocodile was greatly reduced in numbers, human deaths were frequent in the estuarine areas. However, it must be realized that only in a few special hunting communities were the majority of the men all skilled crocodile hunters. These people frequently herded freshwater crocodiles up to 8 feet in length in the grassy swamps, feeling for the crocodiles lying dormant on the bottom, reaching down and clamping their jaws shut with their hands or slipping a noose over their mouths. In one of the few areas known to have a taboo on killing of crocodiles, prior to the rise of the industry, this custom was modified to allow the people to participate to it, because the species was the main available source of food.

The present methods of hunting for commercial purposes are with an electric torch and spears, or rarely a shotgun, at night. Spearing, hooking on baited line and, occasionally, netting are the usual methods, in decreasing

order of importance. Adults are often killed in daylight, sometimes being surprised on land but much more frequently being females attending nests. Eggs and young are frequently harvested but probably at a reduced rate compared with the past.

If protective controls and constructive management projects were brought in on sufficiently large scale there are still adequate numbers of crocodiles of both species to regenerate and sustain a viable industry. However, the problems are not all ecological nor to do with the organization of marketing. There is a reluctance amongst western-oriented economic planners to organize an industry based on such a dangerous unattractive wild animal with so few friends as the crocodile.

Nevertheless, for many indigenous people in several districts of Papua - New Guinea the crocodile is no more unusual than the cattle so familiar to a Western community. It poses much less danger to them than the motor car does to us. Over a wide region, it provides the only source of income in primitive areas, which have little potential for conventional agriculture products.

For these and other reasons special efforts are needed to conserve the crocodile stocks and to organize a stable long-term industry.

Paper No 4

THE STATUS OF FOUR THREATENED CROCODILIAN SPECIES OF ASIA

René E. Honegger
Zoologischer Garten, Zürich

Introduction

Crocodylus palustris palustris, Crocodylus siamensis, Tomistoma schlegelii and Gavialis gangeticus are threatened species. The reasons for their decline are extensive hunting and the loss of suitable habitat.

Crocodylus palustris kimbula is considered to be a less threatened species, due to the present legislation which is highly commendable. With the exception of C.p.kimbula, very little biological information about these crocodiles in the wild is available. The only breeding records in zoos of which I know, pertain to the typical race of C.palustris; in addition, in a private farm in Thailand, great numbers of C.siamensis hatchlings are reared to skinning-size.

The details are set out below in the style and under the headings used in IUCN's Red Data Book (Vol. 3, Amphibia & Reptilia), references being indicated by numbers in brackets.

Geographical Distribution (1)

BRUNEI	Tomistoma schlegelii
BURMA	Crocodylus palustris palustris (?)
	Gavialis gangeticus
CAMBODIA	Crocodylus siamensis
CEYLON	Crocodylus palustris kimbula
INDIA	Crocodylus palustris palustris
	Gavialis gangeticus

INDONESIA	Kalimantan	Tomistoma schlegelii
	Java	Crocodylus siamensis
	Sumatra	Tomistoma schlegelii
IRAN		Crocodylus palustris palustris
LAOS		Crocodylus siamensis
MALAYSIA	Malaya	Tomistoma schlegelii
PAKISTAN	Western	Crocodylus palustris palustris
		Gavialis gangeticus
	Eastern	Crocodylus palustris palustris
		Gavialis gangeticus
SINGAPORE	(14)	Tomistoma schlegelii
THAILAND		Crocodylus siamensis
VIETNAM	Northern	Crocodylus siamensis
	Southern	Crocodylus siamensis

* * *

Crocodylus palustris palustris Lesson 1831

Marsh crocodile, Mugger

Status:

India: "Exterminated in most areas of its range" (2). "Extremely rare" (3).

Iran: "Relatively rare and depleted -- a rough estimate of the population (Sarbaz River in south-east Baluchistan from 5 km north of the village of Rask to the Gulf of Oman) would be from 60 to 100 individuals" (4).

Pakistan, West: "Extremely endangered, near extinction" (5).

Reasons for decline:

India: "The major portion of skins exported was made up by this species" (6). "Poor enforcement of hunting rules, highly profitable foreign trade in skins, loss of habitat and food resources" (6).

Iran: "Past poaching activity and habitat interferences are the major

factors in the crocodile's reduced numbers. Low rainfall and scarcity of suitable pools in the rivers are natural factors limiting their numbers" (4).

Protective measures taken:

India: "Officially protected" (3).

Iran: "Protected by the Game Ordinance of the Iran Game and Fish Department. It is unlikely that anyone has ever been apprehended for taking crocodiles, since the area of S.E. Baluchistan is isolated and poorly protected by this department" (4).

Protective measures proposed:

India: "a) Prohibition of export of skin and any other part of crocodile,
b) hunting and shooting to be prohibited for ten years,
c) game laws to be more rigorously enforced outside Government forests, by some appropriate agency,
d) preservation of breeding stock and establishment of crocodile farms to be encouraged.
e) a survey to be undertaken of the species' present status" (6).

Iran: "Establishment of a Sarbaz River Protected Region and increased patrolling and recognition of the wildlife and habitat resources of the region" (4).

Number in captivity:

"At least 2 males, 2 females, plus 94 specimens, of which 48 were hatched in captivity, in 13 zoos" (8).

Breeding records in captivity:

Ahmedabad Zoo (1960?, 1962, 1969); Baroda Zoo (1964); Bangkok Zoo (1965); Jaipur Zoo (1960?, 1962, 1963, 1965, 1967, 1968) (16).

Remarks:

"Average size: 315 cm, maximum size: 410 cm" (10).

Research:

"An extensive study on this species was planned for November 1970 by the Game and Fish Department of Iran. A preliminary study made in April 1970, showed the species to be in imminent danger of extinction due to poachers and habitat interferences. Following our recent survey we have made recommendations for the establishment of a Sarbaz River Protection Region" (4).

* * *

Crocodylus palustris kumbula Deraniyagala 1936

Ceylon swamp crocodile; Kimbula

Status:
"This crocodile can be observed, at least in Ruhuma National Park, regularly in larger numbers and in various age groups" (11).

Reasons for decline:
"Past poaching and hunting for their skins" (17).

Protective measures taken:
"In the 1964 Fauna and Flora Protection Ordinance, the Ceylon swamp crocodile is cited as an animal which shall not be shot, except on a special licence at any time of the year. Special licences, obtainable from the Government Department of Wildlife, allow the taking of only one individual" (17). "The possession of skins of this species is an offence, the export of skins is totally banned" (18). "It is considered that the above legislation will ensure the future of this crocodile. It is the value of their skins that has almost wiped out many species of crocodiles. The legislation in force in Ceylon is highly commendable" (17).

Number in captivity:
"At least 3 specimens in 3 zoos" (8).

Remarks:
For biological information on this species see Deraniyagala's publications (15, 15a).

* * *

Crocodylus siamensis Schneider 1801

Siamese crocodile

Very little information is available on this species.

There is a farm in Thailand which holds mature C. siamensis, and is currently producing young, of which a large percentage is reared to skinning size (19). (See also Papers 8, 10 and other references in these Proceedings.)

Number in captivity:
"At least 1 male, 3 females, plus 14 specimens, in 15 zoos" (8).

Remarks:
"Average size: 315 cm, maximum size: 380 cm" (10).

* * *

Tomistoma schlegelii (Müller 1838)

False gavial, Malayan gavial

Status:
In Malaya the false gavial is protected in the States of Selangor, Negri Sembilan and Malacca under the Wild Animals and Birds Protection Ordinance 2 of 1955. Trapping and hunting may be carried out throughout the State of Malaya, even where the species is protected, requiring a licence. In the Taman Negara National Park, all species of wildlife are protected (12).

Number in captivity:
"At least 2 males and 51 specimens in 35 zoos" (8).

Remarks:
"Average size: 280 - 310 cm, maximum size: 500 cm" (10).

* * *

Gavialis gangeticus (Gmelin 1789)

Indian gavial, Gavial

Status:
India: "Extremely rare" (3).
Pakistan: "Extremely endangered, near extinction" (5). "A rare species" (13).

Reasons for decline:
India: "The commercial exploitation of crocodiles during the last few decades for their skin has seen the extermination of the species in most areas of its range" (2). "The gavial faces extinction because of poor enforcement of hunting rules, highly profitable foreign trade in skins, loss of habitat -- diversion of river waters into canals -- and reduced food sources" (6).
Pakistan: "The main reason for their decline has been the extravagant shooting for their skin" (13).

Protective measures taken:
India: "Officially protected" (3).
Pakistan: "The export of Gavials, both live specimens and skins, has been totally banned from East and West Pakistan. Their shooting has been controlled. They may be shot in West Pakistan only under a special permit from December 1st to March 31st" (13).

Protective measures proposed:
India: "a) Prohibition of export of skin and any other part of a gavial,
b) hunting and shooting to be prohibited for ten years,
c) game laws to be more rigorously enforced outside Government forests, by some appropriate agency,
d) a survey to be undertaken of the present status,
e) preservation of breeding stock and establishment of crocodile farms to be encouraged" (6).

Number in captivity:
"At least 6 males, 9 females plus 37 specimens in 23 zoos" (8).

Breeding records in captivity:
None.

Remarks:
"Average size: 380 - 470 cm, maximum size: 675 cm" (10).

* * *

References

1. Wermuth, H. and Mertens, R. 1961. Schildkröten, Krokodile, Brückenechsen. Fischer, Jena.
2. Daniel, J.C. 1970. A review of the present status and position of endangered species of Indian reptiles. IUCN Publ. (N.S.) No 18:75-76.
3. Seshadri, B. 1969. The twilight of India's wild life. London.
4. Kinunen, W. in litt. 24.10.70 - 28.12.70.
5. Mertens, R. 1969. Die Amphibien und Reptilien West-Pakistans. Stuttg. Beitr. Naturkunde 197:1-95.
6. Misra, R.N. 1970. The endangered crocodiles of India. IUCN Publ. (N.S.) No 18:77-81.
7. Jarvis, C. 1967. International Zoo Yearbook, 7. London.

8. Lucas, J. 1970. International Zoo Yearbook, 10. London.

9. David, R. 1970. Breeding the mugger, Crocodylus palustris, and water monitor, Varanus salvator, at Ahmedabad Zoo. Int. Zoo Yearbook, 10:116.

10. Schmidt, K.P. and Inger, R. 1957. Knaur's Tierreich in Farben: Reptilien. München, Zürich.

11. Honegger, R.E. Pers. obs. Feb./March 1969.

12. Mohammed Khan bin Momin Khan, in litt. 10.2.71.

13. Siddiqi, M.S.U. in litt. 5.10.70.

14. Harrison, J.L. in litt. 11.2.71.

15. Deraniyagala, P.E.P. 1939. The tetrapod reptiles of Ceylon, 1, Testudinates and Crocodilians. Ceylon J. Sci. Colombo.

15a. Deraniyagala, P.E.P. 19--. A colored atlas of some vertebrates from Ceylon. Vol.11: Tetrapod Reptilia. Ceylon National Mus. Publ.

16. Honegger, R.E. 1971. Zoo breeding of crocodiles and a crocodile bank. These Proceedings, Paper No 9.

17. Bustard, H.R. in litt. 9.7.69.

18. De Alvis, L. in litt. 14.12.67.

19. Bustard, H.R. in litt. 3.9.70.

Paper No 5

EXTERNAL TRADE STATISTICS OF WEST MALAYSIA FOR UNDRESSED CROCODILE SKINS

Paul Wycherley
President, Malayan Nature Society, Kuala Lumpur

The imports are nearly always less than the exports, which include re-export of imports.

	Exports		Imports	
	lb	$(Malayan)	lb	$(Malayan)
1953	312,865	2,130,580	272,467	1,114,339
1954	305,020	2,022,344	232,554	1,045,767
1955	350,276	2,451,564	280,611	1,413,919
1956	354,225	2,288,953	243,821	1,176,424
1957	366,155	2,617,423	327,811	1,577,322
1958	425,697	2,479,079	332,165	1,773,513
1959	308,840	1,982,182	184,275	985,202
1960	4,998	20,359	1,052	3,121
1961	7,157	26,453	8,933	14,191
1962	3,004	15,987	4,892	12,535
1963	3,276	12,939	8,298	10,210
1964	4,074	12,326	3,571	5,228
1965	3,821	21,029	0	0
1966	1,321	7,730	168	1,060
1967	2,037	12,240	802	2,058
1968	1,323	6,795	25	100
1969	1,386	7,580	44	500

Table 1. Weight in lb and value in Malaysian dollars (M$ 3 = US$ 1).

The imports were from Sarawak, Sumatra, Thailand and other surrounding countries for re-export, sometimes after some dressing or tanning. Figures for the export of dressed hides were unobtainable. One difficulty is that dressed skins of both snakes and crocodiles are lumped together in the trade statistics. There may be some wastage in dressing skins which reduces the weight but increases the value.

The few figures thus available in respect of dressed skins are therefore fragmentary and cover the total trade in snake and crocodile skins:

	lb	$ (Malayan)
1962	1,447	19,100
1963	7,075	12,592
1964	56,688	13,819
1965	522	4,272
1967	85	470
1968	704	1,430

The decline in imports of undressed crocodile skins may be due to the other countries concerned trading directly with consumers; and the decline in exports of undressed crocodile skins may be due to a larger proportion being dressed and reduced in weight before export. However, the few figures available for dressed skins (including snakes) do not suggest that dressed skins have been counterbalancing the rather abrupt fall off the trade in undressed skins which occurred in 1960. Previous to that year, namely up to 1959, the total trade (i.e. the export figures) averaged 154.5 long tons of skins per year and the value averaged M$ 2,281,732/-. Thereafter exports fell to an average of 1.45 tons valued at M$ 16,341/-, i.e. to less than 1% of the former figure.

There does not seem to have been any fall off in the demand, or not enough to account for this decline. I conclude that crocodiles (especially Crocodylus porosus) are now very rare. Supporting evidence I can quote is that, for example, the Pilot for the Straits of Malacca published in about 1950 (I have not a copy in front of me and I am quoting from memory), comments that crocodiles abound in the estuary of the River Klang at Port Swettenham and that they are frequently to be seen basking on the mud banks. No one from among my friends at the Port Swettenham Yacht Club, passengers and crew of ships, parties of students from the University of Malaya and so on, have reported seeing any crocodiles in the River Klang estuary for years.

One planter made a living by shooting crocodiles during the depression of the 1930s. However, the Malayan Zoological Society had great difficulty in obtaining specimens for display when the Zoo opened in 1964. Even experienced Malay and European hunters could not find many at that date and today crocodiles are quite definitely scarce.

In 1954, I visited the Langkawi Islands off the north-west of Malaya and I was advised not to swim in the sea, except within a stockade, because of a recent death and a maiming of swimmers by large crocodiles. I understand that sea bathing is now considered quite safe in these waters.

Therefore the status of C. porosus is probably critical; I regret I have little information about Tomistoma schlegelii.

Paper No 6

SITUATION REPORT ON CROCODILIANS FROM THREE SOUTH AMERICAN COUNTRIES

Federico Medem
Instituto "Roberto Franco", Villavicencio (Meta)

Introduction

This report was originally planned to refer to the actual situation of crocodilians from all South American countries. This proved to be impossible because communications difficulties inhibited the acquisition of exact data from Venezuela, Ecuador, Bolivia, Paraguay, Uruguay, Argentina, Guyana (former British Guiana), Surinam and Cayenne. Thus, official statistics from Brazil (Amazon Valley), Perú and Colombia only were available for up to date reference.

It is evident that all crocodilians suffer from heavy hunting pressure, due to the excessive demands of the tanning industry; several species are either greatly diminished or virtually extinct. Crocodilians are generally considered to be useless or even regarded as pests. This they are certainly not since they play an important rôle in the nutrient cycle within their natural habitat, as shown by Fittkau (1970). Local inhabitants from the Amazon Valley discovered, to their surprise, that the fish populations in various lakes diminished considerably after the extermination of caimans. Apparently there existed an interdependence between the metabolism of the latter and the larvae of those fishes which spawn in the lakes. The excreta of caimans form the basis of nutrition for bacteria, phyto- and zoo-plankton, and these again comprise the main food source for larval stages and juveniles of several larger fish species, as well as for juveniles and adults of many species of small fish, which serve as food for the former. The same happens in Colombia, where most fishes of commercial value have diminished at an alarming speed during the past ten years, even within those areas where no over-exploitation occurs.

Official statistics about the exportation of hides and living specimens from Colombia refer to material already exported; those submitted by the tanning industry in Bogotá include both exported skins and others still stored in the warehouses. There exist, however, discrepancies between the official reports and those given by local traders; official statistics do not always correspond to the facts, mainly because traders submit faked data and altered accounts, and that there are not sufficient inspectors to control the transport

by land and air of hides which are frequently concealed beneath other merchandise or in empty gasoline containers. As is well known, a well-organized national and international illegal trade exists, which is hard to control. All these uncertain factors must therefore be taken into account, if one wants to assess the real situation. Thus, the actual data that can be presented give only a smattering of knowledge concerning the actual state of crocodilians in South America.

In the following country by country reports we refer to the official and unofficial information in each.*

Brazil

Melo Carvalho (1967) refers only to the 'Jacarés' as a whole, but does not give corresponding separate information on 'Jacaré-açú' (Melanosuchus niger) and 'Jacaré-tinga' (Caiman sclerops or crocodilus). According to his statistics for the various Brazilian States which geographically belong to the Amazon Valley, the following are the numbers of hides of the Black and Spectacled caimans traded between 1960 and 1964:

State	Hides traded (1960 - 64)
Rondônia	24,512
Acre	6,361
Amazonas	231,038
Roraimá	7,181
Pará	176,094
Amapá	16,046
Maranhão	1,470
Total	462,702

Table 1

Note: The State of Maranhão, east of Belém do Pará, is not situated in the Amazon Valley proper, but the Tocantíns River, which runs in part through its territory, flows into the Baía de Marajo close to Belém.

---

* I am indebted to Dr F. Wayne King, Curator of Herpetology at New York Zoological Society's Zoological Park (Bronx), to Dr Pedro Rodriguez Guerrero, Jefe Programa Parques y Fauna, INDERENA, in Bogotá, and Dr Julio Gutierrez Arango, Jefe Seccional del Meta, INDERENA, in Villavicencio, for their collaboration in gathering both the official statistics and unofficial data.

The same author has also presented an account of the number of hides which were traded from a single State between 1950 and 1965:

State	Year	Hides traded (1950 - 65)
Amazonas	1950	4,926,908
	1951	262,020
	1952	362,051
	1953	430,774
	1954	407,341
	1955	---
	1956	1,039,923
	1957	13,884
	1958	6,450
	1959	1,773
	1960	490
	1961	600
	1962	1,983
	1963	327
	1964	29,044
	1965	33,658
	Total	7,517,226

Table 2

Amazonas State comprises roughly the middle Amazon and Rio Negro, together with its upper course, known as Rio Solimões, as far as Rio Javarí which forms the boundary of Perú; the lower Amazon, from Nhamundá to the mouth, is included in the State of Pará.

It can be presumed that the majority of hides, possibly until 1963, belonged to the Black caiman Melanosuchus niger, since these are of greater value for the tanning industry; the very discernible decline in numbers between 1957 and 1963 may indicate the progressive scarcity of this species. Hides of the Spectacled caiman Caiman sclerops were used only when those of M. niger became more and more rare. In 1955 no skins were traded, but possibly the quantity given for 1956 indicates the total number for both years. There is no doubt that a considerable decline in the number of hides sold has occurred, even if one assumes that demand by the tanning industry has also been less for several years.

Data for Brazil, since 1965, could not be obtained. Equally lacking are statistics on the status of two other caimans; Caiman latirostris locally known as 'Jacaré de papo amarelo' or 'Ururaú', and Caiman yacare called 'Jacaré'. The former ranges from Rio São Francisco south to Rio Grande do Sul, and the latter occurs in the Paraguai River (Rio Paraguay in Spanish

speaking countries) in the State of Mato Grosso, but also enters the Rio Guaporé which forms the boundary between Brazil and Bolivia (Medem, 1963, p. 13).

During an expedition on the Amazon from Belém to Manaus in September-November 1969, we observed only nine small juveniles of M. niger in the area of the upper Rio Trombetas. Few hides were traded in Oriximiná and other villages, all of them belonging to juvenile specimens (50 - 150 cm in length). On the other hand, skins of Caiman sclerops were seen in great abundance in most villages and settlements, the majority belonging to adult specimens.

In a letter to Dr King (13 October 1970), the director of the Zoological Garden in Rio de Janeiro, Adelmar F. Coimbra Filho, stated: "What I myself can advance for sure is that the 'jacaré-açú', Melanosuchus niger, of the Amazonian Basin is rare nowadays. Its population is very reduced. The old giant Amazonian 'jacarés-açús' are now seldom if ever seen".

Perú

Crocodylus acutus 'Lagarto'; 'American crocodile'.

Hofmann (1970) made a survey from 24 July to 2 August 1970, of the Rio Tumbes, a river which flows into the Pacific Ocean close to the border to Ecuador. Only six specimens, between about 40 and 120 cm in length, were observed at night in the lower course close to the mangrove zone, and 16 more were seen within the sector La Capitana to Cabo Inga. There is no commercial hide hunting, but local fishermen, hunters and cattle growers kill every crocodile they meet. In the lower course of the river and in the mangrove zone C. acutus is virtually extinct. According to information given by natives of the area, small populations still survive in the brackish water zone close to Puerto Pizarro and El Salto, as well as in the uppermost course of Rio Tumbes, called Rio Puyango, between Murciélago and Cabo Inga.

Extermination has been due to the following reasons:

1) intensification of fishing activities within the mangrove zone by means of large nets across the channels;
2) killing of crocodiles because of fear of the damage they could do to people and cattle;
3) the hides are considered as trophies by hunters; and
4) the tail meat is eaten by local inhabitants.

The author recommends that further surveys should be carried out at the following sites:

Mangrove zone: Puerto Pizarro; El Salto.

Rivers: Rio Zarumilla, north of Tumbes; Rio Puyango (uppermost course of Tumbles River); Rio Chira and Rio Piura, both south of Tumbes.

The best time for field studies is April - May; a period of about three weeks would be sufficient to investigate all the places named.

Hunting of Crocodylus acutus is prohibited by law (Resolución Suprema No 343, 16 October 1950).

Caiman sclerops 'Lagarto blanco'; 'Spectacled caiman'.

Specimens of a size less than 1.50 metres are protected (Resolución Ministerial No 2525, 18 November 1955).

The report of a survey, undertaken by FAO in 1970 on the Peruvian Amazon (Rio Marañón), records the numbers of hides sent to Lima from Iquitos and Pucallpa as follows:

Year	Hides
1963	17,839
1964	20,650
1965	20,506
1966	16,629
1967	14,628
1968	19,788
1969	17,601
Total	127,641

Table 3

The number does not include hides imported from other countries; such importations took place until 1966. From Lima about 106,075 caiman hides were exported, the rest being used within the country.

Considerably greater numbers of hides, however, were exported from or, to be exact, traded in Leticia (Comisaría Amazonas), the capital of the Colombian Amazon and main trading place on the upper Amazon River. To quote the FAO report (p. 2): "In Colombia the minimum size is 1.20 m, and in Brazil 1.00 m. However, in Leticia (Colombia), the only place in

Colombia not affected by protective regulations, small-sized hides (50 - 100 cm) were traded freely. The number of hides traded in Leticia amounted to 399,404 in the one year period 1 July 1969 - 30 June 1970. The majority of these derived, it appears, from Brazil and Perú..."

The report recommends as follows (p. 3): "It is urgent that the Amazonian countries unify their legislation on hunting and trade of this species. A reasonable solution would be to have Colombia and Brazil raise their minimum size to 1.50 m, and to have exports of undersized hides from Leticia stopped..."

Melanosuchus niger 'Lagarto negro'; 'Black caiman'.

Specimens of a size less than 2.00 m are protected (Resolución Ministerial No 1813, 19 November 1950).

The above mentioned report by FAO refers to the hunting pressure, based on data about the number of hides traded in Iquito, Pucallpa and Puerto Maldonado, as set out in the following table (hides imported from elsewhere are not included):

Year	Hides
1962	4,834
1963	3,799
1964	2,914
1965	3,536
1966	3,230
1967	2,333
1968	3,171
1969	2,646
Total	26,463

Table 4

Concerning the trade via Leticia the report states (p. 4): "In Colombia this species is totally protected, except in Leticia, where 35,525 hides were traded between 1 July 1969 and 30 June 1970. The minimum size in Brazil is 1.00 m". In order to rebuild populations of this species, a total protection is "necessary over a period of five to ten years". According to FAO, both caimans have declined in the Peruvian Amazon; most hunters now find it more difficult to obtain hides of Caiman sclerops than five years ago, and Melanosuchus niger is now absent in areas where it was previously found.

Note: According to Colombian official statistics, in 1970 there were about 299,973 hides of Caiman sclerops and 30,105 of Melanosuchus niger (see below), while the FAO report refers to the quantity traded between 1 July 1969 and 30 June 1970, as amounting to 399,404 hides of the former and 35,525 of the latter. The discrepancy may, however, be due only to the fact that the Colombian statistics cover the period January to December 1970, while those of FAO are for the period of one year starting six months earlier. Unfortunately the FAO report does not give monthly figures for the Leticia trade. What is quite clear is that the trade of hides in Leticia does considerable damage to neighbouring Amazonian countries.

Colombia

Colombia is one of the principal countries for the trade in hides and living animals, due to its geographical situation. As already stated Leticia is the main trading centre on the upper Amazon, from which aircraft travel directly to Miami. Other centres of trade are: Bogotá, D.E.; Barranquilla (Atlántico), at the mouth of Rio Magdalena; Villavicencio, capital of Departamento Meta, Orinoco Basin; Puerto Carreño (Vichada), capital of Comisaría Vichada, situated on the Orinoco close to the mouth of the Meta River; Puerto Inírida, capital of Comisaría Guainía, Orinoco Basin; Cali, capital of Departamento Valle, and Buenaventura (Valle), the principal harbour on the Pacific coast. To a lesser extent also Mitú, capital of Comisaría Vaupés, and Miraflores on the upper Vaupés River, Amazon Basin; Florencia, capital of Intendencia Caquetá, situated on Rio Orteguaza, a tributary of upper Caquetá River; La Pedrera, a village on lower Caquetá; Tarapacá, on lower Putumayo River, close to the Brazilian border; and Puerto Leguízamo (Putumayo), on the middle Rio Putumayo, Amazon Basin. This geographical introduction is necessary to understand the official statistics presented below. Several tanning companies exist in Bogotá and, therefore, crocodilian hides are now exported tanned, and not crude as formerly (Resolución No 16, 21 October 1969, Consejo Directivo de Comercio Exterior).

The national institution responsible for the protection of natural resources is the Instituto de Desarrollo de los Recursos Naturales Renovables (INDERENA), which was created in 1968 (Decreto No 2420, 24 September 1968) and replaced the former Division of Natural Resources of the Ministry of Agriculture, and the CVM (Corporación Autónoma de los Valles del Magdalena y del Sinú), founded in 1962. INDERENA is actually divided into various Sections: for instance, "Sección Regional - Central" has its headquarters in Bogotá, D.E.

The following crocodilians are totally protected in Colombia (Resolución No 411, 16 July 1968, Ministerio de Agricultura; Resolución No 573, 24 July 1969, INDERENA):

1)	Crocodylus acutus	'Caiman'; 'American Crocodile'.
2)	Crocodylus intermedius	'Caiman'; 'Orinoco Crocodile'; confined to the Orinoco Basin.
3)	Melanosuchus niger	'Caiman negro'; 'Cocodrilo'; 'Jacaré-assú'; 'Black Caiman'.

Furthermore, restrictions exist on commercial hunting for various subspecies and local populations of the Spectacled caiman, in so far as animals under 1.20 m length are protected:

4)	Caiman sclerops apaporiensis	'Babilla'; 'Jacaré-tinga'. Known from upper Apaporis River only.
5)	Caiman sclerops chiapasius	'Babilla'; 'Tulisio'. Chocó, Pacific coast, Gorgona Island.
6)	Caiman sclerops fuscus	'Babilla'; 'Baba'. Atlantic coast; river systems of Magdalena and Sinú.

The collection of eggs and hatchlings of all crocodilians is also prohibited (Resolución No 1023, 30 July 1959, and Resolución No 411, 16 July 1968, Ministerio de Agricultura).

The two species of the genus Paleosuchus are not protected since their skins show a high degree of ossification and were not formerly traded. Actually, the hide of their 'flanks' (lateral sides) are now being used (see below). The two species in question are as follows:

7)	Paleosuchus trigonatus	'Cachirre'; 'Jacaré-coroa'; 'Smooth-fronted Caiman'.
8)	Paleosuchus palpebrosus	'Cachirre'; 'Jacaré-coroa'; 'Dwarf Caiman'.

Both are to be found in the Amazon and Orinoco Basins.

Recently, the previously mentioned Resolución No 16 (Consejo Directivo de Comercio Exterior) caused a certain confusion. According to Article 1, it is permitted to export tanned hides of reptiles only, among which all those species which are protected by INDERENA were also named. But, in contradiction to this, Article 2 reveals that the prohibitions already adopted for

the defence of endangered species (in the various Resolutions mentioned above) are still in force!

Furthermore, no limitations on the size of hides or on trade in living specimens of endangered species which are otherwise protected in Colombia, are applied at Leticia (a fact to which the FAO report has already and correctly drawn attention); this trade centre is considered by the Colombian Government to be a 'free port' for certain merchandise. In short, it would seem to be quite evident that the lack of a unified approach in the application of resolutions, regulations and laws to the country as a whole, an approach which would not be subject to any exceptions, creates confusion and favours loopholes which are rapidly detected and eagerly exploited by traders.

Finally, it must be emphasized that considerable wastage of crocodilian resources is caused by the fact that 'flanks' are in great demand by the tanning industry because of their small scales. These 'flanks', locally known as 'corte de chaleco' (waistcoat cut) or 'flancos', form a minimal part of the whole skin; after tanning they have the size of a belt. In many cases, hide hunters now skin only these lateral sections and leave the rest of the hide to rot.

According to official statistics issued by INDERENA (March 1971) for the year 1970, the following numbers of hides and living caimans were exported:

Species	Hides	Living specimens	Total
Caiman sclerops	599,397	366	599,763
Melanosuchus niger	7,633	259	7,892

Table 5

Additional statistics cover the trade in skins, broken down according to different localities. However, the information on which these statistics are based, which was supplied by local inspectors, is incomplete, and, with the exception of Leticia, does not cover the full year 1970. Moreover, no data about the size of the hides has been included. The statistics are as follows:

Locality	Hides (C. sclerops)	Hides (M. niger)	Period
Leticia	299,973	30,105	Jan.-Dec. 1970
Tarapacá	3,171	436	Feb.-Nov. 1970
Miraflores	2,704	---	Feb.-Aug. 1970
Mitú	165	---	Feb.-Apr. 1970
San José del Guaviare (Vaupés)	4,994	---	Feb.-May 1970
Pto. Inírida	16,607	---	Jan.-June 1970
Sta. Rita- (Vichada)	16,607	---	Jan.-June 1970
Pto. Carreño	32,261	---	Jan.-Aug. 1970
Villavicencio	60,983	---	Jan.-July 1970
Pto. López (Meta)	91,533	---	Jan.-June 1970
La Macarena (Meta)	260	---	Feb.-Apr. 1970
Neiva (Huila)	1,900	---	Jan.-June 1970
Florencia	1,273	---	? 1970
Yopal (Casanare)	113	---	? 1970
Pto. Boyacá (Boyacá)	8	---	? 1970
Total	532,552	30,541	

Table 6

Concerning the trade in Leticia, discrepancies between the official report by INDERENA in Table 6 and the 1970 report by FAO (see paragraph following Table 3) are evident. The former quotes 299,973 and the latter 399,404 hides for Caiman sclerops. For Melanosuchus niger 30,105 hides are listed by INDERENA and 35,525 by FAO. The possible reasons for these differences have already been mentioned in the final paragraph of the section on Perú. Moreover, the number of hides of M. niger, deriving from Leticia and Tarapacá (30,541; see Table 6) are definitely not included by INDERENA in Table 5 which lists only 7,633 hides of this species as exported. Nor is it by any means clear whether the 299,973 hides of C. sclerops from Leticia listed in Table 6 were or were not included in the total figure quoted in Table 5. For the purpose of my final computations of the export of hides of both caiman species, I shall therefore use the figures quoted in the FAO Report for the Leticia trade.

Other discrepancies to be noted from Table 6 are that the number of hides of Caiman sclerops which passed through Villavicencio from January to July 1970, is given as 60,983, while another report, also based on data supplied by INDERENA, listed 64,089 hides between January and May of the same year (Medem, 1970, p.5). Again, Puerto Leguízamo, the main trading centre on the middle Putumayo River, is not included and is said not to have listed a single caiman hide, which seems to me impossible. Probably hides from Pto. Leguízamo were exported via Buenaventura, to which INDERENA (Regional - Pacífico) attributes 74,600 units included in the overall Table 5 statistics. It will be apparent, therefore, that there are a number of discrepancies between the official annual reports, which makes it of great interest to refer to the statistics submitted to INDERENA by two Bogotá tanning companies which specifically cover the skins exported during 1970, including 'flanks' as well as whole skins. The statistics, incidentally, clearly show that, in addition to hides of specimens over 1.20 m, hides of less than 1.20 m in length were also used, in spite of the fact that in Colombia caimans under 1.20 m are protected (Resolución No 411, 1968).

Month	Hides (greater than 1.20 m)	Hides (less than 1.20 m)
January	7,400	15,000
February	5,500	12,000
March	5,000	---
April	55,000	35,000
May	---	---
June	10,000	22,500
July	---	---
August	31,000	---
September	3,200	12,000
October	2,500	---
November	2,000	---
December	7,500	1,000
Total	129,605	Total 97,500

Grand total: 227,105 hides

Table 7. Export of tanned hides of Caiman sclerops by Mendal, HNOS., in 1970.

Month	Hides (greater than 1.20 m)	Hides (less than 1.20 m)	Flanks
January	---	10,000	10,000
February	5,000	15,000	12,500
March	10,000	10,000	---
April	21,250	10,000	20,000
May	6,000	10,000	10,000
June	---	---	14,000
July	57,000	3,000	---
August	---	6,000	42,000
September	3,100	---	5,000
October	---	---	---
November	14,828	5,000	9,500
December	6,500	---	---
Totals	123,678	69,000	123,000

Grand total: 316,078 hides

Table 8. Export of tanned hides of Caiman sclerops by LAO in 1970.

The combined totals of hides exported by Mendal, HNOS and LAO in 1970, are:

Hides greater than 1.20 m	253,283
Hides less than 1.20 m	166,500
Flanks	123,000
Total	542,783

The latter total works out at 56,614 hides less than that officially reported by INDERENA for Caiman sclerops (599,397; see Table 5).

For Melanosuchus niger, Mendal, HNOS. listed 1,300 hides in February and 1,333 in October or a total of 2,633 hides. LAO exported 5,000 tanned hides of the species, all in March. Thus, the total number of hides of the Black caiman, exported legally, comprises 7,633 units, not including the

material from Leticia (see Table 6), which agrees with the quantity quoted by INDERENA in Table 5.

The newspaper "El Espectador" of Bogotá published, on 8 June 1970, an article on the activities of INDERENA, which stated that the total number of hides of Caiman sclerops, legally exported in 1969 - 1970, to the United States, England, Germany and Japan, comprised 1,461,870 units.

The plain fact is that all the various official and unofficial reports seem to reflect rather approximate numbers only and ones which are certainly less than the real quantity of hides obtained by the tanning industry. In the following summary of the figures, I try to disentangle the diversity which exists between the various sources in order to come as close as possible to approximate estimates of officially exported hides of both species of caimans.

1) Brazil. Melo Carvalho, 1967. No separate data for both species.

a)	State of Amazonas (1950-1965):	7,517,226
b)	Six other States (1960-1964):	231,664
c)	Total number for both caimans:	7,748,890

2) Perú. FAO, 1970.

a)	Caiman sclerops (Spectacled caiman):	127,641
b)	Melanosuchus niger (Black caiman):	26,463

3) Colombia. INDERENA, March 1971. Not including Leticia.

a)	Caiman sclerops (hides and living specimens):	599,763
b)	Melanosuchus niger (hides and living specimens):	7,892

4) Colombia. FAO (Leticia only).

a)	Caiman sclerops (hides):	399,404
b)	Melanosuchus niger (hides):	35,525

5) Colombia. Including Leticia.

a)	Caiman sclerops (total number):	998,930
b)	Melanosuchus niger (total number):	43,417

6) Number of Caiman sclerops from Colombia and Perú.

a) Total: 1,126,571

7) Number of Melanosuchus niger from Colombia and Perú.

a) Total: 69,880

8) Number of hides and living specimens of both caimans exported.

a)	No species defined (Brazil):	7,748,890
b)	Caiman sclerops (Colombia, Perú):	1,126,571
c)	Melanosuchus niger (Colombia, Perú):	69,880
d)	Total number:	8,945,341

What this amounts to is that almost nine million Spectacled and Black caimans have been exterminated, within the periods of time and space covered by the figures. Many more of these two species were no doubt killed in other areas, not to mention other species and the crocodiles proper. About the latter there exist some approximate data on hide hunting, mainly submitted by old and experienced professional hide hunters, locally known as 'caimaneros'. Commercial hunting on a large scale was abandoned in the mid to late 1940s, because of the lack of sufficient crocodiles, but was still carried on irregularly by settlers and fishermen; it is still illegally done, and as soon as a crocodile is reported everybody runs to fetch his gun!

The data submitted, and partially already published, are as follows:

1) Crocodylus acutus

a) Chocó, Atlantic and Pacific side (Medem, pp. 298, 302). Atrato River: 8,400 hides; Beaudó River: 1,800; Togoromá River: 1,280; San Juan River: 600; Total: 12,080.

b) Colombian Pacific coast between the Chocó and the border to Ecuador (Departments of Valle, Cauca and Nariño). From the rivers Yurumanguí, Cajambre, Naya, Guápi, Iscuandé, Tapaje, Amarales, Patía, Santiánga, Pital, Guachal, Salá Honda, Limones, Borbón and Mira, about 10,000 crocodile hides were obtained between 1929 and 1932 (Medem, op. et loc. cit.).

c) Laguna de Betanoí (Depto. Córdoba), a lake 5 km wide during the rainy season, completely drying out in the dry season, situated in the middle Sinú River area and connected with the river by an affluent, the Caño Betancí. The Sinú flows into the Caribbean Sea,

west of the Magdalena and east of Atrato River. About 30,000 hides were obtained from this lake alone; there are no available data about the number from the Sinú area as a whole (Medem, 1958, p.47).

d) Rio Magdalena Basin: about 300,000 and 450,000 hides; data obtained from different sources. In 1953, hide hunters from Ciénaga Grande, east of the Magdalena, told me that hunting began in 1928 and was organized by French tanning companies; during a single night it was possible to harpoon between 80 and 120 middle-sized crocodiles (2.50 m in average length); hides of larger specimens were not wanted; the crews of two boats worked together; hides were skinned the next morning (Medem, unpublished).

It would certainly be no exaggeration to reckon the total number of hides of Crocodylus acutus taken at about 500,000 at the least, taking into account the lack of information from various other areas not mentioned above, as, for instance, the Peninsula Guajira and the Catatumbo Territory, which form parts of the border with Venezuela.

2) Crocodylus intermedius

a) Rio Guayabero - Guaviare, westernmost affluent of the Orinoco; the upper course from the headwaters to the mouth of the Ariari River is known as Guayabero, and the sector between the Ariari and Orinoco as Guaviare. From the upper Guayabero - Guaviare, close to the village of San José del Guaviare and the mouth of the Ariari, about 15,000 hides were derived between 1940 and 1943; from the upper and middle Guaviare the total number of hides was calculated as about 45,000 (Medem, 1958, p.47).

b) The Rio Meta and its affluents produced about 154,000 hides between 1938 and 1948 approximately; the hide hunting on the Guaviare and Meta Rivers was organized by French and German tanning companies (Medem, op. et loc. cit., gave the number of hides taken as at least 40,000; later more complete data became available). From the scanty information collected, the total number of hides of the Orinoco crocodile known to have been taken may be calculated at about 199,000; no information is available for the Rio Arauca, east of Meta River; and for the rivers which cross the Vichada, such as the Rio Vichada itself, the Tuparro, Tomo and Bita, as well as the lower Guaviare and its affluent, Rio Infrida, all situated west of the Meta.

The approximate total number of hides of the two Crocodylus species, which are known to have been derived from Colombia, thus comprises at least 700,000 units.

Conclusions

1) Without exaggeration and undue sensationalism it must be stated that the present situation concerning the South American crocodilians is rather pessimistic.

2) Despite some excellent legislation, most of it exists only on paper, since it is neither continuously nor sufficiently enforced. This is due either to the lack of wardens or to the joint pressures exerted by commercial circles and local politicians.

3) Concerning the establishment of National Reserves and Breeding Centres for crocodilians, the excellent proposals discussed at the meeting (see Sections 14-23 of the Minutes, Part 2 of the Summary, on pp. 23-25 of these Proceedings) need not be repeated.

4) A very reasonable solution of the present situation would be to have the Amazonian countries, e.g. Brazil, Colombia and Perú, establish an international agreement and unify their legislation. This, however, would not mean a final solution, but only a major step towards it.

5) The Colombian Institution for the Protection of Nature, INDERENA, should be approached by IUCN with a view to an agreement about the trade in Leticia, which remains separated from the protection laws prevailing in the rest of the country; this does much damage not only to Colombia itself but also to neighbouring countries.

6) It would be highly desirable and basically essential, in order to rebuild the populations of crocodilians, to establish total protection over a period of at least ten years.

7) It is desirable to define actual limits of size, and in particular to protect very young animals which are easy to catch. Reproduction diminishes rapidly both as the result of killing adults and also by disturbing them in the breeding season. It is important to anticipate and prevent the reaching of a dangerous 'point of no return' when individuals become so scarce that the sexes have little chance to meet and reproduce.

8) What is recommended, therefore, is that hunting of specimens of a size between 1.00 and 1.20 m only, should be allowed and that hatchlings or small juveniles of between 23 and 100 cm in size and all adults (the hides of which, as is well known, are considerably more ossified) should be protected.

9) The use of 'flanks' must be totally prohibited, since it not only does harm to still existing populations but constitutes an undue waste of natural resources which cannot be tolerated under existing conditions.

10) Finally, the urgency of the recommendations for a general survey should be stressed, in view of the importance of finding out the actual up to date situation prevailing in most of the South American countries and of obtaining more exact data on the ecology and reproduction of crocodilians, with special reference to the breeding seasons within their natural habitats.

* * *

References

FAO 1970. Utilization of Caiman sclerops and Melanosuchus niger in Perú. Extracts from a report of a survey undertaken by FAO in 1970, pp. 1-4. Mimeographed. Lima.

Fittkau, E.-J. 1970. Role of Caimans in the Nutrient Régime of Mouth-lakes of Amazon Affluents. Biotropica, vol.2, No 2, pp. 133-142, fig. 1.

Hofmann, Rudolf K. 1970. La Distribución actual del Cocodrilo Americano (Crocodylus acutus Cuvier) en el Departamento de Tumbes. Informe Técnico, No 25, pp. 1-6. Mimeographed. Lima.

INDERENA, Regional - Central.
1970a. Legislación vigente sobre Fauna silvestre, Bogotá, D.E.
1970b. Estatuto de Fauna silvestre y Caza, pp. 1-15. Bogotá, D.E.
1971. Exportación Nacional de Animales vivos y Pieles silvestres, March 1971, pp. 1-20. Bogotá, D.E.

Medem, Federico
1958. Problemas faunísticos de Colombia. El conocimiento actual sobre la Distribución geográfica y Ecología de los Crocodylia en Colombia. Rev.Univ.Nal., vol. 23, pp. 37-57, figs. 1-16, map 1. Bogotá, D.E.
1962. La Distribución geográfica y Ecología de los Crocodylia y Testudinata en el Departamento del Chocó.

Rev. Acad. Colomb. Cí. Exact., Fis., Nat., vol. 11, No 14, pp. 279-303, figs. 1-56, map 1. Bogotá, D.E.

1963. Osteología craneal, distribución geográfica y Ecología de Melanosuchus niger (Spix). (Crocodylia. Alligatoridae). Ibidem, vol. 12, No 45, pp. 5-19, figs. 1-10, tabs. 1-4, map 1.

1970. El estado actual respecto a la exterminación de los Crocodilídeos en la hoya del Orinoco Colombiano. Unpublished typescript, pp. 1-8.

Melo Carvalho, José Cándido de, 1967. A Conservação da Naturaleza e Recursos Naturais na Amazonia Brasileira. Atas Simpósio Biota Amazonica, vol. 7, pp. 32-33. Rio de Janeiro.

Paper No 7

THE STATUS OF CROCODILIANS IN THE UNITED STATES, MEXICO, CENTRAL AMERICA, AND THE WEST INDIES

James H. Powell, Jr.
Plainview, Texas, USA

There are five species of crocodilians, representing at least six subspecies, in the New World north of South America: Alligator mississippiensis, Crocodylus acutus, C. moreletii, C. rhombifer, Caiman crocodilus crocodilus, C. crocodilus fuscus and Crocodylus intermedius (the last mentioned recorded only from Trinidad). However, the intermedius records represent strays from the South American mainland and, as there is no permanent breeding population of this species on the island (though one might some day become established), it will not be dealt with further in this paper.

Alligator mississippiensis

The range of the American alligator includes all of Louisiana and Florida and parts of Texas, Arkansas, Mississippi, Alabama, Georgia, North and South Carolina, and perhaps a sliver of extreme southeastern Oklahoma. Theoretically, it extends from Tyrrel County, North Carolina to the Rio Grande; inland, there are records from at least as far up the Mississippi Valley as the mouth of the Arkansas River and from as far west as 100° W in Texas. Actually, it is unlikely that wild alligators exist in Texas today south or west of the Corpus Christi area. The last confirmed sighting from the Rio Grande was in 1949, near Eagle Pass (1). Originally, the range was much wider, and may have extended along the Atlantic coast to as far north as New Jersey. The greatest concentrations of alligators are now found in southwestern Louisiana, southeastern Georgia, and southern Florida (2, 3).

As crocodilians go, the status of A. mississippiensis is enviable. It now has complete legal protection in every state where it occurs naturally, and some of the newer laws provide for severe penalties: in Florida, for example, alligator poaching is now a felony. In addition, federal law prohibits the interstate shipment of illegally taken alligator products, with a maximum penalty of $ 10,000 fine and/or one year in prison. Several states (Florida, New York, New Jersey, and California), as well as New York City, have laws prohibiting or restricting the sale of crocodilian products. The Mason Act, a New York state law outlawing the sale of products from a

number of animals, among them all species of crocodilians, has been particularly effective, owing to New York City's strategic position in the fashion industry. In general, enforcement of these laws is conscientious.

The results of this upsurge of legislation are already noticeable. There is a residual traffic in illegal hides, and it is probable that the hide buyers are trying to develop some way of smuggling skins into the European market. In Florida, there is also a traffic in live alligators which is difficult to control, as there are so many legal alligator displays in that state. But overall poaching has declined drastically. Most of the buyers are going out of business, and the alligators are beginning to thrive again. In 1970, young alligators were noticeably more common in the Everglades, and for the first time in many years the reptiles have appeared in roadside canals. Law enforcement agencies in Florida have also been swamped with phone calls from frightened suburbanites asking them to remove 'nuisance alligators' that had taken up residence in their backyard ponds or lakes -- a sure sign of a healthy population (4, 5).

The total alligator population of the southeastern United States is now estimated at 500,000. Approximately 270,000, or slightly over half, are believed to be in Louisiana, distributed as follows: 170,000 in the coastal marshes -- 102,000 on private lands, 68,000 on refuges -- (these coastal marshes cover from 3,500,000 to 4,000,000 acres (1,416,350 - 1,618,690 hectares), of which about 2,865,000 acres (1,159,385 ha) are privately owned); and an additional 100,000 alligators from other types of habitat in the state. The total alligator habitat for Louisiana is estimated at 8,000,000 acres (3,253,000 ha), and parts of it are now believed to be approaching maximum carrying capacity (6).

The alligator's spectacular comeback is dramatic proof of the resiliency of crocodilians -- a resiliency which brought them through the reptilian doomsday at the end of the Cretaceous, and which can bring them through again if given half a chance. Yet the very success of alligator conservation has raised another problem. Should A. mississippiensis continue to be treated as a threatened species? For the time being, I believe it should. 500,000 alligators may sound like a lot, but I see no reason to wait until a species is on the verge of extinction before taking action. The present optimistic outlook is the result of vigorous protection, and could quickly reverse itself at the slightest complacency.

Crocodylus acutus

Outside of northwestern South America, Crocodylus acutus occurs in Central America (Panama, Costa Rica, Nicaragua, Honduras, El Salvador, Guatemala, British Honduras), Mexico (both east and west coasts), Cuba,

Jamaica, Hispañola, and extreme southern Florida (7). In Mexico, there are records from the following states: Territory of Quintana Roo (Isla de Mujeres), Campeche, Colima, Guerrero, Michoacán, Oaxaca, Tabasco, Vera Cruz, Nayarit, Jalisco, and perhaps Tamaulipas (8). I know of no official record from Sinaloa, but the species certainly occurs there (9). There is an 1899 sight record from Maria Magdalena Island of the Tres Marias Islands, Nayarit (10).

On the Pacific side of Mexico, C. acutus ranges at least as far north as the Piaxtla River in Sinaloa, 23° 45' N. lat. Its northern limit on the Gulf side is uncertain, as many of the older records from Tamaulipas and northern Vera Cruz may refer to C. moreletii. In southern Florida, C. acutus is now confined to the keys, the islands of Florida Bay, and the mainland from Biscayne Bay south and west around the tip of the peninsula (11). It is unlikely that a permanent population of C. acutus exists on the west, or Gulf, coast of Florida. There have been numerous hearsay sightings, but only two confirmed records, both of which could have been escapees (12).

In Florida, the status of C. acutus is critical. There are only about 200-300 individuals left in the state. Of these, about 50 are believed to be in the Everglades National Park, perhaps another 20 in the Big Pine Key Refuge, the rest scattered -- many in areas threatened by real estate development. Wherever possible, these last are being captured and transported to protected areas. There are also plans for stocking the newly-established Biscayne National Monument. Owing to habitat destruction, it is unlikely C. acutus will last out the century in unprotected areas. Even in protected areas its status is precarious. The species is here at the northern limit of its range, and even marginal human disturbance, which would have little effect elsewhere, can be disastrous (13).

In Cuba, a crocodile sanctuary has been established in the Zapata Swamp, and all crocodiles found in the wild are to be brought there. While primarily for the protection of C. rhombifer, this decree applies to C. acutus as well. I have no data on the number of the latter species in the sanctuary, or on the status of wild populations in other parts of the island.

I likewise lack reliable data for Haiti, except that there is no legal protection, and that the species does not seem to be hunted to any great extent (14).

In the Dominican Republic, populations of C. acutus are found in the swampy areas near Monte Cristi, in the northwestern part of the country, and in Lago Enriquillo. There is legal protection, though I have no details. There is a certain amount of poaching, but there does not seem to be systematic hide-hunting (15).

The C. acutus population of Jamaica is estimated at 2,000 individuals, concentrated principally in the Peake Bay, West Harbour, and Black River Morass areas on the south shore of the island. Smaller populations exist in the brackish marshes around Great Salt pond and Port Henderson, just west of Kingston, and in the Moneymusk area, about 50 miles southwest of Kingston. The reptile is under pressure from habitat destruction and from sport and hide hunting. It is now illegal to export crocodiles or crocodile products without a special licence, and as of September 1970, no such licences had been issued. However, hunting for sport has continued unabated and the local inhabitants kill them and destroy their nests whenever possible. The Jamaican government is concerned about the problem and seems anxious to co-operate in a crocodile conservation program. The University of Florida is planning a detailed study of the species' ecology (16, 17, 18).

One of my most distinguished colleagues describes the C. acutus population of Mexico as 'healthy', but to this I would agree only if by 'healthy' one means not quite dead yet. Populations do exist and would surely recover if left alone, for the immediate problem here is hide-hunting rather than habitat destruction: I have often cruised for miles through optimum habitat without seeing a single crocodile. All crocodilians are legally protected in Mexico, but the law is poorly enforced and seems to have little effect. The best C. acutus country I have personally encountered in Mexico has been the mangrove swamps on the Pacific coast near San Blas, Nayarit. Here, during field work in 1966 and 1967, I averaged one sighting per day.

In British Honduras, C. acutus is rare on the mainland, especially in populated areas, somewhat more common on the off-shore islands. There is no legal protection (19).

In Guatemala, crocodiles have been hunted heavily for the past few years, and are becoming rare. There are said to be three areas, one only 25 miles (40 km) from Iztapa, Escuintla, where specimens over 20 feet (6 m) long may still be found. This needs confirmation in the field. There are protective laws, but only in the last year has there been any attempt at enforcement. The price of hides has also recently dropped, and I understand many of the crocodile hunters are showing less interest than formerly (20).

In El Salvador, C. acutus is becoming scarce from hunting. Fishermen regard it as a nuisance and kill it whenever possible. The best remaining populations are probably on the northwestern shores of Lake Guija and at the drainage end of Lake Jocotal (21).

I have no data for Honduras.

In Nicaragua, populations of C. acutus have been greatly reduced, primarily through hide-hunting. Over the last four years, only 915 hides of this species have been exported from Nicaragua -- an indication of its rarity.

Since 1957, there have been protective laws setting minimum sizes and designating restricted zones where hunting is prohibited, but these laws have not been effectively enforced. The best remaining populations are found along the Caribbean coast and, on the Pacific side, in the northwest corner of the country adjoining the Golfo de Fonseca (22).

In Costa Rica, C. acutus has declined from a ubiquitous animal to one seen only sporadically, mostly as a result of hide-hunting. Best remaining populations are probably those in Guanacaste Province and in the Tempisque River and its tributaries. Legally, all crocodilians are protected from 1 December to 31 May on the Pacific side, and from 1 August to 30 November on the Caribbean side. It is, of course, very easy to collect whenever one wishes for export during the open season. There is also a contraband traffic across the border into Nicaragua which has been impossible to control.

On the positive side, a Forestry Department has just been created within the Ministry of Agriculture and Livestock, and has received its first funds to start operations. Also, funds have for the first time been specified for the enforcement of existing laws. Meanwhile, two national parks have been established which will have significance for crocodilian conservation: Tortuguero National Park, situated 80 km north of Limón on the Caribbean coast; and Santa Rosa National Historical Park. In Santa Rosa there has been de facto protection since June 1970. For Tortuguero, patrol launches are being purchased, and several rangers have already been appointed. Future preserves are planned for Guanacaste and the Osa Peninsula (23, 24, 25).

In Panama, as elsewhere, C. acutus has declined, though perhaps less so than in most other parts of its range. While it seems to be nowhere really abundant, there are a number of areas where it is not really **rare** either. It is most common in eastern Panama, where the rivers are long and sluggish, and also exists in some numbers in the Balsas and Chagras Rivers and in Gatun Lake. There is no large-scale hide industry in Panama and hide-hunting is here only one cause of decline. There is also heavy hunting for sport and ranchers and fishermen kill crocodiles whenever possible. The US Military is particularly bad about killing them on sight and as a part of their jungle survival exercises.

Except on Barro Colorado Island, crocodilians have no legal protection in either Panama or the Canal Zone. However, protective legislation has been proposed and the chances for passage seem good.

To the Cuna Indians of Darien Province and the Territory of San Blas, the crocodile has religious significance, and is protected for this reason (26, 27, 28, 29, 30).

Crocodylus moreletii

The range of Morelet's crocodile is imperfectly known. Wherever suitable habitat occurs -- and wherever it has not been exterminated by man -- it is found along the Caribbean side of Guatemala and British Honduras; throughout the Yucatan Peninsula, the Peten and Alta Verapaz sections of Guatemala, the interior basin and northeastern rain forests of Chiapas, and the swamps of the Tabasco coastal plain; thence north along the Gulf Coast to southern Tamaulipas. It also occurs on the Pacific side of Guatemala and Chiapas -- a distribution sometimes treated as controversial even in quite recent papers.

C. moreletii has become rare throughout its range, primarily because of hide-hunting. Owing to its restricted distribution, it is more vulnerable to such pressure than the wider-ranging acutus. In the Sibun Swamp west of Belize, British Honduras, where Karl Schmidt rediscovered the species in 1923, it is virtually gone: with luck, a local fisherman may twice a year glimpse the little crocodile whose existence was here first confirmed for science.

Undisturbed populations of C. moreletii may still exist in the wild and imperfectly explored jungles of northeastern Chiapas.

The legal status of C. moreletii in Mexico, British Honduras, and Guatemala is the stame as for C. acutus.

Two World Wildlife Fund projects, Nos 376 and 317, involve the Morelet's crocodile.

Crocodylus rhombifer

A few Cuban crocodiles, mostly small individuals, still exist in a completely wild state in the Zapata Swamp and in the Lanier Swamp on the Isle of Pines. About 3,000 live in a state of semi-domestication in protected enclosures, or 'corrales', in the crocodile sanctuary at Laguna del Tesoro in the Zapata Swamp, to which they have been transported from their original ranges by government decree. Here they have complete protection. However, they share the sanctuary with C. acutus, and there have been reports of inter-breeding. Should this result in fertile hybrids, it might eventually be a wise Cuban crocodile that knows what, let alone who, his father was (31).

Caiman crocodilus crocodilus

On Trinidad, the Spectacled caiman is still common throughout the lower elevations of the island, including brackish estuaries. It is not normally found in the north or central ranges, though there are local exceptions: for example, it is abundant in the Hollis Dam Reservoir in the north range. It does not occur on Tobago. The heaviest concentrations are in the swampy areas in the east and south: Prof. J.S. Kenny, of the University of the West Indies, recently counted over 20 adults in a one-half mile section of canal in the Nariva Swamp. On the more populous western side of the island the caiman is rarer, but may still be locally abundant wherever there are ponds, ditches or reservoirs. It is still reasonably common in mangrove swamps only a few miles out from Port-of-Spain.

There is nominal legal protection for six months of the year, but this is not enforced. However, there is relatively little hunting and no significant market for hides. A few are killed to be stuffed as curios, or whenever a farmer feels they are threatening his livestock (32,33).

Caiman crocodilus fuscus

In Central America, Caiman crocodilus fuscus ranges as far north as Nicaragua on the Caribbean side, and to the Isthmus of Tehuantepec on the Pacific side (34). Throughout this area it seems to be faring much better than Crocodylus acutus, presumably because it is less prized as a hide animal. In Panama, it turns up in nearly every pond or stream of any size except those in the immediate vicinity of American settlements. The one exception to this pattern is El Salvador, where the caiman seems less abundant than the crocodile (35).

However, the increasing scarcity of crocodiles has caused hide-hunters to turn their attention to caimans. As an example, over the past four years only 915 C. acutus skins were exported from Nicaragua, while during that same period the country exported 37,984 caiman hides (36).

The legal status of the Central American caiman is the same as that of C. acutus for the respective countries.

Summary

Alligator mississippiensis and both subspecies of Caiman crocodilus seem reasonably secure for the moment. However, they should be closely watched, and I would consider it unwise to remove the alligator from the endangered species list just yet. Because of its wide range, Crocodylus acutus may not be in immediate danger of disappearing as a gene pool. But its situation is almost everywhere precarious, and I think it should be rated as an endangered species. Further field work may eventually disclose larger populations of Crocodylus moreletii, than those now known, and hopefully there will in the future be more vigorous conservation practices by the countries concerned; until then, the species should definitely be considered as endangered. The same is true of Crocodylus rhombifer. Barring absorption by C. acutus it may be safe enough within its sanctuary; but as only 3,000 individuals are left its rarity alone would entitle it to special concern.

* * *

References

1. Grant, Chapman, Alligators in Western Texas. Herpetologica Vol. 12, Part 2, 1956, p. 90.

2. Carr, Archie, Alligators: Dragons in Distress. National Geographic Vol. 131, No 1, January 1967, p. 136.

3. Chabreck, Robert H., The American Alligator -- Past, Present, and Future. A paper presented at the twenty-first annual conference, Southeastern Association of Game and Fish Commissioners, New Orleans, Louisiana, September 1967.

4. Fogarty, Michael J., Wildlife Biologist, Florida Game and Fresh Water Fish Commission, in litt. 11 August 1970.

5. Kennedy, Joe, Acting Superintendent, Everglade National Park, in litt. 15 June 1970.

6. Notes taken at 1970 American Alligator Council meeting, Wakulla Springs, Florida.

7. Wermuth, Heinz, and Robert Mertens, Schildkröten -- Krokodile -- Bruckenechsen. VEB Gustag Fischer Verlag, Jena 1961.

8. Smith, Hobart M., and Edward H. Taylor, An Annotated Checklist and Key to the Reptiles of Mexico Exclusive of the Snakes. United States National Museum Bulletin, No 199, 1950, p. 211.

9. Schmidt, Karl P., Notes on Central American Crocodiles. Field Museum Natural History Zoological Series, Vol. 12, 1924, p. 84.

10. Zweifel, Richard D., Results of the Puritan-American Museum of Natural History Expedition to Western Mexico: 9. Herpetology of the Tres Marías Islands. Bulletin of the American Museum of Natural History, Vol. 119, Article 2, 1960, p. 95.

11. Moore, Joseph C., The Crocodile in the Everglades National Park. Copeia, 1953, No 1, 26 February, pp. 54-59.

12. LeBuff, Charles R., The Range of Crocodylus acutus along the Florida Gulf Coast. Herpetologica, Vol. 13, No 3, 1957, p. 188.

13. Ogden, John C., American Crocodiles and the National Park Service. News release from United States Department of the Interior, National Park Service, Everglades National Park and Fort Jefferson National Monument, 30 July 1969.

14. Wainwright, Joseph, Chef de Service de Conservation des Sols, Département de l'Agriculture, des Ressources Naturelles et du Développement Rural, in litt. 14 December 1970.

15. Armstrong, F.H., Forester, U.S. Aid Mission to Dominican Republic, in litt. 6 January 1969.

16. Goodbody, I.M., Professor of Zoology, University of the West Indies, Kingston, Jamaica, in litt. 3 January 1968.

17. Hall, Keats C., Conservator of Forests and Chairman Wild Life Protection Committee, Forest Department, Kingston, Jamaica, in litt., 16 September 1970.

18. Campbell, H.W., University of Florida, in litt. 31 July 1970.

19. Campbell, H.W., University of Florida, in litt., 31 July 1970.

20. Printemps, Victor E., in litt. 2 June 1970.

21. Serrano, J.F., Professor, Sección de Zoología, Universidad de El Salvador, in litt., no date.

22. Camacho S., Ruben, Director de Recursos Naturales Renovables, Ministerio de Agricultura y Ganaderia, Managua, Nicaragua, in litt. 3 September 1970.

23. Nanne E., Herbert, Sección Pesca y Vida Silvestre, Ministerio de Agricultura y Ganaderia, San José, Costa Rica, in litt. 19 August 1970.

24. Boza, Mario Andrés, Jefe, Departamento de Parques Nacionales, Dirección General Forestal, Ministerio de Agricultura y Ganaderia, San José, Costa Rica, in litt. 11 September 1970.

25. Robinson, Douglas C., Professor de Biología y Director, Museo de Zoología, Universidad de Costa Rica, in litt. 24 July 1970.

26. Campbell, H.W., in litt. 31 July 1970.

27. Tovar A., Dario, Executive Secretary, Comisión Nacional de Protección de la Fauna Silvestre, Ministerio de Agricultura, Comercio e Industrias, Panama, in litt. 15 September 1970.

28. Rand, A. Stanley, Smithsonian Tropical Research Institute, Barro Colorado Island, Canal Zone, in litt. 22 December 1967 and 17 July 1970.

29. Myers, Charles W., University of Kansas, in litt. 18 January 1968.

30. Myers, Charles W., Amphibians and Reptiles protected in Panama. Herpetol. Rev., Vol. 2, No 3, September 1970, p. 10.

31. Cuban Crocodile. Animal Kingdom, Vol. 72, No 5, October 1969, p. 29.

32. Boos, Julius, Amoco Trinidad Oil Co., in litt. 21 December 1970.

33. Kenny, J.S., Professor of Zoology, The University of the West Indies, St. Augustine, Trinidad, in litt. 15. January 1971.

34. Smith and Taylor, op. cit., p. 212.

35. Serrano, J.F., in litt.

36. Camacho S., Ruben, in litt. 3 September 1970.

Paper No 8

STATUS REPORT ON THE CROCODILES OF THAILAND

Utai Yangprapakorn, Samut Prakan, Thailand.
Jeffrey A. McNeely & Edward W. Cronin, Association for the Conservation of Wildlife, Bangkok.

The Present Situation in Thailand

General statement

Three species of crocodilian occur in Thailand: 1. the False gavial Tomistoma schlegelii; 2. the Freshwater crocodile Crocodylus siamensis; and 3. the Saltwater or Estuarine crocodile Crocodylus porosus. Although siamensis can occasionally be seen at Beung Boraped Reservoir, it is now quite rare. Porosus and schlegelii are restricted to the southern peninsula of Thailand, if they exist at all. Dr Boonsong Lekagul, Secretary-General of the Association for the Conservation of Wildlife in Thailand and an active member of the IUCN and the Survival Service Commission, has been studying the wildlife of Thailand for decades; he estimates that there may be less than 100 crocodilians left in the wild in Thailand. Although Dr Boonsong's estimate may be slightly pessimistic, it does give some idea of the seriousness of the situation.

Exploitation

The Thai people have historically considered the crocodile a malevolent pest; crocodiles are often mentioned in classic Thai folk tales, in which they usually play the part of the villain. Buddhism is the national religion of Thailand, and although its doctrine prohibits the killing of any animal, in practice the Thai villager will shoot any animal that comes within range of his gun, especially if the animal will bring him economic gain. Since an untreated skin from a crocodile a few years old will sell for about US$ 75 on the open market, depending on species, condition, and size of the skin, the crocodiles have often been hunted for their skin. US$ 75 represents about 50% of the average annual income of a Thai villager; with potential financial gains of this magnitude, it is unrealistic to expect villagers to voluntarily refrain from hunting crocodiles.

Habitat destruction is also playing an important part in the reduction of crocodile populations. As the human population continues to explode

(Thailand has an annual growth rate of 3.3%, one of the highest in the world), the amount of land needed to support the people also increases. And since it is doubtful whether crocodiles can coexist with man, in Thailand, the crocodiles are inexorably being exterminated.

Conservation

The Thai Government has not shown any interest in the plight of the crocodiles; there is no legislation whatsoever regarding crocodiles of any species. Nor does it appear likely that any laws regarding the crocodile will be enacted in the foreseeable future. Further, the conservation laws which exist in Thailand for other species have been ineffective, mostly due to lack of enforcement. Crocodiles are probably doomed in their natural state in Thailand, and within the next few years the only crocodiles to be found will be in zoos or private collections.

The situation of the crocodiles, except for schlegelii, is much better in captivity. At the Samut Prakan Crocodile Farm in Thailand, there has been great success in breeding both porosus and siamensis (for details of the breeding, see Paper No 10). The Farm was started in 1950 with 20 wild-caught individuals. Today we have over 11,000 individuals, most of which were hatched at the Farm. Since 1963, our hatching record has been as follows:

1963	600	1967	1,000
1964	200	1968	2,500
1965	200	1969	3,000
1966	500	1970	3,500

We believe that this breeding record conclusively demonstrates the feasibility of breeding crocodiles in captivity, given the proper conditions. In Thailand at least this seems to be the only way to ensure the future existence of crocodiles.

Research and education

At the present time, very little research is being done in Thailand on crocodiles. Dr Ubon Srisomboon, D.V.M., is studying the normal blood count of the Samut Prakan crocodiles, and that is the extent of research currently being conducted. Education fares a little better, mostly due to the efforts

of Dr Boonsong Lekagul and the Association for the Conservation of Wildlife. They publish a monthly Conservation Letter for Thai Youth; a recent issue dealt with the crocodiles of the world, so Thai students, at least, are aware of the situation of the crocodile.

Future National Requirements in Thailand

General statement

As mentioned earlier, crocodiles seem to be doomed in the natural habitat in Thailand; I see no practical way to change this situation at the present time. However, when the political situation in Southeast Asia stabilizes somewhat, it is conceivable that the Thai Government may be convinced of the necessity of setting up a reserve or sanctuary for crocodiles. There are several areas in Thailand which would be suitable for this, but further research should be done to determine the best site. If and when such a park is created, and if it is properly patrolled, I will make breeding stocks of porosus and siamensis available to the government for restocking. In the meantime, we will continue to breed these crocodiles, and will renew our efforts to breed schlegelii and any other crocodilians we are able to obtain.

Research

The field of research is wide open. Probably the first project to be undertaken should be a survey of the status of the three species, though this is apt to be quite discouraging. Other possible research topics include the effect of water-borne DDT on crocodile reproduction, the variation of internal temperature during breeding, and movements of crocodiles in the natural habitat. At the Samut Prakan Crocodile Farm, we hope to devise and implement a system of numbering our breeding females, so that we will be able to correlate age, size, number of eggs laid, number of eggs hatched, etc.

* * *

I am sorry to present such a dismal picture of the situation of Thai crocodiles in the natural habitat, but if this is balanced with the dramatic success we have had in breeding crocodiles in captivity, perhaps we have cause to be optimistic. As long as we are able to maintain and expand our breeding population of siamensis and porosus, we still are able to hope that perhaps some day we will be able to return some of them to their former habitat.

Paper No 9

ZOO BREEDING AND CROCODILE BANK

René E. Honegger
Zoologischer Garten, Zürich

Although crocodiles (including alligators, caimans, true crocodiles and gavials) are standard animals for exhibition in zoological gardens (see Appendix I), breeding success with these reptiles is a rare and remarkable event. Reproduction is impossible when crocodiles, often with remarkable longevity records, are kept in large groups of various species and sizes in more or less unbiological enclosures.

The starting place for a crocodile-breeding programme in captivity lies in the building up of a suitable breeding group under optimal conditions.

Sex determination in living crocodiles was rather difficult up to a few years ago, when most methods included measurements such as head-length versus tail-length that proved to be of little value, especially when no comparative data were available. Chabreck (1967) and Brazaitis (1969) described a practical method for determining sex in living crocodiles of various species. This simple method relies on manual probing for the penis in the cloaca of the male, and is suitable for determination of sex in specimens over 75 cm in length. Once its sex has been determined, an individual can be marked with a metal tag fastened to the webbing between the toes of its hind leg.

A healthy, sexually mature pair of crocodiles is usually not enough to start a breeding programme. In establishing a breeding group of a certain species, the various distinct size and age classes of a free-living population (for Crocodylus niloticus, see Cott 1961: 277) must be taken into consideration. If the building of a breeding unit is tried arbitrarily without observing this basic need, the larger specimens will disturb, injure and eventually kill smaller specimens.

Environmental factors as outlined by Hediger (1965) for mammals, are also of great importance for a successful breeding programme with crocodiles.

Enclosures

In zoological gardens of temperate and cold zones, space for reptiles is generally limited to the availability of heated rooms. Since the construction of suitable terraria, including efficient heating systems, is extremely expensive, the available space is usually very limited but the number of specimens rather high, mostly as a concession to the paying visitor. As a result, injuries in such crowded quarters are frequent.

To deal with intra-specific aggression it is essential that sufficient space, in the form of terraria, is available. In such terraria, individual crocodiles can be raised until they have reached a size which permits introducing them to other specimens.

The keeper must, of course, take precautions when introducing new specimens of known sex to an already established group. The introduction is best done on a cool, cloudy day, preferably when food is not provided for the crocodiles. A number of logs should be added to the pool in order to separate the individuals for some time. Close control of the animals is essential.

Separate breeding enclosures, preferably not open to disturbance by curious visitors, would be ideal.

Quality of Space

It is customary to display crocodiles in rather simple terraria, such as a pool with a small amount of land. The visitor to the zoo wants to see the specimens at any time of the day, and he normally dislikes the presence of logs, dens or other hiding places under which crocodiles might retreat (Pooley, 1969c). This problem, however, could be solved by labelling the breeding enclosure to explain why a few specimens only are being kept, and giving some data on the biological requirements of the species, for example that they need space for digging a nest.

In a terrarium with limited space, the provision of hiding places is difficult, if not impossible. Men, both visitors and keepers, are always around, and the animals, if not tame, are more or less forced into defensive behaviour.

Temperature

Despite the fact that all species of crocodiles with the exception of Alligator sinensis come from the tropics and subtropics, they are often treated like

reptiles native to temperate zones: in the summer, they are kept inside or even outside with no additional heating; in the winter, they are often maintained with a minimum of heat. Extreme temperature variations favour eye and respiratory infections, so that the crocodiles do not feed regularly and sufficiently. For their optimal growth, conditions should be similar to those from known stations in the wild, including seasonal and daily variations. McIlhenny states that: "Alligators are inactive during the winter and spend about five months, from early October to late March, in holes or dens" (1935: 26) and that they "take no food during hibernation" (ibid: 57).

Though they can stay alive in air heated by tubes or cables, crocodiles like radiant heat. It is advantageous to arrange radiant heat units in vivaria in such a way that reptiles can choose the temperature zones they prefer. Regal (1965) showed that Boa constrictors Constrictor constrictor move to warmer areas in their cages after feeding, and that the basking activity ceased at once after defaecation. The value of this response for survival is clear: "Elevated temperatures probably accelerate enzymatic and mechanical digestive functions". It is understood that rain, which acts as a stimulator (Pooley, 1969a), must also be balanced according to temperature and season, and that an enclosure for crocodilians needs good ventilation.

Light

Reptiles, including crocodiles, generally observe a diurnal rhythm of activity. Crocodiles, although nocturnal, like bright radiant light at least some hours per day for basking. It is known from the field work of Cott (1961) that "there are two main basking periods, in the morning between 0700 and 0930 hours and in the afternoon between 1430 and 1720 hours" and that "early morning basking evidently plays an important role in the restoration of heat lost during the night". It is also known that a high light intensity, at least during certain seasons of the year, activates the reproductive organs. The relative activity of crocodiles which move around when parts of their cage are brightly lit is far more attractive to visitors than when they lie motionless, as they otherwise tend to do.

Sufficient light is also very important for a healthy growth of tropical plants surrounding the exhibit. These plants serve as a biological background by giving shelter and shade to the animals. Furthermore, live plants guarantee sufficient humidity and temperature in a breeding enclosure.

Food

The easiest way to feed crocodiles is to use cheap beef or horse meat, perhaps enriched with vitamins. Such a diet may be sufficient to keep individual giants alive, but it is by no means the optimal food for breeding specimens. According to the feeding habits of free-living crocodiles, the food offered to captive animals should be of variety, such as insects, crustaceans, molluscs, fish, amphibians, birds and mammals.

Additional information shows that the food requirements of juveniles and adult crocodiles are different (McIlhenny, 1935; Cott, 1961; and Pooley, 1962). This fact must be taken into consideration in rearing juvenile and subadult specimens to breeding size.

Breeding Records

As far as I know, a few zoos only have started effective breeding programmes for selected species of crocodiles; a large number of institutions simply acquire every species they can lay hands on. In most cases, these specimens are then added to the zoo's collection and given some short publicity.

An artificial environment has been provided for a pair of Chinese alligators A. sinensis at the Bronx Zoo (Brazaitis, 1968), and it appears that successful breeding of A. mississippiensis is only a question of time at the Manchester Zoo (Legge, 1969). At the Zurich Zoo a pair of A. mississippiensis approximately 17 years old mated on several occasions in their artificial environment. On 8/9 July 1970, the female laid 34 eggs in an area of decaying plant material and soil. Some of the eggs were fertile but failed to hatch.

It must be noted that institutions for the breeding of alligators for economic purposes so far simply do not exist, despite the fact that there are so-called 'Alligator Farms' (Shepstone, H.J., 1931; St.G., 1913). Today these 'Alligator Farms' are merely tourists traps, in which large numbers of alligators are kept together (Honegger, 1969).

The breeding of crocodiles for conservation under an artivicial environment, e.g. in zoos and institutions situated in temperate and cold zones, poses difficulties. Research on these problems is under way in the state of Louisiana, and although Georgia has four licensed breeding farms, no data are available concerning their production or success (Long et al, 1969). In addition to the financial problems, due mainly to housing and heating costs, all species of crocodilians are relatively slow breeders as far as we know. The females of A. mississippiensis start breeding at about seven years of

age (McIlhenny, 1935), and in Crocodylus niloticus possibly not until the female is at least 19 years old, as Cott (1961) states: "Sexual maturity is attained by the male at a length of about 2.9 to 3.3 m, and by the female at a length of about 2.4 to 2.8 m. Present knowledge of the growth rate indicates that females do not attain sexual maturity until they are at least 19 years old".

The available breeding records (International Zoo Yearbook, Vols 2-10 (1960-1970)) are listed in Appendix II. It is striking that from the records, most breeding took place in the area of the geographical distribution of the particular species, that is, under climatic conditions which are natural for it. Breeding under controlled conditions in qualified institutions can contribute to our knowledge of crocodilian biology. Moreover, such breeding in captivity can provide the necessary data for determining optimal conditions under which crocodiles can be bred in their home habitats. It is important to recognize that the conservation of crocodilians cannot be achieved simply by breeding them in captivity in zoos and in zoological institutions. Even if the number of animals bred filled the needs of such institutions, their conservation per se is not assured. This goal can be achieved only with simultaneous conservation in their habitats and farming in the proper climate.

Ideally, crocodiles would be bred in their home habitats. There, climatic conditions are natural, and food can be raised on the spot. Suitable space can usually be obtained at a more reasonable price than elsewhere, and the cost of labour and construction is also less expensive.

In addition, the establishing of a crocodile conservation programme within the geographical area of a species and the employment of native helpers can create a better understanding about conservation in the community. At a later stage the breeding farms could, at least to some extent, be open to the public and tourists and thus eventually bring in an income. The establishment of crocodile stud-books might be of great interest, but it is perhaps premature to suggest it.

Artificial Incubation

Various means of incubating reptile eggs have been described (Bustard, 1969; Legler, 1956). At the Zurich Zoo the modified method developed by Zweifel (1961) is used. Plastic bags are filled with a mixture of damp peat-gravel (2/3) and sand (1/3); the eggs are placed in these bags, which are inflated slightly and then closed with a rubber band except for a small plastic tube for air-circulation. The individual bags are placed in human infant incubators where the temperature can be adjusted. We regularly maintain them at 30° C, with a range from 29° C to 31° C. Regular control of the

eggs is important to prevent spoiling. By this means we were successful in hatching several species (see Appendix III).

There are few data on artificial incubation of crocodile eggs. Hirschfeld (1966) gives an account of the artificial incubation of Caiman crocodilus, and Pooley (1962, 1969b) achieved artificial hatching of C. niloticus eggs. In his research with Crocodylus novaeguineae, Bustard (1969) demonstrated that 38° C is the highest temperature for incubating crocodile eggs. However, when incubated at this temperature the hatchlings failed to emerge on their own, and when removed by hand showed a deformed tail. Bustard concludes that this relatively high temperature is near the upper lethal value.

Modha's (1967) observations on the nests of Crocodylus niloticus indicate that the temperature varies with depth, ranging from 29,5° C (15 cm) to 35° C (35-45 cm). The incubation period for this species is stated to be between 11 and 13 weeks (Cott, 1961; Modha, 1967); but according to Pooley (1969), in Zululand it varies between 12 and 14 weeks.

In 1931, McIlhenny (1934, 1935) recorded the nest temperature of A. mississippiensis throughout incubation, and found the incubation period to vary between 62 and 64 days under natural conditions. This information can be used as a guide for a systematic breeding programme under controlled conditions.

Raising Small Crocodiles

Bustard (1970) states that "400 crocodiles in their first year can be housed in an enclosure measuring 40 x 40 ft and will consume on average 20 lb of fish per day throughout the first year"; but King (in Pooley, 1969b) recommends that a maximum population should be about 100 hatchlings per pond (50 x 50 ft x 20 in deep). Pooley's (1969b) experience has shown that a population of 25 animals per pool of the above dimensions is a more desirable number.

Everyone familiar with raising baby reptiles knows how difficult they are to feed. Great efforts are necessary to provide the food which corresponds with their very variable likes and dislikes. Pooley (1962) reports on the diet of young crocodiles during the first months of their lives, and gives also a series of growth records. I feel that in raising hatchlings and young crocodiles one should follow Pooley's outline.

* * *

References

Brazaitis, P. 1968. Alligator sinensis. Animal Kingdom 10: 24-27.

1969. The determination of sex in living crocodilians. Brit. J. Herpetol. 4,3: 54-58.

Bustard, H.R. 1969. Tail abnormalities in reptiles resulting from high temperatures in egg incubation. Brit. J. Herpetol. 4,5: 121-123.

Bustard, R. 1970. Management of crocodile resources. IUCN Bull. (NS) 2,14: 117.

Chabreck, R.H. 1967. Alligator farming hints. Publ. Louisiana Wild Life and Fisheries Comm. 1-21.

Chaffee, P.S. 1969. Artificial incubation of alligator eggs, A. mississippiensis, at Fresno Zoo. Int. Zoo Yb. 9: 34.

Cott, H.B. 1961. Scientific results of an inquiry into the ecology and economic status of the Nile crocodile (Crocodylus niloticus L.) in Uganda and Northern Rhodesia. Trans. Zool. Soc. London 29,4: 211-356.

Cloudsley-Thompson, J.L. 1964. Diurnal rhythm of activity in the Nile crocodiles. Anim. Behav. 12: 98-100.

Del Toro, M.A. 1969. Breeding the Spectacled caiman, Caiman crocodilus, at Tuxtla, Gutierrez Zoo. Int. Zoo Yb. 9: 35.

David, R. 1970. Breeding the Mugger, Crocodylus palustris, and Water monitor, Varanus salvator, at Ahmedabad Zoo. Int. Zoo Yb. 10: 116.

Hediger, H. 1965. Environmental factors influencing the reproduction of zoo animals. In F.A. Beach, Sex and Behaviour, New York, 319-354.

Hirschfeld, K. 1966. Zucht von Krokodilen (Caiman crocodilus) im Vivarium Kehl. DATZ 19: 308-310.

Honegger, R.E. 1969. Alligatoren-Farmen existieren nicht. Aquaria.

1970. Red Data Book. Vol. III "Amphibia & Reptilia", IUCN Morges.

Jarvis, C. 1961 - 1968. (Editor) International Zoo Yearbook, Vols 2 - 8, Zool. Soc. Lond.

Legler, J.M. 1956. A simple and practical method of artificially incubating reptile eggs. Herpetologica 12: 290.

Long, H.B. and E.R. Ricciuti. 1969. Proceedings of the American Alligator Council, 1968-1969.

Lucas, J. 1969 - 1970. (Editor) International Zoo Yearbook, Vols 9 and 10. Zool. Soc. Lond.

McIlhenny, E.A. 1934. Notes on incubation and growth of Alligators. Copeia 80-88.

1935. The Alligator's Life History. Christopher Publ. House, Boston.

Modha, M.L. 1967. The ecology of the Nile crocodile (Crocodylus niloticus L.) on Central Island, Lake Rudolf. East African Wildlife J. 5: 74-95.

Pooley, A.C. 1962. The Nile crocodile Crocodylus niloticus. Notes on the incubation period and growth rate of juveniles. Lammergeyer 2,1: 1-55.

1969a. Preliminary studies on the breeding of the Nile crocodile Crocodylus niloticus in Zululand. Lammergeyer 3,10: 22-24.

1969b. Some observations on the rearing of crocodiles. Lammergeyer 3,10: 45-57

1969c. The burrowing behaviour of crocodiles. Lammergeyer 3,10: 60-63.

Regal, P.J. 1966. Thermophilic response following feeding in certain reptiles. Copeia: 588.

Shepstone, H.J. 1931. Wild-beast to-day. London.

St.G. 1913(?) Aus einer Alligatorenfarm. Kosmos 10,9: 341-344.

Wermuth, H. and R. Mertens. 1961. Schildkröten, Krokodile, Brückenechsen. Jena.

Yaday, R.N. 1969. Breeding the Mugger crocodile, Crocodylus palustris, at Jaipur Zoo. Int. Zoo Yb. 9: 33.

Zweifel, R.G. 1961. Another method of incubating reptile eggs. Copeia: 112-113.

APPENDIX I

Number of crocodilians kept in zoological gardens (1969)
(Lucas, 1970: 334 - 337)*

Species	males	females	sex uncertain	zoos
Alligator mississippiensis	74	74	1031	152
Alligator sinensis	12	11	50	38
Caiman c. crocodilus	11	3	446	83
Caiman c. apaporiensis			6	3
Caiman c. fuscus	1	1	17	12
Caiman c. yacare	3		28	16
Melanosuchus niger		1	19	14
Paleosuchus palpetrosus	2		12	10
Paleosuchus trigonatus	2		19	16
Crocodylus acutus	2	4	98	50
Crocodylus cataphractus	6	2	37	27
Crocodylus intermedius	1		23	16
Crocodylus johnsoni	2	3	16	10
Crocodylus moreletii	3		28	16
Crocodylus niloticus	15	19	220	78
Crocodylus novaeguineae	3	3	21	11
Crocodylus palustris	2	2	97	15
Crocodylus porosus	5	4	67	32
Crocodylus rhombifer	2	2	14	15
Crocodylus siamensis	1	3	14	15
Osteolaemus tetraspis	10	8	122	59
Tomistoma schlegelii	2		51	35
Gavialis gangeticus	6	9	37	23

* These numbers are approximate only as some zoos failed to return the questionnaire.

APPENDIX II Crocodilian breeding records by zoological gardens and institutions

Species	Locality	Year	Source		Remarks
Alligator mississippiensis	Miami, Crandon Park, USA	1960	Jarvis	1961: 278	
	Silver Springs, USA	1960	Jarvis	1961: 278	
	Oklahoma City, USA	1961	Jarvis	1962: 285	
	Murrells Inlet, USA	1965	Jarvis	1967: 348	
	Phoenix, USA	1966	Jarvis	1968: 338	
	SilverSprings, USA	1966/67	Jarvis	1968: 338	
		1968	Lucas	1969: 268	
	Fresno, USA	1967	Lucas	1969: 268	
			Chaffee	1969: 34	
	Jerusalem, Univ., Israel	1968	Lucas	1970: 304	
Caiman crocodilus (syn. C. sclerops)	Chiapas, Mexico	1961	Jarvis	1962: 285	
	Kehl, Germany	1966	Hirschfeld	1966: 308	
	Tuxtla, Mexico	1966	Jarvis	1968: 338	
			del Toro	1969: 36	
	Atlanta, USA	1967	Lucas	1969: 269	
	Tuxtla, Mexico	1968	Lucas	1970: 304	
Caiman latirostris	Erfurt, Germany	1964	Jarvis	1966: 424	
	Rio de Janeiro, Brazil	1966	Jarvis	1968: 338	

Species	Locality	Year	Source		Remarks
Crocodylus niloticus	Tel Aviv, Univ., Israel	1963	Jarvis	1965:364	
	Elizabethville, Congo	1964	Jarvis	1966:424	
	Tel Aviv, Univ., Israel	1964	Jarvis	1967:424	
	Tel Aviv, Univ., Israel	1965	Jarvis	1967:348	
	Tel Aviv, Univ., Israel	1966	Jarvis	1968:338	
	Tel Aviv, Univ., Israel	1967	Lucas	1969:268	
Crocodylus palustris	Ahmedabad, India	1962	Jarvis	1963:254	
	Baroda, India	1964	Jarvis	1966:424	
	Bangkok, Thailand	1965	Jarvis	1967:348	
	Jaipur, India	1965	Jarvis	1967:348	
	Ahmedabad, India	1966	Jarvis	1968:338	
	Jaipur, India	1967	Lucas	1969:268	
			Yadav,	1969:33	
	Jaipur, India	1968	Lucas	1970:304	
	Ahmedabad, India	1969	David	1970:116	Incl. 1960-65 data
Crocodylus rhombifer	Havana, Cuba	1965	Jarvis	1967:348	
Crocodylus spp.	Ahmedabad, India	1960	Jarvis	1961:276	Prob. C. palustris
	Jaipur, India	1960	Jarvis	1961:278	Prob. C. palustris
	Jaipur, India	1962	Jarvis	1963:254	Prob. C. palustris
	Jaipur, India	1963	Jarvis	1965:364	Prob. C. palustris

APPENDIX III

Species of reptiles incubated in human infant incubators, System Drägerwerk, Lübeck, Germany, and Air-Shiled, Hatboro, Pa., USA. Temperature average 30° (range 29° C - 31° C).

Species	Incubation period (days)
Emys orbicularis	60
Siebenrockiella crassicollis	69, 71, 77
Malacochersus tornieri	116, 134, 154
Testudo carbonaria	113, 146, 147
Gekko gecko	53, 78 - 182
Phelsuma madagascariensis	59
Physignathus lesueuri	54
Anolis equestris	100
Basiliscus basiliscus	85
Varanus salvator	207, 209
Python reticulatus	92 - 105
Dasypeltis scaber	61
Elaphe oxycephala	100

Paper No 10

CAPTIVE BREEDING OF CROCODILES IN THAILAND

Utai Yangprapakorn, Samut Prakan, Thailand
Jeffrey A. McNeely & Edward W. Cronin, Association for the Conservation of Wildlife, Bangkok

It is important to point out at the onset that I am not a scientist, but a businessman who is involved in the captive breeding of crocodiles for commercial purposes. I started the Samut Prakan Crocodile Farm in 1950 with an investment of US$ 500. After 21 years, I have an investment of around US$ 1.5 million. I started with 20 wild-caught crocodiles; today the farm has over 11,000 individuals. In 1960, 150 crocodiles were hatched at the Farm; last year about 3500 were hatched.

Commercial Aspects of Raising Crocodiles

We usually slaughter our crocodiles at about three years of age; beyond this age, the law of diminishing returns begins to take effect. The skin of a three year old porosus is sold for US$ 75 before processing; siamensis skins are sold for about 10% less. There is no price differential between our captive crocodile skins and skins from wild crocodiles. About half the skins are salted and shipped abroad; the other half are processed in Thailand and sold locally. The meat of the slaughtered crocodiles is sold for both animal and human consumption.

Last year the Farm was opened to the public, and now receives about 3000 visitors per week. The admission charge is 15¢ for children, 30¢ for adults, and $ 1. for foreign tourists. Special care has been taken to make the grounds attractive. Elevated walkways have been built around the breeding ponds to allow visitors an unobstructed view. Besides crocodilians, we also have several other species of interest to visitors.

The commercial success of the Farm is to a great extent due to the favourable conditions in Thailand. The climate is, of course, tropical, with high temperatures, high humidity and seasonally high rainfall. The cost of labour is quite low and building materials are comparatively inexpensive; this permits adequate staffing and a substantial physical plant at low cost. A major expenditure is for food; approximately 700 kg of fish are needed per day for the breeding stock; about 1000 kg are needed daily for the immature crocodiles. Proximity to the rich fishing areas in the Gulf of Thailand

assures us a constant supply of inexpensive trash fish not suitable for human consumption; the price is 5¢ per kg.

Breeding of Crocodiles in Captivity

We have two large breeding ponds, one about a half acre (0.2 ha) in area, the other almost one acre in area; at present we are building a third breeding pond. The ponds are surrounded by a land area somewhat larger than the water area; this large area permits a good deal of freedom of movement to the crocodiles. Shade is plentiful at both pools. Near the water's edge the land area is covered with concrete to prevent too much soil, sand and debris from falling into the water; away from the water, there is both sand and grass. The ponds are concrete and of irregular shape. The depth is about 1.5 m. The ponds are never drained because this disturbs the crocodiles; instead, fresh water is circulated as necessary. About 300 m^3 of water are used per day. The water is not treated and algae has not been found to be a problem. Around the edges of the land area, there are 50 nesting stalls each measuring about 4x4 m, with a 60x60 cm door facing the pool; this door is easily defended by the female. The top of the stall is open to the air and each stall has a drainage ditch in the rear to avoid flooding of the nests during rainy periods.

Adjoining the large breeding ponds are smaller feeding ponds, which are approximately 8 m square and 50 cm deep. The water level of the feeding ponds is maintained 20 cm lower than the water level in the breeding ponds to minimize contamination. Each day at 1630 hrs fish are dumped in the feeding pond; the pond is cleaned daily after feeding. The crocodiles are given as much food as they will eat, and any food left over is subsequently removed. Since the crocodiles all come to the feeding ponds, it is possible to observe any illness or injury to individuals.

Each pond contains over 200 individuals, with ages varying from 12 to 35 years. We have found that siamensis reaches sexual maturity in 10-12 years and that porosus reaches sexual maturity in 12-15 years. The sex ratio in the ponds is one male to three females, but we believe that during the breeding season one male forms a relationship with only two females. The presence of the third female helps assure that each male will be able to have two receptive females. The mating season lasts from December until March and the majority of mating activity occurs at night. During this period, the males occasionally fight among themselves, usually at night; such fighting results in one or two deaths per year.

Eggs are laid from the end of April until July. We place nesting materials of dried grass in a loose pile in the nesting stalls about two weeks prior to egg laying. Females usually choose a stall about one week before

the eggs are laid; they make frequent trips into their stall, and actively defend its area against other females. Fighting occasionally occurs between two females attempting to nest in the same stall. The female takes from one to seven days to prepare the nest; nest building activity is greater during the night. The female mixes grass and sand with her hind leggs, forming a soft depression about 20 cm deep and 25 cm wide. She rarely uses her front legs in nest building, but her mouth is used to help crush grass to mix with the sand. Large tears can be seen streaming from the corners of the female's eyes from three to five days prior to egg laying. The laying of eggs usually takes place between 0600 and 0900 hrs. The 20 to 50 eggs are laid in the depression in about five minutes. The female then uses her tail to sweep a larger pile of grass over the eggs, building a nest with a total height of about 70 cm from ground level. Occasionally the female urinates on the nest; we believe this may help the decomposition process.

After egg laying, we chase the female out of her nesting stall; she is denied subsequent entry. The temperature of the nest is tested at least four times a day, especially just after sunrise and just before sunset. If the temperature exceeds 98° F, grass is removed from the top of the nest, thus lowering the temperature; if the temperature drops below 95° F, grass is added to the nest to raise the temperature. During an unusually dry year, water is sometimes sprinkled over the nest to maintain sufficient moisture.

If a shortage of stalls occurs, several nests are moved into one stall. Porosus lays about 30-50 eggs, which hatch after 78-80 days; 40-50% of the eggs hatch. Siamensis lays about 20-40 eggs, which hatch after 67-68 days; 50-60% of the eggs hatch. In 1970, we were able to hatch a total of 3500 eggs.

Care of Young Crocodiles

When the eggs are hatched, the young crocodiles are placed in concrete nursery tanks measuring 30 x 50 x 40 cm. These tanks have a wooden floor and a small bathing trough; they are screened against rodents and insects, especially mosquitoes. About 8-15 young are placed in each of over 200 nursery tanks. The young do not eat for the first week or ten days; thereafter, they are fed coarsely chopped fish until they are large enough to be moved to a larger tank, at which time they are fed whole fish. Around 20-30% of the hatchlings die in the first year of life; some of these early fatalities are stuffed and sold as souvenirs. The fatality rate among crocodiles over one year of age averages less than 5% per year.

As the young crocodiles grow, they are moved to larger and larger concrete tanks, always being kept with age-mates and in crowded conditions. We have 30 tanks 1.25 cm square, 28 tanks 2 m square, and 80 tanks 3.6 m square. Partitions between tanks can be removed to make larger tanks.

Summary

To summarize, we feel that there are eight necessary factors leading to our success in breeding porosus and siamensis:

1) Climate. The climate at Samut Prakan is the same as that of the natural habitat of these two species.

2) The breeding population. Our breeding populations are quite large, with over 200 invididuals in each of two breeding ponds.

3) Feeding. The crocodiles are fed as much as they will eat; feeding is done in the water, not on land.

4) Nesting stalls. The stalls are individual, with a small, easily defended door facing toward the water.

5) Nesting material. Nesting materials are similar to those used in the natural habitat, and the female is allowed to make her own nesting arrangements.

6) Incubation. The incubation temperature is carefully checked, but is controlled by 'natural' means.

7) Sex ratio. The sex ratio of one male to three females allows enough flexibility to ensure that each male will have access to two receptive females.

8) Breeding area. The breeding area is large enough to allow the crocodiles a large degree of freedom of movement.

We are very fortunate in Thailand to have the requisites for breeding crocodiles, and we will be happy to make facilities available to IUCN for the breeding of other endangered species of crocodiles. We will care for them, feed them, show them to the public to increase interest but, most important, when we have breeding success, we will ship the offspring to other breeding stations and zoos which are approved by IUCN. Hopefully, in the future, we will even be able to return crocodiles to their former natural habitat, or at least to protected national parks or game reserves. To speed the arrival of this time, I invite any accredited scientists who would like to conduct research in crocodiles to come to the Samut Prakan Crocodile Farm. We are eager to make your research most profitable for the continued existence of the endangered species of crocodiles.

ANNEX

A NOTE ON SOME DISEASES OF CROCODILES IN THAILAND

U. Srisomboon, D.V.M.
Bangkok, Thailand

Until 1970, diseases of crocodiles in Thailand had not been studied; although the Bangkok Zoo has several species of crocodile, they have been found to be the animals most resistant to disease in the zoo, so veterinary care is seldom required. Until the private crocodile farm belonging to Mr Utai Yangprapakorn was opened to the public in 1970, few crocodile carcasses were sent for examination to the Veterinary Laboratory at the Department of Livestock Development. Since the opening of the Farm, I have been the consulting veterinarian for Mr Utai; I have set up a small laboratory at the Farm, and am now studying normal blood counts. The normal blood structure is as follows:

White blood corpuscle	609,200 / mm^3
Red blood corpuscle	497,700 / mm^3
Haematocrit	25 - 28%
Haemoglobin	7.34 gm / 100 ml

Mature crocodiles do not seem to be susceptible to infections; only benign tumours caused by chronic wounds are observed. These are removed by surgery when necessary. Wounds usually occur during fighting among the crocodiles, especially among males in the breeding season.

In crocodiles up to the age of $1\frac{1}{2}$ years, infections of the alimentary tract are sometimes observed; most of these are due to food poisoning. The species of bacteria found include Enterobacteria, Staphylococcus spp., Streptococcus spp., and Leptospira.

We have experienced trouble among crocodiles which the Farm has bought from outside sources; these animals have often been mistreated and most of them are in poor condition. The first symptom observed is the inflammation of the eyelids, followed by general weakness and diarrhoea; death usually follows in about two days. Post mortem examination shows that the alimentary tract is involved. Bacteriological examination has shown that a pathogenic strain of enterobacteria was involved. Since we take

sanitary precautions with the fish we feed to the crocodiles, there are few such cases among the crocodiles hatched at the farm.

Generally, the crocodiles seem to be quite immune to disease; in 1970, 39 cases of disease or injury only were found in a population of 11,000 individuals. These were distributed as follows:

Disease	Cases
Leptospirosis	2
Roundworm (Ascaris)	2
Tapeworm	1
Pneumonia	3
Stomatitis	6
Food poisoning	1
Benign tumour	18
Pericarditis	2
Oedema in pericardial cavity	3
Pleuritis	1

Conclusion

Disease in mature crocodiles is not common, though some young crocodiles at the age of 1-2 years may be affected by enterobacteria. In a few cases, leptospirosis is involved; contamination of fish is probably the cause. Sanitary precautions in feeding minimize the incidence of disease.

Paper No 11

CROCODILE REARING AND RESTOCKING

A.C. Pooley
Natal Parks, Game and Fish Preservation Board

In almost every country in which the Nile crocodile Crocodylus niloticus is found, it is in a serious plight. Illegal poaching by tribal people with their simple but highly effective traps and snares, as well as professional hunters operating with power boats, spotlights and modern firearms have decimated this animal over most of its former range. In addition, each year more swamps and marshlands are drained, rivers dammed, riverine forest denuded and disturbance of breeding areas created. Suitable habitat is disappearing rapidly. Conservation departments have been slow to introduce protective legislation for an animal that does not engender sympathy; because most departments are short-staffed and have enormous areas to police, this protection is largely ineffective.

The writer is fortunate to have been working with the Natal Parks, Game and Fish Preservation Board in Natal, where complete protection has long been given to crocodiles in the game and nature reserves, and, for some time, even outside these areas. Interest in captive propagation arose largely because of a noticeable reduction in the crocodile populations outside the wild life sanctuaries; the Board encouraged this interest and permitted the author to establish an experimental crocodile farm in northern Zululand. The programme of protecting nests from predators, artificially incubating eggs, distributing hatchlings and releasing young reared animals has proved to be a successful conservation exercise.

During the past few years there have been several attempts at commercial crocodile farming but most have failed because the prospective farmers lacked experience. Many thousands of eggs perished and young stock died of disease.

The purpose of this guide is to describe a simple method of rearing crocodiles, based on practical experience of hatching and rearing 1000 crocodiles over several years. In addition, other workers and the available literature have been consulted and most of the commercial farms operating in Africa have been examined. Many conservation bodies may in the future establish crocodile rearing projects and others will be responsible for issuing permits to private enterprise. Some legislative and administrative recommendations are therefore also included.

Conservation Recommendations

General

Legislation should be in operation throughout the country protecting the crocodile. It should be unlawful to kill, capture by any means whatsoever, disturb wilfully or pursue any crocodiles, or harvest, collect or gather any crocodile eggs without a permit.

A permit should be required to import or export any crocodile whether dead or alive, or any portion of a crocodile, whether processed or not, from any country.

No crocodile egg or eggs should be allowed to be imported into, or exported out of any country, without a permit.

No person should possess, sell, buy, donate, receive consequent upon a donation, convey, keep in captivity or display any live crocodile, without being the holder of a permit.

Before any rearing scheme is commenced, a survey of the breeding grounds should be undertaken to determine the number of nests available.

These breeding grounds should be fully protected and tourists on foot, by vehicle or in launches should not be allowed to visit or disturb breeding crocodiles.

The area should be fenced off for better protection if there is undue disturbance by large mammals, domestic stock or humans.

Prior to the commencement of egg-laying it may be necessary to take precautions to prevent fires from nearby human habitation from spreading to the breeding grounds.

Predators, such as troops of baboons and monitor lizards, should be artificially reduced if found to occur at breeding grounds. Predator control should in no way disturb the crocodiles and should be carried out prior to egg-laying or after hatching of every nest has been completed.

In addition to the culling of predators, protective screens may be used over nests. These should be placed in position soon after laying commences. When a nest is found, the soil is dug away and levelled to within a few inches of the top layer of eggs. A 1 m square screen, constructed of heavy gauge wire mesh (either plain or plastic coated) with a mesh size of not less than 3.5 cm, is laid over the nest area and pegged at 30 cm intervals around its perimeter before the nest is again covered over with soil.

At some breeding grounds, where several crocodiles nest in close proximity in sandy soil, it may be difficult to determine the exact position of each nest. To locate the eggs a 75 cm length of welding rod is used to probe the soil for nests.

During a season of exceptionally high floods it may be advisable to collect all the eggs from a particular breeding ground before these are destroyed, for artificial incubation, hatching and distribution of the young to safer areas. Often, the sparse vegetation affords little or no protection to hatchlings in the vicinity of breeding grounds.

The presence of numerous predators, such as monitor lizards, storks, herons or pelicans, is also a threat to the survival of eggs and hatchlings. After incubation, the hatchlings can be distributed to more suitable habitats.

If the policy is to incubate, hatch and rear the young for release at a later stage, then the following factors should be considered.

To avoid egg wastage, decide how many crocodiles are to be reared. Artificial incubation should hatch 80% of the total number of eggs collected. Thus 500 eggs will be required to produce 400 crocodiles.

If eggs are to be harvested annually, nests should be raided in rotation, collecting from a given nest one year, then leaving it undisturbed the next year. If nests are systematically robbed year after year, the parent will abandon the nest site. Where crocodiles nest colonially, every effort must be made not to disrupt the cology. Colonial nesting offers more successful defence against predators, which may devour the eggs before protective screens can be placed. The collection of eggs should be staggered throughout a breeding colony and here it is useful to map the locality of each nest for future reference.

Control of commercial farms

Before granting a permit for private enterprise to establish a farm, the Department should investigate the applicant's land tenure and financial resources, particularly since the farm will have to operate for some three to four years before producing crocodiles suitable for culling. The applicant's ability and experience of rearing crocodiles should be determined. A plan of the proposed farm, including details of water and food supply, as well as the proposed methods of harvesting food, should be examined.

It is suggested that permits should be issued on the following basis:

No permit for egg harvesting should be issued until adequate rearing

facilities have been prepared. The permit should state name of holder and/or his authorized representative, the annual total number of eggs allocated for harvesting and the area where collection is permitted.

Permits should be issued on an annual basis only. The applicant should understand that the department may refuse to renew or issue further permits if the farm is not managed satisfactorily or if permit conditions have not been observed.

The applicant should understand that the farm and all production records should be available for inspection by an official of the conservation department.

The farmer should be required to submit monthly reports detailing the total number of nests raided, eggs harvested, egg-mortality and number hatched. Thereafter, details of numbers held in captivity, mortality and its causes if known, and animals sold or culled, should be submitted in each monthly report.

It is recommended that the permit holder should release 5% of his annual crop of hatchlings in order to restock the natural habitat. In addition, a further 5% of the hatchling crop should be reared to a length of 1 m before being similarly released; thus bringing the total release of young crocodiles to 10% of the annual crop of hatchlings.

The distribution of hatchlings and of young reared animals should be supervised by the conservation department.

Practical Farming

Hatchery requirements

The practice of building the hatchery alongside the rearing ponds is not recommended because of the liability to disease-transport by flies, ants and beetles attracted to the discarded egg shells and, in turn, to the food in the rearing ponds.

The hatchery site should be chosen with a view to the prevailing wind direction and heavy rains and it should have a sunny aspect. The area should have a well drained sub-surface, since an impermeable layer of rock just below or at nest-depth will lead to the flooding of each nest after heavy rain. The hatchery should not be built close to any foot path, road or human habitation, the reason being that the young are sensitive to vibration or surface-disturbance close to the time of their emerging, so this should be minimized.

The hatchery should be adequately fenced against burrowing and avian predators, using netting of 1 cm mesh buried to a depth of 60 cm and extending above ground to a height of 2 m. Larger mesh (or even criss-crossed strands of baling wire) may be used to make the roof.

A section of the enclosure should provide shade at all times of the day and should afford shelter during heavy rain or hailstorms. A windbreak should also be provided where the young may find shelter.

A shallow pool or trough of water about 30 cm deep must be provided under the shaded area of the enclosure. This should be designed to enable the young to rest partly submerged, and must allow easy access an exit from the pool. Once hatching commences this pool should be drained, cleaned and refilled daily.

Harvesting eggs

Eggs should be collected soon after being laid, especially if the journey back to the hatchery involves a considerable distance over rough roads. With eggs in an advanced state of incubation there is the danger that the delicate system of blood vessels or the yolk sac will rupture. Excessive bumping or jolting will bring about premature hatching and these crocodiles have a poor survival rate.

Collection should preferably take place during the cooler hours of the early morning or late afternoon. Opening a nest at midday, or placing eggs on the hot sand near the nest produces a severe temperature shock that may cause premature hatching, even if the eggs would have required another two to three weeks incubation. Prolonged exposure will certainly kill the embryo.

Each egg is marked on its upper surface to show how it lay in the nest, and individual clutches are kept separate from the time of collection to final incubation. When hatching commences it is then easy to determine from which clutch the croaking sounds come, and this eliminates the unnecessary disturbance of hundreds of other eggs. After collection of the eggs the empty nest cavity is filled in and levelled off ready for the next season.

Transport of eggs

Corrugated cardboard containers well padded with grass, straw or even vegetation are ideal, being light and easily carried long distances if necessary.

Once packed, care should be taken to keep the containers shaded from

direct sunlight. In particularly hot weather the contents of each container can be thoroughly sprinkled with water before the lid is closed.

An alternative method is to pack the eggs in wooden boxes filled with soil from the nest. The box then must be filled completely to avoid damage to the eggs during transport. The disadvantage of this method is the weight of a full box.

A mattress of straw or dried grass 30 cm deep can be laid on the back of a vehicle or in a boat before loading the eggs. This is important if the journey back to the hatchery is likely to be a bumpy one.

The permissible time-interval between collection and re-burying of eggs depends largely on the prevailing temperature conditions. Suitably-packed eggs can be transported by air, boat or road for several days, but when air temperatures drop below 15° C for a period of some hours, death will occur.

Incubation techniques

Each egg should be examined carefully before re-burying. Pierced, badly dented or flattened eggs should be discarded, as should infertile and rotten eggs which are detectable by their glazed or discoloured blue/green or grey appearance. The contents of an addled egg will be liquid. The main reason for removing these eggs is to avoid attracting ants, beetles and other harmful insects to the nest.

Within the hatchery, artificial nests are excavated in the sand in parallel rows, allowing a footpath 1.5 m wide between rows and spacing nests 1 m apart. A nest size of 45 cm square is adequate, even for large clutches, and should initially be dug to a depth also of 45 cm. The eggs are then buried in three layers as is usually found in the wild nest. A space between them allows for humidity. The soil should be damp enough to squeeze a handful into a form. The depth at which the top layer should be buried below the surface depends on the soil type. Thus, in loam or clay, they should be 15 to 20 cm deep and in fine sand about 30 to 45 cm.

A suitable nest temperature range would be in the region of 28 to 34° C at an average depth of 30 cm. This should be checked at intervals because temperatures tend to rise as incubation progresses. Once the eggs have been buried a series of temperature recordings should be taken at two-hourly intervals. From these it will be possible to establish whether sand should be removed or added over the nest site to achieve the desired nest temperature.

Hatching success is greatly improved if a book recording details of each clutch is kept, which indicates the number of eggs remaining in each clutch and the date on which hatching commenced. This is important because, while

some clutches may hatch prematurely, others may require up to an additional 14 days of incubation. Generally, once hatching commences and the crocodiles are seen to be normal, the remaining eggs are not left to incubate more than ten days. If the hatchlings are premature (i.e. with extended abdomen), the remaining eggs may be left up to 14 days, after which period they are opened and will survive even if still premature. Often the unhatched crocodile becomes entangled with the umbilical cord and movement within the egg is restricted. Unless these eggs are opened the crocodiles will perish.

In regions of poor summer rainfall or during a drought, it is necessary to check the moisture content of the soil weekly. If necessary, the nests can be sprinkled with water until the sand around the eggs is suitably damp. This should be done during the early morning or late afternoon.

As incubation progresses, the egg shells may crack extensively and pieces may peel off. Providing the nest soil is suitably moist this is not harmful. Should the soil become dry, the inner rubbery skin of the egg will harden and adversely affect hatching success. Eggs in this condition can be thoroughly dampened to soften this skin.

Nests should never be opened or inspected during the heat of the day. Even if the young are heard croaking the nest can be left until it becomes cooler.

The incubation period may vary between 11 to 13 weeks, with an average of 84 days. This will depend largely on the weather and nest temperatures. Incubation may extend to 98 days.

If, after 84 days from the time of collection of newly laid eggs, there is no apparent sign of hatching, the nest should be visited twice a day and the surface sand distributed by scraping or patting over the nest. After 90 days, the nest may be opened to expose the eggs for an hour during the early morning. Frequently this change in temperature induces hatching. The playing of tape recordings, if available, of the grunts or croaks of the young is an excellent stimulus to hatching.

No attempt should be made to break the umbilical cord of hatchlings still attached to the empty egg shell. This cord will soon dry out, become brittle and snap off of its own accord. For this reason crocodiles in this state are not immediately put into the water.

Once discarded, the egg shells should be removed from the hatchery before they attract numbers of insects. Addled eggs and dead embryos are removed and buried elsewhere.

Hatchlings are normally kept for a period of 24 hours before removal to the rearing ponds. Before removal they are washed and packed in closed

containers for transport. Any that may be premature (shown by their having an extended yolk sac) are retained in the hatchery until such time as the umbilical scar has healed. These individuals should be separated from the others.

Rearing Pens

Siting

When selecting a site for a rearing station, several factors should be considered: the volume of water available throughout the year; the distance to pipe water to the ponds; and pumping costs. The quality of the water should be established. Samples should be tested for salinity and acidity and, should the supply be from mineral springs, analysed for harmful chemicals. Chlorinated water must be regularly tested to ensure that the chlorine content is not too high and the nature of any factory effluents present should be determined. It is of great importance to establish whether fish, frogs, crabs, molluscs or aquatic insects survive in the water intended for use.

Bacterial analysis is advisable in instances where the water is drawn from a river that drains an area densely populated by humans and livestock. If the water is found to be contaminated, the use of the stagnant pond rearing pen system is not advisable, particularly when Salmonella spp. are present in high concentrations.

A filter system has advantages if water is pumped straight from a river carrying a heavy silt load. Apart from not being able to see the animals in the pools, the use of unfiltered water makes the pools more difficult to clean and pipe lines become clogged with sludge. This can be eliminated by drawing water from a deep pit close to the river, so that the water collected seeps through sand or mud and is thus filtered.

A reservoir or a series of supply tanks is very useful as an additional method of filtering water and, in the event of failure of pumping equipment, such a reserve supply may prove vital to the health and survival of the crocodiles.

The ponds should be sited to receive the maximum amount of sunshine, particularly during the winter months. The type of pens required will depend on winter temperatures. Should these be cold, earth dams will be useful. An ideal combination is to have earth pools for winter and cement pools for summer use. The soil types are the next consideration. If sandy and porous, earth dams are impractical, or require a lining of concrete to retain water. On the other hand the water supply may be inadequate.

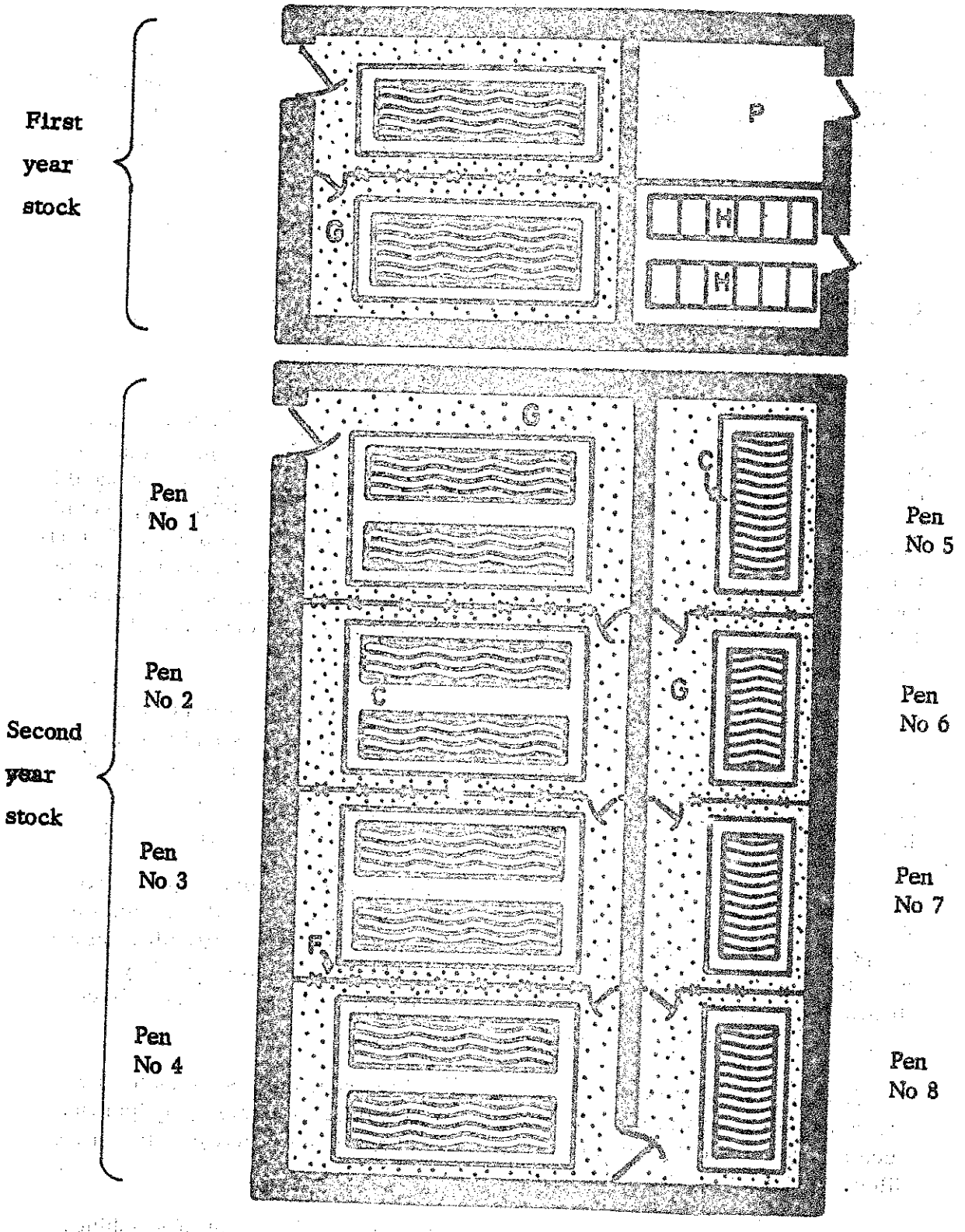


Figure 1. Theoretical farming complex, incorporating design faults.

C	Cemented perimeter, under shade
F	Wire mesh fencing
G	(Stippled areas) Gravel or grassed floor
H	Nest boxes, in hatchery room
P	Food store and preparation room

A series of winter air temperature recordings would be useful in the siting of rearing pens, since very often valley temperatures are several degrees lower than they are 50 to 100 m farther up-hill. Preference should then be given to the warmer aspect, taking into account the direction of local winds and heavy rains.

Drainage of the ponds must be carefully considered. If these are built on a slight rise, drainage is far easier than if the ground is level. It is not desirable to allow water fouled in the ponds to stagnate nearby, so the drainage system must be efficient.

It is recommended that the pens be spaced a minimum distance of 8 m apart, and that drainpipes from the ponds should be led underground 10 m away from each pond, and only then into an open furrow.

Design faults

Several design faults which should be avoided when planning a rearing station are shown in Fig. 1. Some commercial farms suffered very severe losses and others were forced to close down because of the disease problems resulting from such faults.

In one farming complex as many as 15 pens (enclosures with pools) were built adjacent to each other, and the whole complex surrounded by a wall 2 m in height. Fresh air circulation was hindered by this outer wall and also, between pens 1 and 5, 2 and 6 etc., was blocked again by inner walls dividing these pens. The air in the pens was stale and a strong odour was prevalent. Furthermore, the hatchery was built adjoining the rearing pens, while food was prepared next to the complex where large numbers of fish were scaled, gutted and chopped up daily. Large numbers of flies were attracted to the hatchery, to the food and into the pens to faeces and uneaten food.

Many of the pens contained two pools each. The pen area was 25 x 2 m and the pools were 60 cm deep. The pools were separated by a smoothly plastered apron about 1 m wide, with an apron of the same width around the perimeter of each pool. The main basking area was of coarse sand, gravel or grass. These pens housed 200 crocodiles of from two to three years of age, the largest animals being up to twice the size of the smallest.

The pools were drained and scrubbed clean daily, but the basking area in each pen could never be satisfactorily cleaned because crocodile faeces and small scraps of uneaten food remained in the gravel or grass. It will be seen from the sketch that pens 1 and 2, 3 and 4, etc., are divided only by a wire grid. For purposes of hygiene therefore, they were not in fact separated at all.

Entry into the complex was gained through a single entrance gate in the outer wall and then through each pen in succession.

During the first few months of operation, there were no disease problems apparent in this system. With the onset of colder winter temperatures, however, there was a reduced intake of food, lowering the crocodiles' disease resistance. The smaller animals then succumbed to respiratory ailments in the cold cement pools and the infection spread rapidly. The majority of the animals became ill and refused food, the weaker ones died, and paralysis or partial paralysis of limbs followed, with diarrhoea and blood-stained faeces. The resultant epidemic brought about 200 deaths in a single month. Because of the layout of the farm the sick animals could not be isolated to prevent contamination of the healthy specimens. The bacteria Shigella sp. and Salmonella sp. were isolated from dead crocodiles. The bacterial load in the grass and gravel areas built up rapidly and was transmitted to other pens rapidly by flies, and by people walking through the pens, until every pen contained crocodiles in various stages of illness. A further complication arose from the fact that the crocodiles were not graded into size groups so that bullying at feeding times became inevitable. The smaller animals were bitten on the snout and their jaws and teeth were damaged. Wounds in the gums caused infection to set in, making them soft and spongy, leading to necrosis of the mouth. This infection spread through the process of swallowing and also caused death.

Recommended systems

Single units (cemented pens) (Fig. 2): An important requirement is that the pools should be at least 60 cm in depth, otherwise the water becomes too hot in summer. The pool floor should be sloped towards the drain outlet pipe, to facilitate cleaning and washing away of uneaten food particles. Ideally the outlet pipe should be 10 cm in diameter, with a stopcock outside the enclosure, so that the pool can be cleaned and emptied both efficiently and quickly. It is essential to place a screen in the drain pipe to prevent crocodiles escaping or from being sucked out of the pool during cleaning. After some time, stagnant ponds may become difficult to clean because of the rich growth of algae on their sides. Hard-bristle scrubbing brushes are needed to dislodge this growth. Small amounts of copper sulphate in the water will help control algae, if used regularly.

The entire pond and apron of the enclosure must be smoothly plastered to facilitate cleaning. It is useful to have a water supply point close to each pool from which a hose pipe can be led to pressure-spray and clean the entire pool and its apron.

An important part of the design is a partly-submerged and gently-sloping

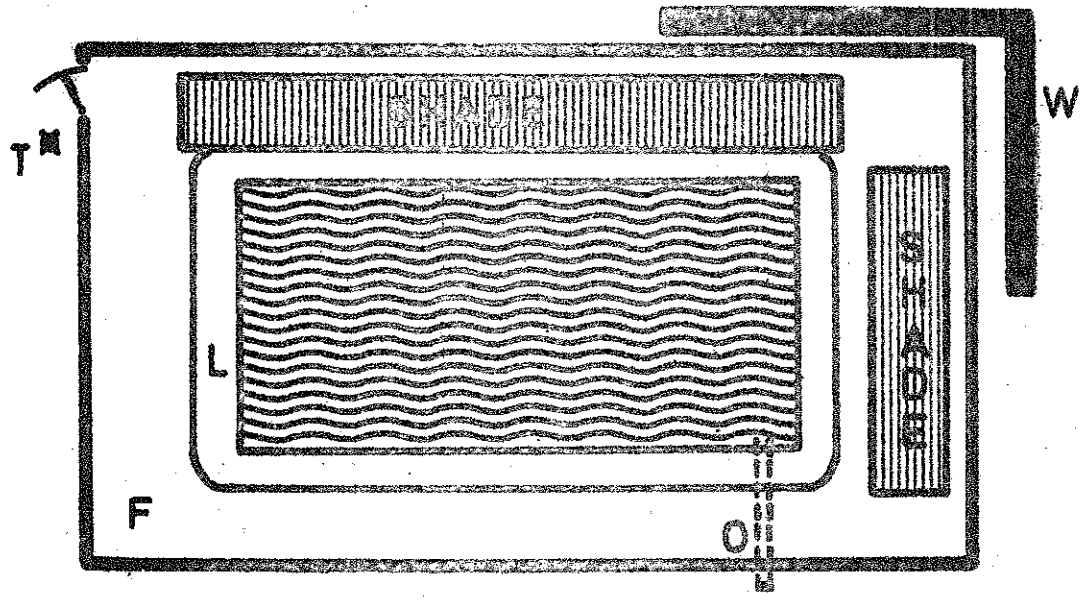


Figure 2. Plan view of single-unit cement rearing pond.

F	Smooth cemented floor
L	Inclined 45 cm wide cemented ledge
O	Underground outlet pipe
T	Water supply point (tap)
W	Wind-screen

Pen size : 9 x 6 m
Pool size : 7 x 4 m

ledge, some 45 cm in width, around the perimeter of the pool. This provides a shallow resting zone for the crocodiles and allows easy access into the water. This ledge is also important in that the crocodiles rest there when feeding, and it also prevents them scraping their bellies and damaging their claws on entering or leaving the pool. The amount of space around each pool is calculated to allow ample basking room for each animal, and an area of shade must likewise be provided.

It is advisable to roof over the entire pen with wire netting, or criss-crossed strands of wire, against predators. The wire netting sides of the pens should not be larger than 1 cm mesh, otherwise hatchlings will injure themselves by trying to climb through this. Young crocodiles can climb vertical wire netting with ease and will escape unless the enclosure is either roofed or its side walls sloped inwards at an angle of 20°. A skirting board

(planking, sheet iron, tin or plastic sheeting) placed against the wire netting flush with the floor prevents them from climbing up the fence to a height, and then dropping back onto the concrete below.

These pools are useful for summer because they can be scrubbed clean and because the volume of water used is small. Normally they need only be emptied, cleaned and refilled every third day and there is no wastage through seepage.

The main disadvantage is that cement is a cold surface in winter and crocodiles will be prone to respiratory ailments. If local winter night temperatures of the water or of the air are likely to fall to the 7.2°C, this type of pond would not be suitable. Care must be exercised while cleaning these pools, to avoid a crocodile injuring itself by falling into the empty pool.

Cement pond (trickle system) (Fig. 3): The advantage of this system is that during hot summer weather, when crocodiles are feeding at their maximum rate, small uneaten food particles, faeces and urine, are not trapped in the pool. The constant dilution of the pond's water ensures a low bacteria level.

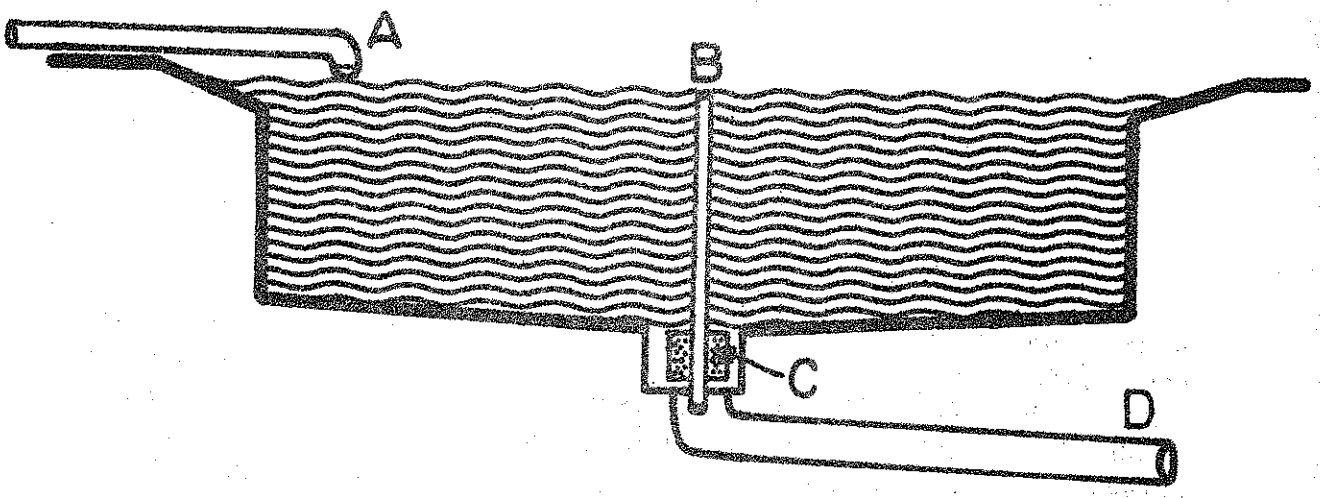


Figure 3. Trickle-system cement rearing pond.

A	Water supply hose
B	Siphon outlet pipe
C	Watertight rubber plug
D	Underground drain pipe

Pool size : 9 m diameter

The pool is drained and scrubbed clean weekly, as is the entire floor of the pen which is smoothly plastered. The enclosure embodies the same design requirements as seen in Fig. 2.

The pool should be circular or cone shaped, at least 50 cm deep at the edges and 60 cm in the centre. An earthenware bend of 10 cm in diameter is sunk flush into the centre of the floor and into this fits a rubber plug. In this a 5 cm diameter hole is bored, through which a 66 cm length of polythene pipe is fitted vertically into the plug so that it can be pushed in or pulled out as required. A wire mesh shield is fitted over the top of this outlet pipe to prevent the escape of small crocodiles. Water is fed constantly into this pool, circulates, and is siphoned out at the same rate as the inflow.

It is helpful to attach string wire handles to the rubber drain plug, so that it can easily be pulled out when the pool is to be cleaned.

Single earth dams (Fig. 4): These are ideal for use in climates where low winter temperatures are likely to cause respiratory illness in the young animals. Earth pools are easy and cheap to build and are a 'natural' habitat where vegetation can be planted, small live fish introduced, while insects,

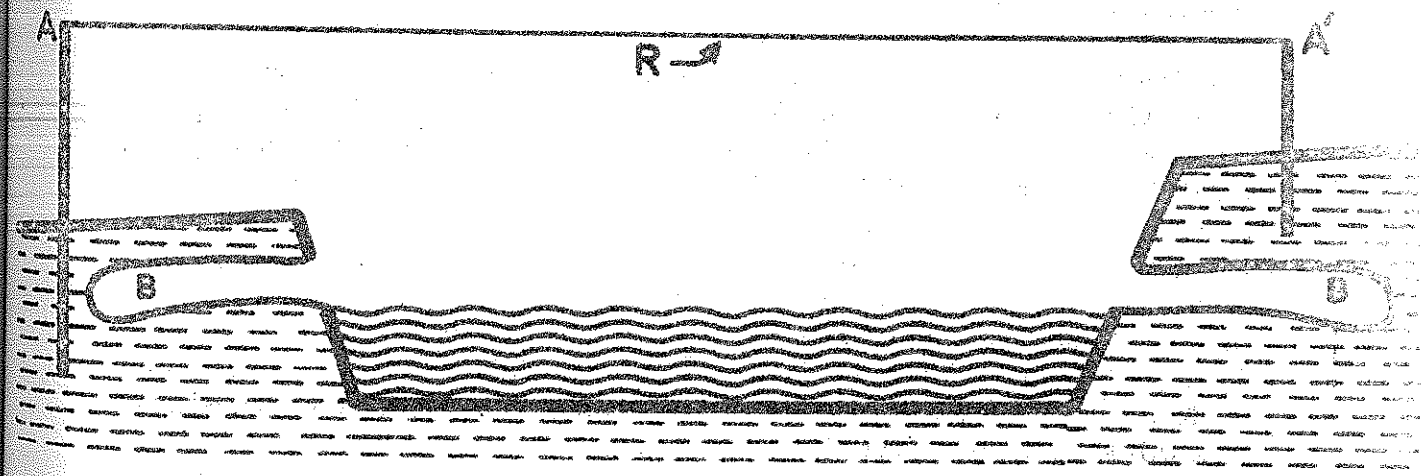


Figure 4. Isolated earth rearing pond or dam.

A	Lower fenceline, buried below level of burrows
A'	Upper fenceline
R	14 gauge wire roof-grid
B	Burrow

frogs and other creatures attracted to the dams will be an important addition to the diet and health of the crocodiles.

During cold weather the crocodiles will burrow into the mudbanks and thus survive nights of heavy frosts. Because of their burrowing capabilities it is important to provide a strip of land, 4 m wide, between the pool's edge and the boundary fence. This is particularly important if the pool is situated at the bottom of a hill such that its lower bank is artificially built up. Where pools are excavated on a level site this precaution is not necessary. The crocodiles burrow into the bank above normal water level and may tunnel beyond the fence line. Normally this will not matter since the burrows will be well below ground level, but if the pool stands on a hill slope the lower fence line should be buried deep enough to intercept the burrows (Fig. 4).

The enclosure fence should be of 1 cm diameter mesh netting for young crocodiles, buried to a depth of 1 m, to exclude burrowing predators. Because these pens are a natural habitat, birds may become a nuisance, either as a threat to the crocodiles or as food competitors. The pens therefore should be roofed, for which a broad-mesh grid made of 14 gauge wire is suitable.

In areas where the soil is porous or sandy the floor of an earth dam can be sealed with concrete or plastic irrigation sheets. A layer of earth conceals this artificial floor.

Drainage is effected by a central pipe and the water siphoned out as in the previous system. The disadvantages of earth dams are that they require a larger volume of water to allow for seepage, and require more maintenance. Earth dams cannot be efficiently cleaned. Even if they are provided with a system of constantly circulating water they eventually become fouled, particularly during hot weather when feeding rate is at its maximum. Ideally, one should have only half the available number of pools occupied at a time, so that they can be used in rotation. In this system, the animals can be moved to fresh pools every two months (or as necessary), leaving the 'used' pools to be drained and allowed to dry out and bake in the sun. After two months' rest thex will be clean and ready for use again.

When the crocodiles are to be removed from an earth dam they will prove difficult to capture with a hand net since most will take refuge in their burrows. A simple capture method is to make tubes from 1 cm mesh wire netting, and about 45 cm in length which are firmly pushed into the burrow entrance and their bases packed around with mud. The tubes are tilted upwards at a slight angle and held in place by prop-sticks. The pool is then drained completely and when the crocodiles venture out, they can be easily caught.

Rearing Techniques

Handling

Dealing with a large population of crocodiles comprising different age groups and sizes requires a great deal of rearing and handling experience. This ability is vital because crocodiles are more delicate than is generally realized and a thorough knowledge of their behaviour and requirements under captive, artificial conditions is essential if rearing is to be successful.

Many disease symptoms are easily overlooked if the observer is not familiar with the normal behaviour of crocodiles under a variety of conditions. It is essential to know intimately how they normally walk, swim, sleep, feed and bask in relation to the time of day, the air and water temperatures, the amount of sunlight or rain, both by day and by night, as well as at different seasons of the year. One should notice the appearance of normal faeces from healthy animals, to be able to detect evidence of diarrhoea.

The observer will soon notice that from one clutch of eggs hatched, some individuals will be aggressive, others less so, others may be shy and some extremely timid. The growth of some individuals will be rapid, others less so, and a few may be classed as runts, hardly growing at all.

It is not easy for an inexperienced person to determine the cause of illness or death, should this occur, and it is time-consuming to capture and administer drugs to sick animals even if the ailment has been correctly diagnosed. Besides, drugs are not always very effective, are difficult to administer and do not prevent sick animals from contaminating the water in a pool. Handling of the animals can often be injurious to their health and behaviour. Therefore, strict emphasis on the prevention of disease, rather than its cure, is by far the best way of ensuring a healthy crop.

Almost inevitably the water in the pools will harbour concentrations of bacteria such as Salmonella sp., but providing strict hygiene and other conditions are observed, the low bacterial level will not be harmful. The commonest forms of disease or conditions adverse to healthy development are summarized in the section on common ailments.

It is recommended that where and when possible, animals found freshly dead should be dissected and vital organs such as the brain, heart, lung, liver, spleen, kidney and stomach removed for veterinary research. Bloodslides should also be taken and faeces samples collected. The various specimens must be carefully labelled, frozen as quickly as possible and packed on ice in a vacuum flask for immediate despatch to the nearest veterinary research institute or pathologist. Alternatively, sich animals may be sent alive for research purposes.

It is advantageous for the handler to become thoroughly acquainted with the animal's internal anatomy to be able to distinguish between healthy and diseased organs. This knowledge, coupled with the veterinary report, and the symptoms noted before the animal died, will be helpful for future diagnosis and treatment.

Diet

Fish is a most suitable foodstuff for the bulk feeding of a large captive population. A variety of methods can be employed to harvest fish but seine- or gill-netting is the most effective. Whole fish chopped up into suitable pieces, and including the livers and hearts forms a balanced diet which may be supplemented by game meat, if available, to make up bulk. However, meat on its own is a poor diet. Small whole fish are particularly suitable. The crocodiles derive calcium from the bones and scales, plus sufficient roughage to facilitate digestion, while the flesh, liver and heart are rich in nutrients and protein. The main difficulty usually lies in harvesting sufficient fish to meet the crocodile's demands.

Any method of supplementing the diet by the addition of live creatures is recommended. For this purpose, a light left burning in each pen about 15 cm above the water is useful for attracting insects. Various types of insect traps may also be used.

In an area where large quantities of meat are available as a result of game-cropping, the livers and hearts of these animals are particularly valuable. Bones can be ground up and thoroughly mixed with the meat to provide calcium if this meat is to be the sole diet of the crocodiles. Cod liver oil mixed thoroughly with the food is beneficial, particularly before the start of cold weather. This is given three times a week, one teaspoonful mixed in for each 1 lb (450 g) weight of food (see also section on common ailments).

Preparation of food

In preparing food for young crocodiles it is important to reduce it to pieces small enough to be swallowed without difficulty.

Large fish should be cut into elongated rather than square pieces since the bones can cause damage during swallowing. Similarly, whole live fish should not be too large lest the dorsal fin cause damage to the reptile's throat and gullet.

Food should not be prepared near the rearing pens, but should preferably

be done in a gauze-enclosed room (to screen out insects) having a large trestle table or cutting block. The floor of the room should be smoothly plastered and well-drained so that all the equipment including the feeding trays and knives can be scrubbed and hosed down.

Deep-freezing is effective for storing food cut into small portions and frozen quickly. Large fish should be scaled and gutted, their heads and fins removed, and washed before being deep-frozen. The food must be completely thawed out before being used for feeding; generally this occurs satisfactorily while the whole fish are being chopped up if the small pieces are laid out on flat metal trays, rather than put into buckets.

Surplus food should never be re-frozen, since repeated thawing permits the bacteria to multiply rapidly so that eventually the crocodiles are being given bacteria-laden food.

Small whole fish are thoroughly washed to remove slime, and packed onto shallow wire trays for freezing. Before feeding, these should be washed again, then allowed to thaw out.

Feeding

The most desirable feeding method is to estimate the amount of food that each group will consume at each meal. By establishing a regular pattern, feeding at the same time each day, it is easy to calculate how much is required. The crocodiles become accustomed to a routine and food is then consumed while still fresh. In the hot summer months, they will devour a full meal every 24 hours, but the feeding rate will slacken off towards the onset of the colder months when temperatures start to fluctuate from day to day. It is then wise to start reducing the feeding frequency and food quantities until food is only required every second or third day according to the local climate. Generally, young crocodiles will refuse food when the air or water temperature falls below 60° F (15.6° C). Even in mid-summer sudden cold spells may occur and at these times it is not worthwhile feeding the animals or trying to coax them to eat until the weather returns to normal.

During hot weather conditions it is preferable to feed late in the afternoon or evenings, the main reason being to avoid placing the food on a hot cement surface. The food should preferably be spread out around the edge of the pool under the shaded area so that the animals do not have to climb over one another or compete unnecessarily to reach it. Because of the more severe evening temperature drop in winter it may be necessary to feed much earlier in the afternoon. In cemented pens the area where the food is laid out should be cleaned and scrubbed two hours after feeding time and any uneaten food removed from the water with a hand net; while at the earth pools, the food

should be placed each feeding time at a different spot along the bank. A useful aid to hygiene is to keep a few barbel Clarias sp. in each pool to clean up scraps of uneaten food (see also section on common ailments).

Population in relation to pen size

Twenty-five crocodiles is considered to be the maximum manageable number per unit, since it results in less competition for food which reduces bullying and fighting which in turn means fewer injuries. A low stocking rate also results in a more even average growth rate; but most important is the fact that the health of the crocodiles is of a higher standard than in a more crowded pen. Disease problems are greatly reduced and the symptoms are easier to detect in a small group. If the units are spaced 8 m apart, there is also less danger of an infectious disease spreading to other pens, while the cleaning of pens is facilitated and the disturbance caused when capturing crocodiles to be moved to other units is minimized. Thus, to house 500 crocodiles in groups of 25, 20 separate pens will be required, whilst an additional two pens should be provided to allow for intensive care of the sick, injured and weaker animals.

During the first year, when animals are graded quite frequently, they will often be moved from one pen to another. It is helpful to keep a record of the numbers housed in each pen so that it is possible to keep track of numbers and movements.

Common ailments

Symptoms	Cause	Treatment or prevention
Broken limbs.	Faulty pen design. Crocodile has either climbed up the side of the enclosure and fallen from a height, or fallen into an empty pool.	Bind broken limbs with waterproof adhesive tape. Isolate animal, avoid handling. Place skirting board 30 cm high round fence to prevent climbing. Before draining a pool, herd animals into the water, so that they remain in the pool when this has been drained.

Symptoms	Cause	Treatment or prevention
Simple cuts, nails worn, toes bleeding or raw. Small cuts in belly skin and thoracic region.	Sharp object in pen. Faulty pond design. Claws get damaged and skin scraped over rough surface, usually at edge of pool.	Clean caseous matter from wound. Apply merthiolate, isolate the individual. Area around edge of pool should be plastered.
Throat red and inflamed. Animals refuse to feed. Repeated scratching of eyes and ears.	Certain algae cause irritation. Poor hygiene, greasy water because pools not cleaned. Check water for acidity, salinity and chlorine content, which may be too high.	Remove animals to another pool. Allow used pool to bake in the sun after being thoroughly scrubbed out. Change water more frequently and treat pools with copper sulphate.
Crocodiles found dead in pen or at bottom of pool. No sign of injury.	Drowning. Below 15° F (7.2° C) animals in the water lose muscle control and balance. Sunstroke. Obstructions in gut. Dissect, check for fish bones in gullet or intestine.	Check overnight water and air temperatures. (These should be recorded routinely.) Move animals to earth dams where they can burrow for warmth. Ensure adequate shade at all times of the day for the entire population in a pen.
Teeth missing, gums and tooth sockets soft, spongy, coloured brown. Scars around snout and jaws. Tongue normally yellow may be spotted with fungal patches.	Overcrowding, fighting at feeding times. Gingivitis infection may result, is spread by swallowing and leads to necrotic enteritis.	Reduce pool population. Grade crocodiles into size groups regularly. Ensure good portions are small enough to be swallowed readily. Observe strict hygiene in feeding and cleaning of pens. Aerosol merthiolate is a good treatment. Keep animal out of water as much as possible.

Symptoms	Cause	Treatment or prevention
Deformities and stunted growth; teeth break off easily or grow crookedly. Spasmodic jerking of limbs, head or tail. Animal trembles when handled.	Severe calcium/ vitamin deficiency, or very cramped quarters.	Add calcium or bone-meal to diet plus multi-vitamin supplements. Feed with live whole fish (unscaled), frogs and crabs. Vitamin E is particularly beneficial.
Hatchlings found dead.	Possibly overcrowding. The young tend to pile up on top of each other for warmth, suffocating those at the bottom. Lack of shade and water. Sudden change or marked drop in temperature.	Divide a section of the hatchery into small compartments to hold fewer animals. Provide a framework of sacking and straw under which hatchlings can crawl for warmth in cold weather.
Animals unwilling to feed. Food taken and then discarded in the water. General loss of appetite over several days. Animals behave sluggishly.	Food mushy, not palatable. Excessive handling or disturbance. Sudden temperature change. Sudden change of diet.	Reduce feeding rate to every 2nd or 3rd day. Ensure fresh food. Move animals to earth dams if warmth required. Add Cod Liver Oil to food. Feed extra quantities of liver in winter.
Belly distended, animal moves sluggishly, finds difficulty in walking.	Insufficient roughage in diet. Sudden change in food. Constipation.	Provide whole small fish, insects, frogs, crabs. Mix coarse grit and small bone chips with meat.
Abdominal swelling in recently hatched crocodiles.	Umbilical abscess. Poor hygiene.	Often too advanced for treatment. Apply antibiotic powder to open wounds. Treat each hatchling with aerosol antibiotic wound spray.

Symptoms	Cause	Treatment or prevention
Paralysis of one or both hind limbs. Eyes closed or partly closed. Tongue puckered and dehydrated. Animal arches spine or raises head and tail vertically in convulsion. Complete paralysis may follow. Diarrhoea evident. Faeces contain blood.	Either Salmonella sp. or Shigella flexneri bacteria. Usually caused by one or a combination of the following conditions: Overcrowding, resulting in a high bacterial concentration. Contaminated food, poor hygiene in preparing food and in feeding. Stagnant water, changed infrequently.	This condition is highly infectious. Isolate sick animals immediately to avoid serious epidemic. Clean pools and change water daily. Disinfect drains. Sterilize all feeding utensils. Reject contaminated food. Cease feeding for a week or more. Mix antibiotics (Tetracycline) with food, giving several times the normal dose per lb-weight of crocodile. (Replaces that lost or dissolved in pool water during feeding.)
Diarrhoea; diarrhoea with loss of appetite.	Sudden change in diet. Food not fresh. Poor hygiene in preparing food and feeding. Contaminated water. Sudden spell of cold weather.	Avoid sudden change in diet. Reject mushy or tainted food. Sterilize knives, boards and food trays routinely. Scrub pools and pens thoroughly. Disinfect drains. Change water more often. Add vitamin E to diet.
Eyes water, exude matter and eventually close. Animal lies with jaws agape, sometimes held vertically. Breathing laboured, may sneeze often. Loss of righting reflex, circular swimming, seizures. Animal 'star gazes'. Pupils enlarged. Animal trembles uncontrollably.	Respiratory ailment. Animal chilled by sudden change or lowering of temperature, cold draughts. (Post mortem will reveal mucus in nasal passage, lungs inflamed or congested.) Hypoglycemic shock (in colder weather). Steatitis (deficiency of vitamin E).	Move animals to earth pools where they can burrow for warmth. Feed diet enriched with vitamins E and A and Glucose, well mixed with food. It will be necessary to supply glucose and vitamin E throughout the cold winter months. Avoid handling animals in this condition unnecessarily. Any disturbance causes extreme agitation.

Symptoms	Cause	Treatment or prevention
White spots on skin, scales sloughing on tail, skin peals between toes. Fungus or slime seen around the vent and behind limbs where skin may be cracked and stained brown.	Fungus (Aspergillosis). Poor hygiene, greasy water, fouled earth dams. Animals using burrows susceptible if an earth dam is used for a long period.	Scrub pools, removing any grease or fat. Empty pool and allow to bake in the sun. Move animals to a fresh pool. Move animals from earth pools immediately & drain pool for at least a month. Wash animals in tepid water, paint infected areas with merthiolate and keep out of water for some days.

Distribution of Hatchlings

Cardboard containers made for day-old chickens make excellent hatchling transport boxes if provided with a layer of straw or grass 3.5 cm deep. Each compartment should not contain more than six hatchlings. Any container should allow adequate ventilation and should have a lid. Crocodiles are best transported in a darkened container in which they tend to remain quiet and docile, whereas in an open one, they will continually attempt to climb out and will injure each other by scratching and climbing over one another.

Thus packed they can be transported by vehicle, boat or by air. Bumping should be avoided, as should cold draughts and exposure to direct sunlight for prolonged periods. If air temperatures become particularly hot the crocodiles can periodically be sprinkled with water.

Preference should be given to well-vegetated pools, swamps or marshes of permanent water such as the reedbeds or well-vegetated zones of large lakes and rivers. The crocodiles should be distributed over as wide a range as possible, individuals spaced at intervals of a half kilometre. Attention should be paid to the available potential food supply in the form of aquatic insects, fish fry, etc. Where possible, avoid restocking habitats which already support a high population of adult crocodiles.

Acknowledgements

I am most grateful to my wife, Elsa, for typing the preliminary copy of this paper and to Mrs T. Anderson for preparing the final draft. Mr R.S. Crass, Chief Professional Officer of the Natal Parks Board is thanked for his comments and advice, and Mr M. Coke, Senior Professional Officer, for assistance with the diagrams.

I wish to thank Mr I.C. Player, Chief Conservator, Zululand, for his interest in the project, as well as my colleagues Regional Warden J.V. Hancock, and Senior Ranger T.P. Dutton, for their assistance.

Mr R.I.G. Attwell, Principal Research Officer, and Mr P. Evans, Deputy Director, Department of National Parks and Wildlife Management, Rhodesia, are thanked for assistance in arranging visits to crocodile farms and for hospitality in Rhodesia.

Mr John Stoneman, Chief Fisheries Officer, Uganda, supplied helpful information, as did Mr John Rutledge from Zambia. I am also grateful to Mario da Costa, Chief Inland Fisheries Officer, Mozambique, for his pleasant co-operation and hospitality, and particularly to Mr and Mrs Angus van Jaarsveld for hospitality and many valuable discussions.

Finally, acknowledgement is gratefully offered to the Natal Parks Board for encouragement and support.

* * *

References

Attwell, R.I.G. 1970. Some effects of Lake Kariba on the ecology of a floodplain of the mid-Zambesi valley of Rhodesia. Biol. Cons. 2(3): 189-196.

Bigalke, R. 1931. Note on the egg of the Nile crocodile. Proc. Zool. Soc. Lond. Vol. ? (2): 555-559.

Blake, D.K. 1970. Crocodile farming in Rhodesia. (Unpublished MS. roneoed.) Dept Nat. Parks and Wildlife Management, Rhodesia.

Brazaitis, P. 1967. Crocodilian pets. Occ. papers; N.Y. Zoo. Soc., : 1-5.

Bustard, R.H. 1969. A future for crocodiles. Oryx 10(4): 249-255.

Cansdale, G. 1955. The Reptiles of West Africa. Penguin Books: London.

Chabreck, R.H. 1967. Alligator farming hints. (Unpublished MS. roneoed.) Louisiana Wild Life & Fisheries Commission. 1-21.

Chapman, C.M. 1967. Survey of the crocodile population of the Blue Nile. Geog. Journ. 136(1): 55-59.

Cloudsley Thomson, J.L. 1969. Water relations of the young Nile Crocodile. Brit. Journ. of Herpet. 4(5): 107-112.

Cott, H.B. 1961. Scientific results of an enquiry into the ecology and economic status of the Nile Crocodile in Uganda and Northern Rhodesia. Trans. Zoo. Soc. Lond. 29(4): 211-356.

1968. Nile crocodile faces extinction in Uganda. Oryx 9(2): 330-332.

1969. Tourists and crocodiles in Uganda. Oryx 10(3): 153-160.

Graham, A. 1968. The Lake Rudolph crocodile population. (Unpublished MS. roneoed.) Kenya Game Dept. 1-145.

Gray, C.W., J. Davis and W.G. McCarten. 1966. Treatment of Pseudomonas infections in the Snake and Lizard collection. Int. Zoo Yb. 6: 278. Zool. Soc. London.

Gregor, G. 1969. Farming crocodiles in Kabwe. Horizon 11(7): 4-9.

Kellogg, R. 1929. The habits and economic importance of Alligators. Tech. Bull. 147: 1-36. U.S. Dept. of Agric.

Mitchell, S.A. 1968. A survey of the crocodile population of the Sinamwenda River and Bay, Lake Kariba. (Unpublished MS. roneoed.) Dept. Bio. Sci.; Univ. Coll. of Rhodesia.

1969. Crocodile report; Jan/Feb. 1969: 1-9. (Unpublished MS. roneoed.) Dept. Bio. Sci.; Univ. Coll. of Rhodesia.

Modha, M.L. 1968a. The ecology of the Nile Crocodile on Central Island, Lake Rudolf. E. Afr. Wildl. Journ. 5: 76-95.

1968b. Basking behaviour of the Nile Crocodile on Central Island, Lake Rudolf. E. Afr. Wildl. Journ. 6: 81-88.

Pawley, R. 1962. Propagating reptiles at Lincoln Park Zoo. Int. Zoo Yb. 4: 95-96. Zool. Soc. London.

Pienaar, U. de V. and V.F.M. Fitzsimons. 1966. The Reptiles of the Kruger National Park. National Parks Board of Trustees. 1-223.

Pienaar, U. de V. 1969. Predator-prey relationships amongst the larger mammals of the Kruger National Park. Koedoe 12: 108-176.

Pooley, A.C. 1962. The Nile Crocodile Crocodylus niloticus. Notes on the incubation period and growth rate of juveniles. The Lammergeyer 2(1): 1-55.

1966. Crocodiles and crocodile farming. African Wild Life 20(3): 211-216.

1969a. Preliminary studies on the breeding of the Nile Crocodile Crocodylus niloticus in Zululand. The Lammergeyer 10: 22-24.

1969b. Some observations on the rearing of crocodiles. The Lammergeyer 10: 45-59.

1969c. The burrowing behaviour of crocodiles. The Lammergeyer 10: 60-63.

1969d. Rearing crocodiles in Zululand. African Wild Life 23(4): 314-320.

1970. Conservation of the crocodile in Zululand. Animals 13(2): 76-79.

Pope, C.H. 1957. The Reptile World. Routledge & Kegan Paul: London.

Reichenbach-Klinke, H. and E. Elkan. 1965. The principal diseases of lower vertebrates. Academic Press: London & New York.

Rutledge, J. 1969a. Crocodile farm. (Part one) Black Lechwe 7(4): 23-25.

1969b. Crocodile farm. (Part two) Black Lechwe 7(5): 4-7.

Stevenson Hamilton, J. 1947. Wild Life in South Africa. Cassell: London.

Stoneman, J. 1969a. Notes on growth and feeding of Crocodylus niloticus. Occasional papers, Min. of Animal Industry, Game and Fisheries Management, Uganda: 11-14.

1969b. Crocodile industry in Uganda. Occasional papers, Min. of Animal Industry, Game and Fisheries Management, Uganda. No 2: 15-21.

Tinley, K.L. 1966. An ecological reconnaissance of the Moremi Wildlife Reserve, Botswana. Okavango Wildlife Society.

Vogel, Z. 1964. Reptiles and Amphibians, their care and behaviour. Studio Vista : London.

Wallach, J.D., C. Hoessle and J. Bennett. 1967. Hypoglycemic shock in captive Alligators. J.Am.Vet.Med.Assn., 151(7): 893-896.

Wallach, J.D. and C. Hoessle. Steatitis in captive crocodilians. J.Am. Vet.Assn. 153(7): 845-847

Welman, J.B. and E.B. Worthington. 1943. The food of the crocodile. Proc.Zoo.Soc.Lond. Series A. Vol. 113: 108-112.

Paper No 12

MANAGEMENT OF THE CROCODILE INDUSTRY IN PAPUA AND NEW GUINEA

M.C. Downes
Senior Ecologist, Wildlife Laboratory, D.A.S., Konedobu

Introduction

Following the peak year of crocodile killing in 1965 - 66 there was much agitation to introduce legislation and a management programme to maintain the skin trade. Native people were concerned at the decrease in crocodiles in districts where there was little other money available to the people.

A private member's bill was passed by the House of Assembly outlining in general terms the possible measures thought to be necessary.

In 1968 the Wildlife Ecology Section of the Agriculture Department recommended the particular regulations which were ecologically sound and appropriate to the special situation in the Territory. In brief these included:

a) System of licences for hunters, skin buyers and exporters through which limitations on the buying and selling of skins could be policed.

b) Collection of detailed statistics on skin production and export.

c) Prohibition of sale and export of skins over 20 inches in width, corresponding to crocodiles between 8 and 9 feet long. There was no ban on the killing of crocodiles.

In 1969, a research station was established at Lake Murray in Western Papua, in the midst of a very extensive swamp system, as a base for field research into the ecology of crocodiles.

In 1970, the station was enlarged to accommodate 500 small crocodiles, to find methods and costs of growing crocodiles from 18 inches to the optimum commercial size in captivity.

History of the Industry

In the 1950s European traders and itinerant shooters built up the export of raw skins, first on the Fly River and later in the Sepik. The level of hunting remained much the same for a decade, utilizing mainly the larger saltwater crocodiles in the bigger rivers, lakes and tributaries.

During this time shooting gangs of indigenous hunters were trained in skinning and preservation techniques. With the decline in the saltwater skins there was a greater need to forage into the intensively overgrown swamps for freshwater crocodiles, and the indigenous hunters in their canoes, working either for traders or themselves, gradually took over the hunting operations. Skins were sold to traders or to co-operative skin buying societies formed for the purpose.

By the late 1960s lack of skins had forced most of the Europeans out of the business. A few remained as traders, but at the present time the skin trade is essentially native operated. In the past year (1970) high water levels and low world prices for skins have caused a break-down in the whole trade. Co-operative skin buying societies have little money to buy goods, and are failing; most private traders are already in other businesses and the poorly organized transport of skins causes significant deterioration in the quality and number of skins reaching the coast.

Management of the Industry

The management of the industry hinges on a few special features which should be explained. The most obvious feature is that despite a production worth more than 10 million dollars over the years, there is a startling lack of any concerted action from within the industry to improve or manage its activities. The hunters are mainly primitive villagers who have learned the rudiments of skinning and skin preservation from passing Europeans. They sell in the village to itinerant skin buyers who have been predominantly short-term traders with little interest in the long-term prospects. In turn these sell to exporters who generally are representatives of overseas companies.

Thus the system of licences was vital for co-ordinating the diverse elements of this scattered trade and managing it as an industry. Without statistics the trends in the industry cannot be measured or analysed; without support and co-operation from those engaged in the industry and a two way passage of information, no management programme can succeed.

On the whole, the hunters are competent at securing the crocodile and in the initial preparation of the skin. However, during its passage to the coast the skin can lose much of its value through lack of reasonable attention. Lack

of salt, poor handling, no protection from moisture, are a few of the factors causing deterioration. If supplies are short the villagers are soon discouraged from providing adequate numbers or quality of skins.

This is of primary concern for the management of the industry. In fact the current system of marketing between hunter and exporter can only cope with the immense distances, and primitive transport arrangements, when skins are plentiful, prices are high and the profits for middle men are large enough to cover considerable losses.

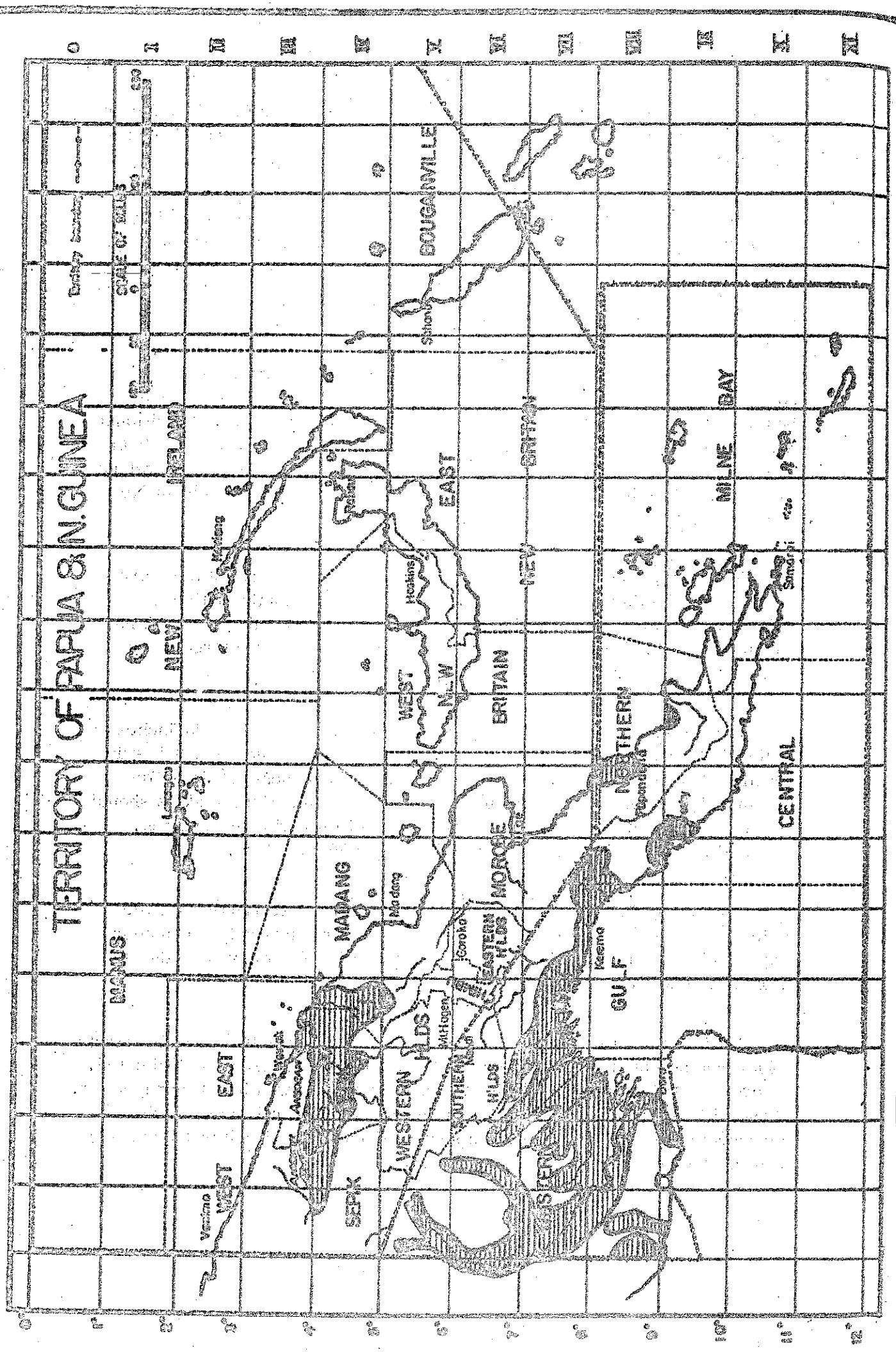
The second important feature of the New Guinea situation is the impossibility of applying western type game laws to native hunters in the bush, particularly those relating to the killing of bush animals. Traditional game laws of the western world are backed by a reasonable chance of being caught by a game warden; or they appeal to the conscience or understanding of an indoctrinated shooter. Neither of these factors apply in New Guinea at present.

Therefore, special attention was concentrated on control of the market at the level of skin buyer and exporter, and on the economic motive to influence controls of over-killing. It was the economic value of the skins which caused the drastic over-killing of the crocodiles in the larger size range from 1956 - 1966.

As a first step the sale and export of crocodile skins over 20 inches in belly width was prohibited. This corresponds to a crocodile over 8 feet in length. This was the sector of the population most heavily hit by the commercial hunting. It was appropriate that the value of these skins should be removed. Although the size at breeding differs with the species, crocodiles above 8 feet are probably all successful breeders.

Later, consideration will be given to a similar restriction on the sale and export of small skins, although these are probably much more expendable and there is in fact far less incentive for their sale due to very low prices.

A third special feature of the New Guinea situation is the extensive tracts of lowland swamp habitat where crocodiles have only slowly been decimated. There are still many areas difficult of access and, even without management, these will provide a small trickle of income for several years. With management, they could provide a source of income and cultural pride for Papuan and New Guineans for years to come.


TERRITORY OF PAPUA & N.GUINEA
BOUGAINVILLE
NEW BRITAIN
MILNE BAY
CENTRAL
GULF
MOROBE
MADANG
SEPIK
MANUS
NEW IRELAND
WEST NEW BRITAIN
EAST NEW BRITAIN
WESTERN HLDS
SOUTHERN HLDS
EASTERN HLDS
NORTHERN
WESTERN
EAST SEPIK
WEST SEPIK

Ban on Large Skins

In the East and West Sepik and Madang Districts, the ban on the sale of skins over 20 inches was opposed and has been removed in those districts. In all other parts of Papua and New Guinea the full regulations apply.

It is obvious throughout the latter areas that there is a reduction in the number of larger crocodiles being killed for commercial purposes. The new regulations have succeeded in this particular objective. Whether this in turn will result in an improved production, it is the aim of the ecological research to determine.

There is no doubt that some large crocodiles are still being killed either for safety, food or illegal sale of skins. But with very few uncontrolled outlets for skins the reduction in the market pressure for breeding-sized crocodiles could bring the hunting pressure back part of the way to that prevailing prior to development of the skin trade.

Crocodile Farms

In order to provide some economic activity in swamp areas with few other commercial products, the people in crocodile areas are being encouraged to experiment with crocodile rearing pens in the villages. It is still possible for the people to catch large numbers of small crocodiles, and if food is cheap and plentiful, their natural interest in handling and rearing these animals could be encouraged.

This is essentially a village level project and is not concerned with breeding nor release into the bush.

Figure 1 (see opposite)

The major areas of alluvial riverine plains, swamps and tidal swamps containing crocodiles in Papua and New Guinea. A few crocodiles inhabit the coast and estuaries of all islands in the Territory.

The Future

There are still sufficient numbers of wild crocodiles to repopulate many districts naturally if the harvest of mature and almost mature animals is kept within ecologically determined limits.

The area of suitable habitat is adequate. Changes in habitat are not yet significant, but mining operations and release of tilapia may yet prove to be seriously detrimental to crocodiles.

Supplies for the hunter, facilities for preservation and marketing are poorly organized and haphazard. No skin quality control nor improvement facilities exist. Unless the industry becomes organized in these matters, it is likely to fizzle out long before the ecological research has provided the basic data on which the conservation of crocodiles and the management of the industry will depend. For this purpose the Department of Agriculture is bringing together representatives of the various aspects of the industry in an effort to achieve the necessary re-organization.

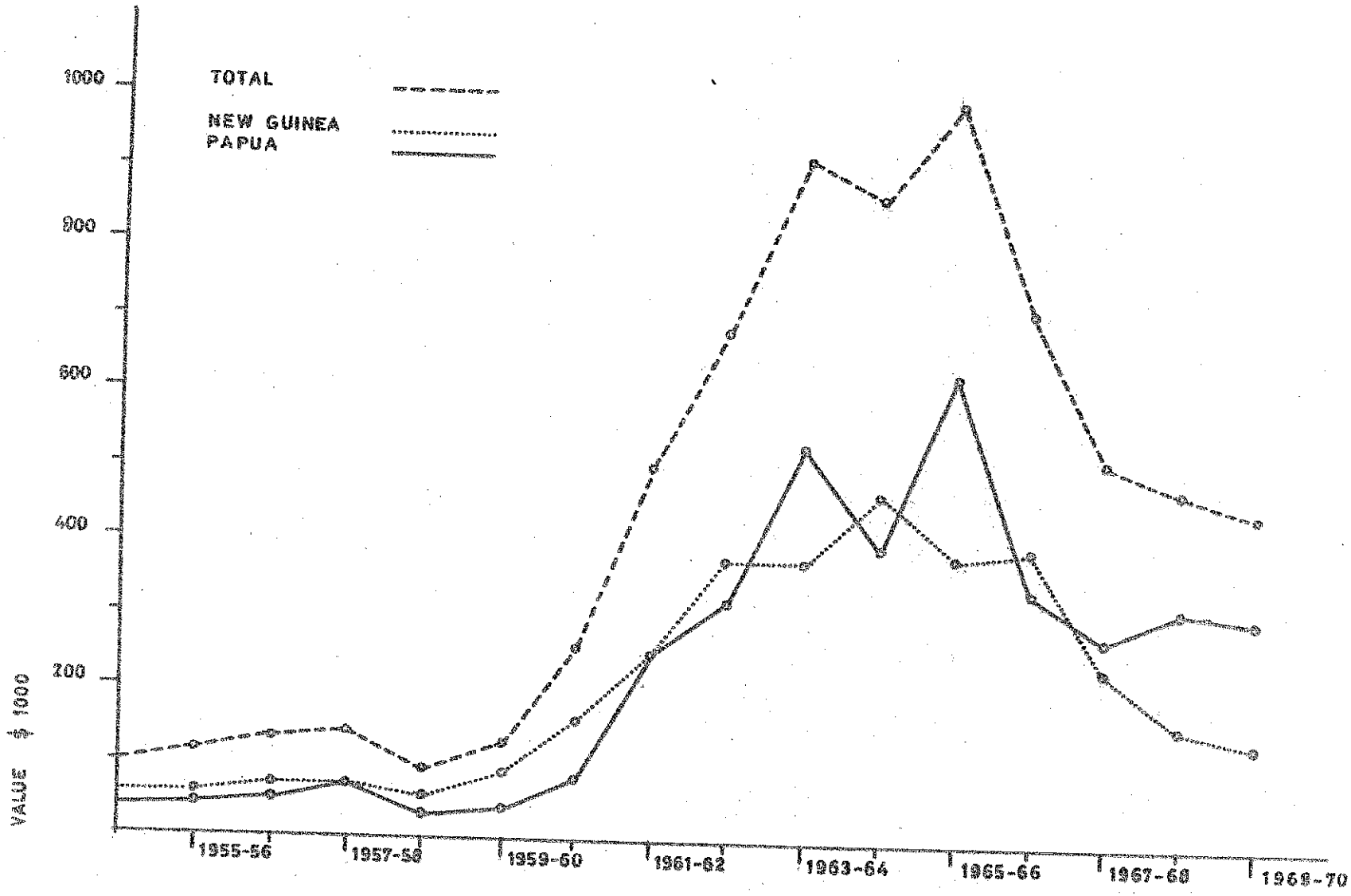


Figure 2. Annual export value of raw crocodile skins for the years 1954-55 to 1969-70

Paper No 13

MANAGEMENT OF THE AMERICAN ALLIGATOR

Robert H. Chabreck
Louisiana Cooperative Wildlife Research Unit,
Louisiana State University, Baton Rouge

Introduction

The American alligator Alligator mississippiensis is native to the southeastern part of the United States. It occurs throughout the states of Louisiana and Florida, and inhabits parts of Texas, Arkansas, Mississippi, Alabama, Georgia, South Carolina and North Carolina.

It was a very important part of the fauna of the southeastern states in the past, and efforts are now being directed toward restoring it to that position. This reptile is looked upon as a renewable resource and has a definite place in the economy of the states involved. It was an important commercial animal in the past, and the tremendous sums spent by the states on management and research, reflect their interest in returning the alligator to this status.

Early settlers and explorers in this region reported the occurrence of large numbers of alligators and the literature contains numerous reports on the abundance of the reptile. Commercial harvesting of alligator skins began in the mid-19th century (Smith, 1893; Audubon, 1931), but sizeable kills of alligators did not begin until late in the 19th century (McIlhenny, 1935). By the end of the 19th century the number of alligators had been greatly reduced; Stevenson (1904) estimated that the alligator population was reduced by 80% between 1880 and 1904. In spite of the heavy kill during this period, alligators were still plentiful in the more remote areas. However, the harvest continued at a rapid rate, and by the middle of the 20th century the American alligator was practically non-existent over most of its original range (Chabreck, 1967a). Concentrations of the animals were found only in areas where rigid protection was provided.

Even though the alligator population continued to decline each year after 1950, no great concern was shown for its welfare until the 1960s. All states within its range enacted protective legislation during this period. Even with closed hunting seasons, illegal hunting continued, and the interstate shipment of skins created new problems. Skins taken illegally could be shipped to states outside the alligator's range, where possession was legal because of the absence of specific protective regulations.

In 1970 the United States Congress put into effect the Endangered Species Act which provided federal penalties for the shipment of alligators or their skins across state lines if taken contrary to federal or state law. This act, coupled with closed hunting seasons by the states, was sufficient to curtail the alligator skin trade, in so far as practical, and subsequently the illegal kill of the animal.

Protection

Prior to passage of the Endangered Species Act, alligator populations were protected by state hunting regulations and in state and federal refuges and parks.

Closed seasons

In spite of closed hunting seasons in the individual states, an illegal kill of alligators took place; however, closure by the states was effective in reducing it. The states are well staffed with law enforcement personnel, and areas with properly planned programmes were effective in apprehending law violators. Nevertheless, the high price for alligator skins, and an attitude of indifference by local courts, contributed to the continuance of illegal hunting.

The prosecution of alligator law violators has been handled through local courts, and many courts do not consider these violations to be serious offences; consequently light penalties are given to convicted violators. However, in areas where strong state laws have been rigidly enforced and have received strong backing by local courts, illegal hunting has been significantly reduced.

Harvest regulations

The American alligator has a high reproductive potential, and past evidence shows that this reptile responds rapidly to protection. In areas with an effective protection programme, they were soon a common part of the local fauna.

Several states in which the alligator population has shown sufficient recovery are likely to establish regulations permitting a controlled harvest. With past experience as a guide, the harvest regulations should be designed to protect the breeding population.

Giles and Childs (1949) felt that it was not advisable to harvest adult

females (over 6 feet (1.80 m) long) from mid-June to mid-September, since nesting was in progress at this time. They also felt that by restricting the harvest to bayous, rivers and canals the take of adult females would be minimized, since they commonly established territories in less accessible areas away from such waterways.

Using radio telemetry, Joanen and McNease (1970) found that, during the breeding season, adult females travel more than normally and spend a portion of their time in deeper waterways and lakes. They recommended that the season be opened only after mid-September. The young are hatched after that time, and the females remain in the less accessible areas.

While size limits can effectively restrict the killing of adult females, they also serve to protect adult males. The alligator is polygamous, and an alligator population normally has a surplus of adult males. Consequently, regulations designed to selectively harvest adult males would be advantageous.

In the future, serious enforcement problems could again arise if a state legalized the taking of alligators without requiring that the animals or skins taken be properly tagged. All alligator skins placed in interstate shipment should be properly tagged, so that the source can be correctly ascertained. Unless this is done, law enforcement efforts will be greatly handicapped. Also, if a harvest is operated on a sustained yield basis, tagging will be necessary in order to limit the take and to restrict the take to specific areas.

Refuges

Wildlife refuges have proven to be very beneficial in the management of the American alligator. Sizeable numbers could be found only on federal, state and private refuges during the early 1960s. Protection and suitable habitat were the main factors responsible for the concentrations found in these areas. Although habitat preservation is important, protection from poachers was the primary factor affecting populations.

After the states enacted laws against their killing during the early 1960s, the alligators on wildlife refuges provided a nucleus from which other populations could rebuild. Unlike most reptiles, alligators move about a great deal and journeys of 20 miles (30 km) or more during a season are not uncommon (Chabreck, 1965). Also, refuges have proved to be a valuable source of alligators for restocking purposes.

Restocking

Whenever an animal population is depleted in an area, one of the first thoughts of most people is that animals from elsewhere should be introduced into the area. Very often this simple solution proves to be effective and the animal flourishes after release. Unfortunately, however, this is not always the case and, as a result, many restocking efforts have met with failure. The factor or factors, which operated to eliminate the original population, operate in the same manner to remove the introduced one.

The restocking of native game animals, such as the White-tailed deer Odocoileus virginianus and wild turkey Meleagris gallopavo, was very successful in re-establishing these species where previous populations had been eliminated through hunting. Where suitable habitat is available and adequate protection is provided, native animal populations should become re-established through restocking.

From 1958 to 1970, about 1700 live alligators were taken from federal and state wildlife refuges for restocking purposes. Most alligators released were from 2 to 5 feet (60 to 150 cm) long, and all were tagged prior to release. In all areas where releases were made, it was agreed that the hunting season for alligators would remain closed for a period of not less than five years.

In 1965, eight areas were surveyed where alligator releases had been made by the landowners in the previous year. Each landowner was contacted as to the status of the animals; only one reported that they had remained in the area where they had been released. Two other landowners reported that the animals were in the area but had moved from the release site. The other five landowners reported that the alligators were seen for a short while and then disappeared. The disappearance was attributed to drought by one landowner, but the other four felt that high water from a hurricane was the cause.

Data on the recapture of tagged alligators revealed that transferring alligators to new locations caused the normal movement rate to increase by three or four times (Chabreck, 1965). Of the 29 alligators recaptured after being transported to a new location, all had moved one mile or more from the release site after the first year. After the third year, eight had moved more than 13 km from the release site and one had moved 30 km. Practically all showed a strong homing instinct, travelling in the general direction of the area from which they were originally captured.

Pen-reared alligators responded similarly to wild alligators, when transferred to new locations and released. Alligators, reared by Louisiana State University for experimental purposes, were released on marshland owned by the Louisiana Wild Life and Fisheries Commission. Of 254 pen-

reared animals released, most dispersed to remote areas and were not seen again; however, two were recaptured 22 months after release (Ted Joanen, unpublished data). Both were females and were 1.64 m long when released. When recaptured, one was 1.84 m long and the other 1.85 m long. Only one was weighed prior to release, and it weighed 19.050 kg; when recaptured, it weighed 21.320 kg. One alligator was recaptured in the same area as released and the other was recaptured 2 miles (3.2 km) northeast of the original release site.

While restocking may be a valuable tool in re-establishing alligators in an area, dispersal of the reptiles from the release site should be anticipated.

Habitat Management

The American alligator is found mostly in areas with fresh to slightly brackish water (Chabreck, 1965). Although they may wander into areas with salinities as high as 20‰, this is temporary, and alligator concentrations usually occur in areas with salinities less than 10‰. A habitat management programme should, therefore, provide methods of maintaining low water salinities.

Areas with stabilized water levels offer distinct advantages as alligator habitat. Coastal marsh impoundments were studied in Louisiana, and those permanently flooded with fresh water contained much higher alligator populations than those permanently flooded with brackish water or fresh water which was drained during the spring and summer to enhance plant growth (Chabreck, 1960). In the permanently flooded fresh water impoundments, both deep and shallow water and an abundant supply of food were available.

Joanen and McNease (1970) found that adult females sought out open water areas during the courtship and breeding period. They believed that such areas were an important part of the animals' habitat. Studies in Florida by Hines et al. (1968) revealed that water level fluctuation may be a limiting factor because of nest destruction. They cited examples in the Everglades where altered drainage patterns had resulted in the summer flooding of vast areas; nests constructed earlier in low-lying areas were inundated and the eggs were destroyed.

Flooding from hurricanes often results in nest looses over fairly large areas. Such tropical storms are common summer occurrences in the Gulf of Mexico, and sea water pushed by strong winds may be driven inland for 15 to 20 miles (24 - 32 km).

Alligator Census

For the proper management and wise utilization of any wildlife population, a knowledge of the population is essential. The size and composition of the population, plus the annual production and annual mortality should serve as a basis upon which harvest regulations are formulated. Detailed information should be obtained when deciding the number of animals to be removed from specific areas.

Several methods such as night counts, recapture of tagged animals, call counts, nest counts and total population computations, have been used for the inventory of alligator populations (Chabreck, 1966).

Night counting is widely used because it is easy and provides information on the ratio of the various size classes in the population. Call counts and nest counts provide information on the breeding population. A method of total population computation using a combination of night counts, nest counts and data from kill surveys has been used to determine the total number of alligators in a particular area.

Alligator Farms

An alligator farm is a fenced area containing alligators, and in which the young hatched are a product of the reproduction of the adult animals confined within the area. There is an increasing interest in alligator farming as a business venture (Chabreck, 1967b).

At present there are a number of alligator farms in the southeastern States. However, I have no knowledge of any which are operating at a profit. Several farmers are now producing a sizeable number of young, but the investment and operating costs are high and several years of production will be necessary before a profit will be realized.

Louisiana and Florida have established research stations where studies on alligator farming are being conducted. Problems given special attention at present are stocking rates of breeding pens, pen sizes, pen construction, feeding, egg incubation, rearing of young, and diseases.

Many states now have special regulations governing alligator farms, and wish to encourage legitimate operations. If alligators could be produced under artificial conditions in sufficient numbers, this would perhaps remove some of the pressure on wild populations.

Information and Education

Although hide hunters were primarily responsible for the decline of the American alligator, a large number were killed as vermin or for sport. Fictitious scenes in movies branded the animal as a vicious swamp creature and a menace to society. Such irresponsible actions by this industry did the animal a great injustice and instilled a sense of fear in the minds of the people.

During the past five years, the status of the alligator has been given wide publicity by various news media and, as a result, the public's attitude toward the species has been greatly influenced. The public now looks upon the alligator with concern, and not with horror as they did in the past. This change of attitude clearly demonstrates the effect of a strong publicity programme.

Public support is essential in any wildlife management programme. A vigorous and well planned programme of information and education can be very important in gaining public support. However, care must be taken not to over-sell an idea to the public. Although illegal hunting cannot be tolerated in a well administered programme, the legal harvest of alligators on a sustained yield basis should be a part of most management plans. Therefore, the idea of total protection should be expressed with reservation.

* * *

References

Audubon, J.J. 1931. Observations on the natural history of the alligator. La. Conser. Review 2(3): 3-8.

Chabreck, Robert H. 1960. Coastal marsh impoundments for ducks in Louisiana. Proc. Annu. Conf. of the S.E. Assoc. of Game and Fish Comm. 14: 24-29.

1965. The movement of alligators in Louisiana. Proc. Annu. Conf. of the S.E. Assoc. of Game and Fish Comm. 19: 102-110.

1966. Methods of determining the size and composition of alligator populations in Louisiana. Proc. Annu. Conf. of the S.E. Assoc. of Game and Fish Comm. 29: 105-112.

Chabreck, Robert H. 1967a. The American alligator -- past, present and future. Proc. Annu. Conf. of the S.E. Assoc. of Game and Fish Comm. 21: 554-558.

1967b. Alligator farming hints. La. Wild Life and Fisheries Comm., New Orleans. 21 pp. mimeographed.

Giles, Leroy W. and V.L. Childs. 1949. Alligator management on the Sabine National Wildlife Refuge. Jour. Wildl. Mgmt. 13(1): 16-28.

Hines, T.C., M.J. Fogarty and L.C. Chappell. 1968. Alligator research in Florida: a progress report. Proc. Annu. Conf. of the S.E. Assoc. of Game and Fish Comm.

Joanen, Ted and Larry McNease. 1970. A telemetric study of nesting female alligators on Rockefeller Refuge, Louisiana. Proc. Annu. Conf. of the S.E. Assoc. of Game and Fish Comm.

McIlhenny, E.A. (1935). The alligator's life history. The Christopher Publ. House, Boston. 117 pp.

Smith, H.M. 1893. Notes on the alligator industry. Bull. U.S. Fish Comm. (1891) 11: 343-345.

Stevenson, C.H. 1904. Utilization of the skin of aquatic animals. U.S. Comm. Fish and Fisheries Dept 1901: 281.

Paper No 14

NATIONAL PARKS, REFUGES, ETC., AS TOOLS IN CROCODILE CONSERVATION

H.R. Bustard
Australian National University, Canberra City

I would particularly wish to draw attention to the title of this paper. National parks and other categories of refuge are not, and can never be, any more than 'tools' in crocodile conservation. This paper is meant to stimulate discussion and hence attempt to throw up some of the problems affecting crocodiles in national parks. It concludes that the creation of national parks as an act in isolation will do little to help crocodile conservation.

National parks legislation must tie in with other legislation and both must be enforceable. We all know of excellent legislation on the books which is no more than 'paper' legislation. I envisage national parks for crocodiles as a follow-up to national or state legislation designed to provide a viable future for crocodiles outside of any proposed national parks. The contribution of the parks is to set aside areas of land where the animals, in this case crocodiles, have first right and where humans or human development pressures are controlled or prohibited. National parks must, of course, be patrolled by wardens and the fines for poaching within national parks should be much more severe than outside.

All this brings us to the first problem -- conservation legislation. I would like to quote a few sentences I wrote on crocodiles published in the WWF Year Book for 1969:

> "Few Governments have suitable conservation legislation for crocodiles. Where legislation does exist often no attempt is made to enforce it. Furthermore, the remote areas inhabited by crocodiles are usually difficult to police. There is little realisation of the profitability of crocodile skin poaching. It is essential, both for the morale of wardens and as a deterrent to poachers, that fines be realistic. Quite clearly a fine must be greater than the operator can recoup in a week-end's work. I have recommended, for first offences, that the fine should not be less than ten times the value of skins poached. Naturally the poacher must lose the skins and all gear in addition to the fine. Subsequent fines should be much larger. Many poachers will evade capture completely or for long periods of time. Unless fines are severe these will merely be added to operating costs."

This brings us to the role of the fauna warden. Wardens have a difficult task under the best of conditions. Crocodile habitat often makes their work extremely tedious and only a highly paid body of men with a sense of dedication, backed up by Government and the Courts, can be expected to perform their duties satisfactorily. It is impossible to enter into any discussion of the role of the fauna warden without a discussion of penalties for poaching.

In my experience many magistrates let crocodile poachers off with only token fines. Hence a situation in which maximum penalties exist but no minimum fines, is unsatisfactory both for conservation and for the fauna wardens. Very few poachers are usually apprehended and those few who are caught and then successfully convicted must consider it very amusing if only a nominal fine is imposed.

For instance, in Western Australia the maximum penalty for illegal possession of freshwater crocodile skins -- $200 per skin -- is rightly very severe. However, this would not be sufficient to deter poachers of salt-water crocodiles. A stiff fine is essential as a deterrent to poaching. Poachers are able to calculate the chance of being apprehended and are at work for large financial gain. Nominal fines of even a few hundred dollars are merely added to operating costs.

In this connection it may be useful to quote the sort of skin values which individuals or two man partnerships brought out of Western Australia in 1969. These figures are based on discussions with crocodile skin buyers who know the individuals concerned and who were offered the skins. The two poachers, operating in Western Australia at the time of my survey, were probably working on their third haul for the season (which lasts for less than six months). The first haul was brought out shortly after the end of the wet season and was valued at between $15,000 and $20,000. I am told that this figure, on present prices for freshwater skins, represents about the maximum number which they can move out of the State by road at one time. If it is assumed that only two hauls are taken each year and the most generous allowances are made for vehicle depreciation/operation then they probably clear between $20,000 and $30,000 each season. I quoted these figures to the Government of Western Australia because I noted almost complete ignorance of the profitability of operations among those people charged with law enforcement. In my view a magistrate in possession of this information would be unlikely to consider the offence as petty. My recommendation to the Government of Western Australia was that there should be statutory fines for first offenders of not less than ten times the value of the skins confiscated. Naturally skins and all gear must be confiscated.

Such fines may appear severe but then the profits to be made from crocodile shooting are enormous. Potential poachers weigh the potential gain against the chance of being caught and the likely fine if they are caught and convicted. So long as a single weekend's operation will cover the fine, even

although they may lose some skins, the odds are heavily stacked in their favour and poaching will continue.

A crocodile shooter, who strongly advocated a fauna reserve for crododiles in the Kimberleys, appealed to me to tell the Government to impose fines ten times greater than normal for any poaching within the reserve. Shooters know the need for strong deterrents. A major problem for conservationists in most places is to have sufficiently large fines imposed for the fines to have real deterrent effect.

Until such time as Government and the Courts face up to their responsibilities and back up the fauna wardens these men will be apathetic towards their work. What is the use of tracking down a poacher, at considerable physical risk to yourself, and going through all the rigmarole of bringing him to Court, if you know he can recoup the fine in a couple of nights?

The role of tha fauna warden both inside and outside national parks is one that requires careful thoughts. In areas where he is backed up by a sound network of honorary wardens he can become a most effective intelligence officer. However, this entails good liaison between him and the honorary wardens and between the Government Department concerned and the professional wardens.

Turning to national parks themselves, I would like to quote from the same WWF article:

> "National Parks, designed specifically for crocodiles, are needed for many species. They are essential where it is impossible to police adequately large areas of the habitat, or where a species has become critically endangered. Within these restricted areas it should be possible to keep poaching to a low level which the populations can withstand. National Parks are there to conserve the crocodiles. Human entry -- crocodiles being popular with tourists -- must be controlled and it may be essential to greatly curtail or even exclude this altogether during the egg-incubating season when the females are guarding the eggs. Dr Cott has shown enormous wastage of incubating clutches of eggs in the Nile crocodile population inhabiting Murchison Falls National Park in Uganda, as a result of tourist launches being allowed to approach the rookeries and so frighten the nesting females into the water. Baboons and monitor lizards (Varanus) are then able to dig up and eat the eggs. This would be impossible while the female was at the nest."

So far I have hardly touched on the biological considerations of national parks for crocodiles. I make no apology for making them appear of secondary importance. Of course, they are not, but the political issues are so

complicated, and their solution such essential prerequisites, that I feel that one must give them detailed attention in the first place.

In setting up any national park or refuge the best available expert advice must be sought and the advice must come from someone free from political pressures. This generally means that he must come from outside the State or country concerned, although, of course, he must be thoroughly familiar with the biogeography of the territory. National parks for crocodiles should be sited in ideal areas of habitat from the crocodiles' point of view but preferably also in regions not too remote from the outside world so that the parks can be adequately patrolled by wardens. Size is of major importance, care being necessary to see that the park is large enough to be completely viable. For instance, the national park about to be gazetted in the Kimberley Division of Western Australia for the estuarine crocodile extends along the Ord River and its adjacent swampland for over twenty miles. All the area is prime habitat for C. porosus, yet is easily patrolled by wardens, one end being just over ten miles from Wyndham, an important township where a full-time fauna warden is stationed. The total area of the proposed park is about 120 square miles. I would reiterate that there are many of us well qualified to select sites for crocodile national parks. The real problems are political and centre round effective protection for an animal living in difficult and often remote terrain which has a high commercial value and is, therefore, subject to intensive poaching effort.

Paper No 15

CROCODILIANS AND PUBLIC RELATIONS

James H. Powell, Jr.
Plainview, Texas

In his book, The Empty Ark, Philip Kingsland Crowe (1967) remarks that "friends of the crocodiles ... have a hard time selling their ideas". Though still a problem, this apathy has shown signs of cracking. Crocodilians have almost, as it were, awakened to find themselves popular. As just one example, in the finale to the current edition of the 'Ice Follies' alligators are depicted in a sympathetic light, while in the lobby, souvenir stands sell, along with colour programmes and skating dolls, some rather realistic rubber replicas of these reptiles. Properly exploited, this current surge of public interest could be a potent weapon. Now, if ever, is the time for crocodilian conservationists to 'sell their ideas'.

The significance of crocodilians might be divided into the practical and the intangible. The latter is, I think, the greater, but let us begin with the practical, for -- albeit for worse -- we live in a materialistic world. The question I am most often asked about my work is "What good are crocodilians?". So far, I have always succeeded in holding my temper, avoiding an assault charge, and attempting some sort of answer. And there are answers. True, one might argue that the super-leather which can be tanned from crocodilians' belly-skins, and which has so nearly brought about their downfall, is used to make luxury status-symbols which the world really needs like Custer needed more Indians. Subtler, but more truly important, is the crocodilians' role in ecology. These reptiles feed heavily on predaceous fish which feed in turn on game and food fishes; both sport and commercial fishing decline where crocodilians have been over-hunted. In areas of the tropics and sub-tropics subject to a dry season, their diggings become important water holes for wildlife and even for domestic stock. And in parts of South America where Caiman crocodilus yacare consumes large quantities of snails, many of them cattle disease vectors, livestock epidemics have often followed the caimáneros (Buchinger, 1965). Since ecology is now receiving wide attention, I think much should be made of the ecological importance of crocodilians and the negative impact on the environment their destruction can have.

Much, but not too much, lest we, too, join technocracy and forget that the ultimate value of a crocodile lies not in its belly-hide, nor its value as a tourist attraction, nor even in its ecological significance, but simply in the fact that it is a crocodile: big and ancient and monstrously magnificent;

It is of magnificance and not economic : that chapter 41 of Job sings. We need crocodilians, not because they are useful, but also in respects in which they are not, and it is sometimes necessary to remind ourselves that the useless can also be precious.

For this, I can think of no better memory aid than to emphasize the close relationship between the Crocodilia and the dinosaurs. For above all else, crocodilians are Archosaurs, the last of the 'Ruling Reptiles'. The perennial popularity of the 'Lost World' school of science-fiction illustrates the very deep, even emotional, fascination which the great reptiles of the Mesozoic hold for the public. I sometimes think that if only the human race could see a live dinosaur, it would die happy! How absurd, then, to exterminate the nearest thing to a live dinosaur we shall ever have this side of a time machine! As Edwin H. Colbert (1945) points out, the largest of the living crocodilians are "reptiles of no mean dimensions when compared with some of the large dinosaurs". Certain extinct forms were even bigger. The 45-foot Phobosuchus of the late Cretaceous was as large as Tyrannosaurus rex, while the gavial-like Rhamphosuchus of the Pliocene of India may have reached 60 feet. In other words, the largest carnivorous reptile yet discovered was not a dinosaur, nor even from the Mesozoic, but a gigantic crocodilian from the late Tertiary. The age of great reptiles need not be over unless we make it so, and I think a skilful presentation of the past and present magnificence of the crocodilian line would do much to show the importance of saving these final remnants of the most spectacular land fauna of all time -- the great reptile empire of the Jurassic and Cretaceous.

However, for this magnificence to be other than theoretical, it will be necessary for individual crocodilians to be allowed to reach full size -- which in reptiles is a very different thing from sexual maturity. Letting a crocodile breed before killing it may preserve the species, but this is not enough for those who want to see the last Archosaurs in all their Mesozoic splendour. A potential for dinosaurian size becomes academic if the animal is 'cropped' at ten feet. As the lumber industry quite correctly points out to the Sierra Club, there are more redwood trees today than ever before; as the Sierra Club quite correctly points out to the lumber industry, most of these are saplings. If crocodilians are to be cropped on a sustained yield basis, then there must also be areas where they are not cropped -- some corner of Louisiana where 18-foot alligators can again cruise the bayous, some fragment of Tanzania where 20-foot crocodiles can still give the shores of Victoria Nyanza the aspect of a lost world.

So much for ends; now to means.

In December 1967, Life magazine devoted an entire double issue, entitled "The Wild World", to the values of wilderness and the need for its preservation. I don't know what the chances would be of our getting a major national

magazine to devote an issue to crocodilians; but if we could the potential impact would be immense.

Meanwhile, I think the members of this Group should prepare a book on crocodilians, tentatively entitled Living Crocodilians of the World. I know of no non-technical book devoted exclusively to crocodilians, although they are discussed in many general works on reptiles; and I feel a publication of this sort would fill a real need, and help to focus interest on these animals. The details of the format can be worked out in discussion, but in general I visualize something similar to the late Armand Denis's Cats of the World. There should be a chapter summarizing the history of the Crocodilia from the late Triassic to the present, with emphasis on their Archosaurian affinities. Each of the living forms should be individually discussed, with range maps and as wide a selection of photographs as possible. Conservation will, of course, be stressed, though with care to avoid sermonizing, as the public can quickly sense -- and resent -- disguised propaganda.

Each member of the Group would contribute chapters on his specialities. In some areas, it may be desirable to seek the collaboration of colleagues outside the Group. As an example, although the American alligator falls within my geographical territory for the purposes of this meeting, there are many students of this species far more competent to write about it than I am. Since no one person would need to write more than a few chapters, it should be possible to get the book into press quickly, before the public interest in crocodilians wanes. Royalties from sales could well go to a special fund for crocodilian conservation projects.

* * *

References

Crowe, Philip Kingsland. 1967. The Empty Ark. Scribner, New York; p.88.

Buchinger, María. 1965. To Save our Natural Resources. Américas Vol. 17, No 8, Aug. 1965; p.27.

Colbert, Edwin H. 1945. The Dinosaur Book. Mcgraw-Hill, New York; p.120.

Editorial note

The proposal made in this Paper was discussed with great interest, but was eventually left in abeyance for the reasons recorded in the Summary of the Meeting (Section 24 of Part 2 of the Minutes) on page 25 above.

Paper No 16

BIOLOGICAL ISOLATION OF SYMPATRIC SPECIES OF SOUTH AMERICAN CROCODILIA

Federico Medem
Instituto "Roberto Franco", Villavicencio (Meta)

In Colombia there exist four different species of caimans and two of crocodiles, some of which are geographically isolated by the Eastern Andes which divide the country into two extensive areas: the first comprising the Caribbean and Pacific coastlands and the river systems NE and NW of the Andes; and the second, the Orinoco Plains and the Tropical Rain Forests of the Amazon.

The first is inhabited by the Spectacled caiman Caiman sclerops fuscus and C. s. chiapasius and the American crocodile Crocodylus acutus, while the second forms the habitat of the following crocodilians:

Orinoco crocodile Crocodylus intermedius, confined to the Orinoco Basin.
Black caiman Melanosuchus niger, confined to the Amazon Basin.
Spectacled caiman Caiman sclerops or crocodilus, subspecies and several different local populations.
Smooth-fronted caiman Paleosuchus trigonatus.
Dwarf caiman Paleosuchus palpebrosus.

In contrast to the crocodiles and to the Spectacled and Black caimans, both species of Paleosuchus are not gregarious but are found singly or in pairs.

In addition to geographical isolation between the species, there exists also an ecological one; in fact certain species show a preference for a specific habitat or ecological niche, even if they may not be completely bound to it.

A remarkable case of apparent geographical isolation is that the Orinoco crocodile does not enter the Amazon Basin by way of the upper Orinoco, the channel of Casiquiare and the Rio Guainía (upper Rio Negro), but the limit of its distribution is found on the Orinoco, upstream from the village San Fernando de Atabapo situated in Venezuela close to the mouth of Rio Guaviare. This fact is not due to commercial hide-hunting in the 20th century for it was observed by Humboldt in 1799 (Medem, 1958b).

Strong currents and even rapids do not inhibit the migration of crocodiles, as is clearly shown by the rapids of Maipúres and Átures, situated below San Fernando, as well as by the narrows on the Rio Guayabero. The Casiquiare, a channel which connects the upper Orinoco with the upper Rio Negro, was probably formed in geologically recent times; this, however, would not account for the absence of the Orinoco crocodile in the Amazon, since it is not found in the upper course of the Orinoco proper either. Actually no further studies about the migration of this species can be made, since it has been almost exterminated by excessive commercial hide-hunting, a deplorable fact which applies also to many other crocodilians.

Thus, all interpretations, since they cannot be based on field data, must remain mere speculations. However, the absence of the Black caiman M. niger in the Orinoco Basin can possibly be explained by ecological factors. This species, which grows to about 5 m in length, prefers quieter waters, such as large bends in big rivers, oxbow-lakes, lagoons and inundated forests. It does not avoid strong currents and was found in large quantities in the Amazon proper (Bates, 1864), but it seems to dislike rivers which contain rocks in abundance and the banks of which are partially formed by rocky walls and stone slabs, as occurs along the Guainía and Casiquiare Rivers.

Besides such ecological factors as quiet or running waters, rocky river beds, or falls and rapids which favour isolation, there must also be taken into account the factor of competition. According to information by professional hide-hunters (Medem, 1962), who worked in the Rio Atrato which flows into the Caribbean Sea in the late twenties and early thirties, there existed at that time well-defined ecological niches for the American crocodile and the Spectacled caiman. While the crocodiles were found almost exclusively in the Atrato River, its larger tributaries and big lakes, the caimans were virtually confined to lagoons, creeks and marshes. This seems to have been due to the fact that the crocodiles fed on caimans; thus the latter were forced to retreat to niches that were inaccessible for larger crocodiles, which gave them protection. In 1954-55, I found almost no crocodiles left but caimans in great abundance in all rivers without a strong current; thus, they had re-invaded the now unoccupied niches.

A definite and almost complete separation of ecological niches exists for the Spectacled caiman Caiman sclerops, the Smooth-fronted caiman Paleosuchus trigonatus and the Dwarf caiman P. palpebrosus, even if all three are to be found together in inundated forests during the rainy season.

Like that of the Black caiman, the ecological niche for the Spectacled caiman consists principally of quiet waters, and, therefore, it is not found near rapids and water-falls but prefers the bends of large rivers, lakes and swamps. By contrast, the Smooth-fronted and Dwarf caimans are both found

in another well-defined niche which consists -- in general terms -- of swift running waters in tropical rain forests. They are present in samll creeks with stony beds, in smaller rivers near rapids and water-falls, and in the vicinity of whirlpools. In large rivers they occupy the same swift-water niche, but also invade quieter waters where they commonly hide below branches overhanging the water or beneath large accumulations of fallen trees along the riverbank: This is particularly true of the Smooth-fronted caiman (Medem, 1958b): the masses of fallen trees cause the formation of whirlpools and sometimes small rapids and, at the same time, are well protected and rich in fishes.

A fair illustration of the different habitats of the Spectacled and Dwarf caiman is provided by observations made in 1952 in the upper Apaporis River (Medem, 1953a). The Laguna 'Inaná', connected with the river and consisting of three individual lagoons inter-connected by a channel and by a small creek, was studied during 15 days from 16 00 to 22 00 hrs. The creek was about 500 m long and had a swift current in which the water was lower in temperature than that of the lagoons. The Spectacled caiman occurred in abundance in all three lagoons but the Dwarf caiman, only in the creek itself and in a lagoon near the mouth of the channel, where four to six specimens appeared between 17 30 and 18 00 hrs each afternoon.

This possibly indicates that water temperature also plays a certain role in the choice of the niche for P. palpebrosus. It was also observed later that the Dwarf caiman shows an extraordinary resistance to low temperature at high altitudes (Medem, 1967). A specimen 74 cm in length was kept in Bogotá (2650 m alt.) without artificial heating at the Institute of Natural Sciences; he escaped and was found in perfect condition after nine days in a small pool, apparently feeding on abundant frog Hyla labialis; the temperature at night was as low as 6° C. On the other hand, a Spectacled caiman, 1.70 m long, died after three days in the Institute where the average temperature fluctuated between 15° and 20° C. The Dwarf caiman later lived in my apartment for more than a year in a shallow water-tank under artificial heating (22° to 27° C), but frequently left the water and remained for several days in a dark corner where the temperature varied between 13° and 19° C; he later lived in the tropics again for another year and, finally, died by accident after entering a salt water tank.

Competition as another possible factor in the choice between the two niches on the Apaporis River should also be mentioned: the Spectacled caiman grows considerably larger than the Dwarf caiman (up to 2.25 m as compared with 1.55 m), is gregarious and feeds frequently on smaller crocodilians. Adult specimens do not enter small creeks, possibly they feel insufficiently protected in rather shallow waters; it has been observed with caimans in their natural habitat and in captivity that, as the individual grows bigger, it prefers deeper water. Thus, the Dwarf caiman seems to be well protected in creeks against predation by Caiman sclerops.

Differences between the ecological niches of the two species of Paleosuchus are still poorly understood, but in general terms the following can be said (Medem, 1967):

1) In several river systems or parts of the same river the Smooth-fronted and Dwarf caiman are sympatric.

2) In the case of such co-existence one of the two species is always considerably more abundant.

3) In other rivers and their smaller tributaries, however, only one of the two species was observed.

4) The dorsal side of the Smooth-fronted caiman is covered by a thick growth of dark-green algae which may indicate that it lives in less turbulent and, therefore, also warmer waters than the Dwarf caiman. This is possibly supported by observations in 1969 on the Apaporis River, where several specimens were found living in large stagnant pools in the forest close to a creek.

5) In the Dwarf caiman a thick growth of algae was never observed on individuals collected in their natural habitat; however, it was found on specimens kept in captivity in rather stagnant waters after about four months, even if not as abundantly as on the Smooth-fronted caiman.

6) There exists a difference in respect of the basking habitat: P. trigonatus was never observed to bask at places exposed to bright sun-light, but rather in the shadow close to trees or below underbrush. On the contrary, P. palpebrosus basks in the sun, sometimes on the shore but mainly in shallow waters close to the riverbank. In large rivers it basks on rocks or stone slabs in shallow water, situated near rapids and water-falls, always with its head erected and looking upstream. One might wonder if the shiny black colouration of the dorsal side in adult Dwarf caimans may be caused by the effect of prolonged exposure to ultra-violet rays and, at the same time, serves as a protective layer against them.

7) Specimens of both species kept in captivity in the Institute "Roberto Franco" in Villavicencio since 1967 and 1968, under rather natural conditions, did not change their specific basking habits.

8) A possible competition between the two species certainly exists. As already noted, the Smooth-fronted caiman grows larger than P. palpebrosus and is, moreover, more aggressive, as observed from specimens in captivity. This may explain perhaps the higher degree of abundance of one of the two species in the case of co-existence, and possibly also the apparent total absence of one or other in extensive areas. It must be remembered, however, that the lack of records does not

always mean a species does not occur in the region, but simply that it has not been observed.

Finally, I want to refer to the impact of commercial hide-hunting on two populations of the Spectacled caiman. In 1952, a caiman was collected from the upper Apaporis River, which was later described as a new subspecies Caiman sclerops apaporiensis, distinguished mainly by its narrow and elongated snout from other long-snouted caimans (Medem, 1955). In February 1969, about 74 adult and semi-adult specimens of both sexes were collected on the upper Apaporis in order to carry out studies on certain horse-flies (Tabanidae) which frequently feed on their blood. It was found that many individuals did not clearly belong to the subspecies apaporiensis but rather to a local population from the upper Vaupés River, situated east of the Apaporis. Since hide-hunting had already begun in the Vaupés in 1967, and caimans were scarce in 1968, it may be presumed that the population occurring in this river underwent a 'forced migration' and were displaced from their original habitat. Moreover, many of them escaped by way of the Caño Tacunema and other smaller affluents into the Apaporis, since the headwaters of the Tacunema are situated close to Lake "El Dorado" on the upper Vaupés. The habitat on the Apaporis was, however, already occupied by the native population. The presence of numerous immigrants may have had a certain impact on the local C. s. apaporiensis, the former trying to move into already occupied territories and the latter defending these.

As can be deduced from skull measurements of the adult specimens of the 74 caimans mentioned above, it seems that apaporiensis was present in smaller quantities than those individuals belonging to the population from the Vaupés. Hide-hunting begun in the Apaporis in 1969 and increased considerably in 1970-71; according to recent information the caimans are now so shy that they cannot be harpooned any more but have to be shot.

This means that the natural habitat of the Spectacled caiman of the Apaporis has been effectively disturbed and that their habits have greatly changed within a period of only two years, so that further studies on territorial behaviour and competition between the two populations, within their undisturbed habitats, will be difficult to carry out in the future.

The main conclusions can be summarized thus:

1) In addition to geographic isolation, all crocodilians are definitely affected by ecological isolation.

2) The principal factors for ecological isolation seem to be the presence of swift running, more quiet and even stagnant waters, together with the different temperatures which prevail in each of these niches.

3) Competition between different genera, species and even subspecies and local populations has to be taken into account.

4) The American crocodile Crocodylus acutus occupies different habitats which range from fresh water streams and brackish water zones to true salt water; thus, it once had an ample geographical distribution along the shores of the Atlantic and Pacific Oceans by means of active migration, and was, moreover, also present on several island groups of the Caribbean Sea in Colombia and the Atlantic Ocean in Venezuela, possibly due to passive migration.

5) The Orinoco crocodile Crocodylus intermedius is -- in contrast to acutus -- a true fresh water form and confined to the Orinoco Basin. Occasionally, specimens have been reported from Trinidad, W.I., having apparently arrived from the Delta of Amacuro, as the mouth of the Orinoco is called, by passive migration.

6) The Black caiman Melanosuchus niger is confined to the Amazon Basin.

7) The different subspecies and local populations of the Spectacled caiman Caiman sclerops prefer more quiet waters and, therefore, their ecological niche consists of lakes, ponds, marshes and the bends of large rivers. Active migration, involving movement on foot large distances overland through forests or across plains at night, takes place. Cases of passive migration are also known: in 1961, specimens were collected from Gorgona Island, situated in the Pacific Ocean at a distance of about 15 miles from the mouth of Rio Guapi; according to information, they arrive at the south-western part of that island on floating aquatic vegetation, trees and even on rafts used by the coastal settlers (Medem, 1962).

8) In contrast to the above mentioned crocodilians the ecological niches of the Smooth-footed caiman Paleosuchus trigonatus and the Dwarf caiman P. palpebrosus consists of swift running waters in the tropical rain forests. However, on the Orinoco Plains both species are to be found along rivers and creeks of which the shores are covered by gallery forest. They are also present in most of the streams along the eastern slopes of the Eastern Cordillera. This area is known as the piedmont and does not belong properly to the Plains, having been originally covered by rain forests.

9) There is a slight but still not fully understood difference in the ecological niches of the two Paleosuchus species.

10) The growth of algae on the back of the Smooth-fronted caiman possibly indicates the preference for more quiet and, therefore, warmer waters.

11) Such a layer of algae has, however, never been observed in the Spectacled caiman which definitely prefers slow running or stagnant waters. A particular morphological composition of the hide in the Smooth-fronted caiman may possibly favour the thick growth of algae.

12) Both species of Paleosuchus move rather quickly on the ground and are, therefore, apt to walk large distances through forests or surmount elevated ridges in order to avoid water-falls.

13) The excessive commercial hide-hunting which becomes more pronounced every year has had a strong impact on all crocodilian populations, several of which have now become virtually extinct.

* * *

References

Bates, H.W. 1864. A Naturalist on the River Amazon. Everyman's Library; London & New York.

Medem, F. 1953. Contribuciones a la Taxonomía y Distribución del Yacaré negro, Paleosuchus palpebrosus (Cuvier), en Colombia. Rev. Colomb. Antropología, Vol. 1, No 1.

1955. A new subspecies of Caiman sclerops from Colombia. Fieldiana (Zool.), Vol. 37. Karl P. Schmidt Anniversary Volume.

1958a. Informe sobre Reptiles colombianos (III). Investigaciones sobre la Anatomía craneal, Distribución geográfica y Ecología de Crocodylus intermedius Graves en Colombia. Caldasia, Vol. 8, No 37. Bogotá.

1958b. The Crocodilian Genus Paleosuchus. Fieldiana (Zool.), Vol. 39, No 21. Chicago.

1962. La Distribución geográfica y Ecología de los Crocodylia y Testudinata del Departamento del Chocó. Rev. Acad. Colomb. Ci. Exact., Fis., Nat., Vol. 11, No 14. Bogotá.

1967. El género Paleosuchus en Amazonia. Atas Sympósio Biota Amazonica, Vol. 3 (Limnologia). Rio de Janeiro.

Paper No 17

THE REPRODUCTION OF THE DWARF CAIMAN PALEOSUCHUS PALPEBROSUS

Federico Medem
Instituto "Roberto Franco", Villavicencio (Meta)

No exact data on the reproduction of the Dwarf caiman Paleosuchus palpebrosus existed until recent times. Those given by Medem (1958, 1967) were not based on personal observations but rather on information by Indians or rubber collectors, people possessing great experience with caimans mainly for the reason that they eat them. Donoso-Barros (1966) published the first illustration of a single egg of P. palpebrosus without giving more data. The same author informed me later (in litt. 28 April 1968) that "the egg was found in the cloaca of a female killed by a shot".

The first exact, even if incomplete data were obtained in 1967. On 1 November a nest was detected in the gallery forest, close to a brook, the Caño Pachaquiarito, situated in the region of Peralonzo, a settlement about 50 km SE of Villavicencio in direction to Puerto López, Departamento Meta, Colombia. This nest was investigated on 4 November 1967 and was found to contain 13 eggs. One was later opened and contained an embryo 132 mm in length which was already moving but still not ready to emerge. The remaining eggs hatched between 18 and 29 December 1967, at the Instituto Roberto Franco in Villavicencio (Meta). Since an unpublished paper has been submitted to the Universidad Mayor de San Marcos at Lima, Perú, I will not enter into more details here.

By good fortune a second nest was found on 8 August 1970 by the administrator of a farm who informed me later that it was evidently built the night before. It was investigated on 18 August. It was situated about 6 km W of the settlement of Peralonzo, within a rather dense patch of gallery forest, and constructed on an elevated site, 87 cm above water level, about 3.35 m from the shore of a small brook, known as the Mata Azul. The nesting place was shaded by a tree and scattered underbrush and exposed to sunlight only from 12 00 - 13 00 hrs daily.

In the case of the 1967 nest, the female was not present. The vicinity of the nest was completely clear of leaves and debris; fresh scratches on the ground indicated the possibility that the female had recently returned either in order to amass more nesting material or to lay the eggs. The nest was constructed of a mixture of rotting and green leaves, grass and twigs, and

earth, with green leaves and grass also used as a lining; the indications were that the nest had been built or re-built recently.

The following measurements and temperatures were taken:

Measurements		Temperatures	
Height	490 mm	Environmental	27° C
Width	1463 mm	In nest (at 50 mm depth)	28° C
Depth	465 mm	In nest (at 220 mm depth)	31° C

All caiman nests, so far studied, have contained an 'egg-chamber', situated in the centre; it consists mainly of earth or clay, mixed with rotten leaves and debris; in older nests the earth becomes hardened almost like 'adobe' (unburnt brick dried in the sun, used to construct the walls of huts) and forms a cover which presumably protects the eggs against desiccation, at the same time keeping the temperature more or less constant.

In the 1970 example, the egg-chamber was situated in the centre, about 560 mm from the outer border of the nest and was 100 mm deep and 158 mm wide. The earth and leaves were still not hard, rather wet and sticky. The top layer of eggs were found at 365 mm below the surface of the nest and the lowest eggs 465 mm down. The top layer (really the ones last laid) had been deposited in a circle, while those of the second and third layer were in irregular, some of them in even almost vertical, positions. All eggs were covered by a sticky mucous substance.

There were 13 brittle-shelled oblong eggs, still white in colour. This indicated that they had been recently laid, since older ones are always covered by a thick black layer formed by debris and the excrement of the abundant ground-termites.

Measurements and weight of the eggs are presented in Table 1.

The eggs, together with some nesting material, were later carried to the Institute in Villavicencio and placed in a Terrarium at a depth of 100 mm. The temperature inside the artificial nest fluctuated between 25° and 31° C, the environmental temperature from 23° to 28° C; heat was maintained at night by an electric light bulb; once a week the nest was moistened; the relative humidity of the air was 90% - 96%. The eggs were numbered and marked 1 - 13, beginning with those of the top layer.

Eggs Nos 1 - 11 hatched normally between 5 November at 17 35 hrs and 7 November at 08 15 hrs; the individual in egg No 12 was weak, with still a

Egg	Measurements (mm)	Weights (g)
6	71.5 x 40.0	69.77
4	70.5 x 41.0	69.20
9	69.0 x 41.0	67.25
13	68.5 x 41.5	68.77
1	68.0 x 40.5	65.00
8	68.0 x 40.5	64.20
7	66.0 x 41.0	65.50
10	66.0 x 41.0	64.82
12	66.0 x 40.5	62.50
11	65.0 x 41.0	65.00
2	64.5 x 39.5	57.80
3	63.0 x 41.0	60.25
5	62.0 x 41.5	61.80

Table 1. Eggs of Paleosuchus palpebrosus, 18 August 1970.

Note: Size of eggs: max. 71.5 x 40 and 68.5 x 41.5 mm, min. 62 x 41.5 and 64.5 x 39.5 mm; weights: max. 69.77, min. 61.8 g. Weights do not appear to correspond exactly to the size of eggs.

a pronounced vitelline sack but no egg-caruncle; egg No 13 was rotten and possibly not fertile. These two last eggs came from the bottom of the egg-chamber and were, supposedly, laid first.

The hatchlings emit a loud quacking sound inside the shell; as soon as the egg is lifted they break it by means of movements and the small, triangular egg-caruncle and literally jump out to hide immediately among the debris of the artificial nest. In cases where the egg is not touched or lifted, they remain often for hours inside the shell with the tip of snout sticking out and call from time to time. Several eggs were lifted and the same reaction occurred each time; the others were left untouched and most of the hatchlings had emerged from the shells by next day, but in a few cases still remained inside the shells.

Egg	Total length (mm)	Head-body (mm)	Tail (mm)	Right foreleg (mm)	Left foreleg (mm)	Right hindleg (mm)	Left hindleg (mm)	Weight (g)
8	237	112	125	42	42	54	56	44.70
10	236	111	125	41	40	55	56	46.65
44	235	116	119	40	41	56	53	45.30
11	235	112	123	42	42	59	56	48.60
3	230	140	119	41	41	55	56	45.20
9	228	119	119	41	41	57	55	42.80
1	227	119	118	37	40	54	55	41.20
2	227	116	121	39	40	54	51	39.87
6	226	118	118	41	41	54	52	49.00
5	226	110	116	36	40	53	55	50.00
7	223	107	116	37	39	55	54	40.30

Table 1. Eggs of Paleosuchus palpebrosus, 18 August 1970.

Note: Size of eggs: max. 71.5 x 40 and 68.5 x 41.5 mm; min. 62 x 41.5 and 64.5 x 39.5 mm. Weights: max. 69.77 g; min. 61.8 g. Weights do not appear to correspond exactly to the size of eggs.

The young are covered by a sticky layer of transparent mucous slime which has more or less dried after a day. They remain hidden among the rotting leaves of the nest, but appear from time to time, seeking the artificial light, presumably in order to dry themselves. An individual which was put into shallow water immediately after hatching in 1967 remained weak and died after two days. Evidently recently born P. palpebrosus must stay on the ground until the mucous layer dries completely before entering the water. This they do after approximately two days.

The colours of hatchlings are the same as those of juveniles and adults, with the exception of the cranial table which is yellowish-brown or even yellow in some individuals and later changes to rusty iron colour typical of palpebrosus, in some cases after six or seven months (Medem, 1953). The mandible, somewhat pinkish in adults, is light brown in hatchlings; the dorsum, uniformly black in adults, is covered by black and brown bands in hatchlings and juveniles. It was established for the first time that the incubation period for P. palpebrosus is 90 - 92 days. The hatchlings began to feed on small pieces of chopped up lung on 25 November 1970, i.e. after about 18 - 20 days. They are still doing well (22 February 1971), mostly staying hidden among dry leaves on the ground during daytime and entering the water between 18 00 and 19 00 hrs.

Corresponding to the numbering of the individual eggs, measurements and weight of hatchlings are set out in Table 2.

Discussion and Conclusions

1) Both nests of Paleosuchus palpebrosus were detected at places containing little undergrowth, were close to a tree and exposed to sunlight for several hours a day. This contrasts with the nests of the Spectacled caiman Caiman sclerops (crocodilus), which are situated in the shadow and often among dense underbrush.

2) The females were not present close to the nest and were not even found during the following night in the nearby stream, which is also in contrast to the Spectacled and the Black caimans Melanosuchus niger, both of which protect and defend their nests.

3) It must be presumed that the female has to return in order to dig out the eggs, since it seems quite impossible that the hatchlings would be able to break the hard cover of the egg-chamber; rainfall, which could soften the earth, is infrequent in November-December. The calling from inside the shell before hatching and the reaction of jumping out as soon as the egg is touched or lifted possibly indicate that the mother aids actively in hatching.

4) The hatchlings do not all emerge on the same day; thus the female possibly has to return to the nest several times, stimulated by calls. A similar case is described by Alvarez del Toro (1969) in his excellent paper on Caiman crocodilus ("crocodylus" in the text). On that occasion the male excavated the eggs whilst the female waited in the water, calling for the hatchlings.

5) In contrast to the hatchlings of the Spectacled caiman, those of P. palpebrosus remain hidden among the nest debris for about two days. In the natural habitat recently born or larger juveniles were never observed together with their mother but always on their own in groups of two to four individuals in shallow waters of small streams. Hatchlings of Caiman sclerops, on the contrary, have been observed close to or even on the back of their mother who leads and defends them; on two occasions from four to six juveniles, of about 60 cm in length and therefore at least a year old, have been observed during the day in company with the female.

6) Since Paleosuchus is not gregarious, in contrast to Caiman and Melanosuchus, it seems possible that the female does not protect her brood but leaves them on their own. This, however, would certainly expose them more to predators, among them adults of the same species; and in fact the claws and scutes of juveniles have been found several times among the stomach contents of both Paleosuchus species.

7) Juveniles as well as adults of P. palpebrosus possess a highly protective colouration. The contrast between the yellowish-brown or reddish colour of the head, even more pronounced in the water, and the alternating dark and light bands on the back (shiny black in adults) produces a disruptive effect. Thus, the shape of head and body seems to be 'dissolved' among the different coloured dead leaves, stones and gravel in running water, even at a depth of about 50 cm (Medem, 1958, 1967). The Dwarf caiman generally remains motionless on the bottom and so becomes almost invisible.

8) According to Alvarez del Toro (op. cit.) a Spectacled caiman in captivity laid eggs 15 days after the nest had been constructed. In the present case the incubation period was counted from 18 August, the day on which the nest was first studied. It is not certain, however, if eggs were laid shortly before this date or on or before 8 August, the date on which the nest had been detected by my informant, who on my instructions had not touched it. However, to judge from the white colour of the shells and the green leaves found inside the nest on 18 August, it seems more probable that the eggs were then less than ten days old.

9) In spite of the fact that exact data on the reproduction of palpebrosus are now available for the first time, there still remain many unsolved

problems. This is also true for all the other caimans. For instance, nothing at all is yet known about the reproduction of the Smooth-fronted caiman Paleosuchus trigonatus; eight specimens kept under nearly natural conditions in the Institute since 1968 have for some unknown reason failed to breed.

10) It has become more and more difficult to study the breeding habits of caimans in their natural habitat. Not only have they become scarce due to excessive hide hunting, but they have also retired progressively to less accessible areas. Moreover, their habits have changed: once rather tame and easy to approach, they are now extremely shy and evasive.

Acknowledgements

A grant (No 68-1418) sponsored by the United States Air Force Office of Scientific Research (AFOSR), for which the author wishes to express his sincere gratitude, enabled him to carry out field studies between 1968 and 1970 on the horse-flies (Tabanidae: Diptera), which attack caimans, and led indirectly to the discoveries discussed in this Paper.

References

Alvarez del Toro, Miguel. 1969. Breeding the Spectacled caiman, Caiman crocodylus, at Tuxtla Gutiérrez Zoo. Int. Zoo Yb. Vol. 9. Zool. Soc. Lond.

Donoso-Barros, Roberto. 1966. Contribución al conocimiento de los Cocodrilos de Venezuela. Conclusión. Physis. Vol. 26, No 72.

Medem, Federico. 1953. Contribuciones a la taxonomía y distribución del Yacaré negro, Paleosuchus palpebrosus (Cuvier), en Colombia. Rev. Colomb. Antropol. Vol. 1, No 1. Bogotá.

1958. The Crocodilian genus Paleosuchus. Fieldiana (Zool.), Vol. 39, No 21.

1967. El género "Paleosuchus" en Amazonia. Atas Simpósio Biota Amazônica, Vol. 3 (Limnologia).

Paper No 18

PARENTAL CARE IN THE CROCODILIA, WITH SPECIAL REFERENCE TO CROCODYLUS NILOTICUS

Hugh B. Cott
Selwyn College, Cambridge

Maternal Care during the Incubation Period

Care at the nest

It was well known to writers of the ancient world that the Nile crocodile mounts guard over the nest. Aristotle (trs. Cresswell, 1862) writing in the fourth century B.C., says: "The river crocodile produces as many as 60 eggs, which are white. She sits upon them for 60 days". According to Pliny (trs. Holland, 1601), "The female layeth eggs as big as geese do, and sitteth ever upon them out of the water". Both writers correctly assumed that parental duties devolved upon the mother; and Solinus (trs. Golding, 1587), who writes "In cherishing up their young, the male and female keep their turns", was mistaken in believing that the male of this species takes any share in these duties.

During the whole three-month incubation period, the female remains in attendance, at or near the nest, though her behaviour differs in accordance with the selected site. When the nest is beneath a tree, surrounded by bush or otherwise shaded, the parent generally lies directly on the nest, with the throat or thorax above the egg-chamber. Nests in more open situations are watched from nearby sites affording shade to the guardian crocodile. In Zululand, Pooley (1969a) found nests that were guarded from as many as three additional sites, where shade ranged from light cover to dense tunnels of vegetation from which only the animal's snout protruded. In places where the rookery is fully exposed to insolation, for example on open sand-bars or beaches, brooding females visit the water periodically during the heat of the day, in accordance with requirements of thermal control, discussed elsewhere (Cott, 1961). Such behaviour has been seen at many breeding grounds on the Victoria Nile. On Central Island, Lake Rudolf, Modha (1967) found that even during the hottest hours when other crocodiles were in the water, females were seen on the rookeries: "At intervals they would go down to the water to cool off but were soon out again and lying near the nest".

In some species the female constructs a special shelter from which she can keep watch over the nest. Writing of the Marsh crocodile C. palustris in Ceylon, Waytialingham (1880) states that the females will sometimes go for a quarter to half a mile to find a suitable sandy site for the nest. "They make, first, a large hole for themselves to live in during the day in order to watch their eggs, and then make a small hole near and sometimes at the very mouth of the previous one, and lay eggs in layers ..." He further states that the females will not allow anybody to go near the nests, that they make a fearful roaring and attempt to attack anyone who approaches; and that they keep a strict watch and seldom or never quit the nesting place during the day.

Referring to the Estuarine crocodile C. porosus Loveridge (1946) reports that the mother digs two wallows wider than, but not so long as, her body, close to the nest. These wallows soon fill with water, and in one or the other the crocodile remains during the period of incubation. The female of the American alligator A. mississippiensis similarly constructs a nest-side wallow or den from which the nest can be guarded during the incubation period (Clarke, 1888; Reese, 1907).

Predatory enemies of the eggs

Egg-eating predators take a heavy toll of unguarded clutches, both by day and night. On the Victoria Nile below Murchison Falls important diurnal predators include the Olive baboon Papio anubis, Marabou stork Leptoptilos crumeniferus and Nile monitor Varanus niloticus; with Black kites Milvus migrans and Palmnut vultures Gypohierax angolensis as camp-followers. At night the work is taken over by the Honey badger Mellivora capensis, White-tailed mongoose Ichneumia albicauda and Spotted hyaena Crocuta crocuta; and less commonly by serval Felis serval (Cott, 1969). Mammalian enemies in other parts of Africa include the Egyptian mongoose Herpestes ichneumon in Egypt (Anderson, 1898); and Water mongoose Atilax paludinosus in South Africa (Stevenson-Hamilton, 1954). In Lake Rudolf (Modha, 1967) Grey heron Ardea cinerea, Goliath heron A. goliath and Sacred ibis Threskiornis aethiopicus are known to prey on the eggs.

Other crocodilian species have different, though often related, nest enemies. Thus, in Colombia, eggs of the Orinoco crocodile C. intermedius are eaten by the Great tegu Tupinambis teguixin and by the South American Black vulture Coragyps atratus (Medem, 1958b). In North Australia, eggs of C. porosus are rooted out and eaten by Wild pigs (Barrett, 1939), just as those of C. niloticus are destroyed in West Africa by warthog Phacochoerus aethiopicus and Bush-pig Potamochoerus porcus (Lavauden, 1934). Again, in Ceylon, the kaberagoya Varanus salvator fills the niche, occupied by V. niloticus in Africa, as an enemy of C. porosus (Deraniyagala, 1939).

Active defence of the clutch

The need for nest-protection is apparent enough. The question remains: do the attendant crocodiles actively defend the clutches when they are threatened by predators? Here it is necessary to distinguish between the behaviour of the reptiles in a natural undisturbed state, on the one hand and, on the other, in areas where they have been harried and hunted and have in consequence learned to fear man. Observations made under the latter conditions -- of crocodiles readily deserting the rookery and failing to drive away marauders -- may give a false picture of primeval nesting behaviour.

I have on several occasions seen nesting crocodiles make sorties against predators. In 1961, while observing a rookery near the Namsika confluent below Murchison Falls at close range from a grass hide, I witnessed a determined attack: a crocodile that had been lying about 15 yards from, and facing the hide suddenly rose up and ran straight in my direction. When it reached the front of the hide -- and as I was preparing to leave -- there was a rustle of dead leaves and I caught a glimpse of a Nile monitor in rapid retreat. Crocodiles that have been frightened from their nests by launches passing the grounds have on a number of occasions been seen to return to the rookery to chase away a foraging monitor or baboon. The presence of monitors in crocodiles' stomachs, as recorded elsewhere (Cott, 1961), indicates that these egg thieves are sometimes taken unawares.

Opportunities for observing crocodiles in the pristine state are diminishing, and Modha's (1967) prolonged studies at Central Island, Lake Rudolf, on what is one of the largest remaining undisturbed populations of the Nile crocodile, are therefore of special interest. He found that guardian females never tolerated the presence on the rookeries of predatory birds such as Grey and Goliath heron, Little and Great White egret, Sacred ibis and Fan-tailed raven. Crocodiles were seen chasing these birds away from the nests. On the other hand, innocuous species which regularly frequent the grounds, such as Egyptian goose, Spurwing plover and Water dikkop, were ignored.

The literature contains several accounts of attacks upon man by nesting crocodiles -- notably by C. porosus, which is generally believed to be the most dangerous crocodilian. Boake (1870) records that a man who was taking eggs from a nest of this species in Ceylon was repeatedly charged by the guardian crocodile and on being attacked by a second individual at the nest was lucky to escape alive. Shelford (1916) refers to an exciting struggle between a party of hunters and a large female crocodile defending its nest on the Baram River in Borneo. A spirited assault upon himself by C. porosus nesting in a pond near Townsville, Queensland, is described by Robinson (1948): "When I was taking the debris away from the nest she charged at me with open mouth and drove me into the boat. One second later and I would have been in her jaws. She came right out of the water and on to the nest, in clear view of the crowd looking on, and only for my having a long stick to jab

into her mouth I believe she would have come into the boat". From the Llanos Orientales, Colombia, Medem (1958a) reports that a Dwarf caiman Paleosuchus palpebrosus attacked a hunter when he approached the nest containing eggs. Del Toro (1969) gives details of nest defence by both male and female Spectacled caiman Caiman crocodilus breeding in captivity. Both parents remained near the nest, not allowing the keeper or anyone else to approach: and it is interesting to note that in this case it was the male who took the main defensive role.

Comatose state in brooding females

Little is known of the night life of females during the incubation period. The crocodile is nocturnally aquatic: yet females are certainly found occupying the grounds at night. However, no all-night observations on particular individuals have been made, and we do not know to what extend an all-night vigil is maintained. In lake- or river-side rookeries it may happen that brooding females take advantage of the nearby water to feed for short periods. Nevertheless, available evidence suggests that females fast throughout the incubation period. Hippel, a professional hunter who had wide experience 25 years ago in the Lower Semliki and in Lake Kioga, and who made a study of the diet of his victims (1946), told me (pers. comm. 1952) he had never found food in stomachs of females taken at the nest. Pitman's (1930) experience was similar on the islands and shores of northern Lake Victoria. Stomachs of brooding females examined by me were likewise empty.

Where cover is dense on a crocodile's breeding ground, and especially where the site is at a distance from the water, the reptiles are very loath to move from their nests. In such places, as incubation proceeds, females are frequently found in a comatose state, unwilling to shift even under the greatest provocation. Pitman (1941) reported from Lake Victoria that shots have been fired close to such crocodiles without evoking the slightest response. In 1957, I examined a rookery in a sand-river below Murchison Falls where some nests were nearly a quarter of a mile from the water. Females in their trance-like state lay motionless, like felled logs: one refused to move even when large stones were thrown on her back; others hissed their remonstrance and shifted a few feet into thicker cover. Similar behaviour has been witnessed by Pooley (1969a) in Zululand. He writes: "One female at St Lucia withstood a barrage of sticks thrown at her, adopting an attitude of defiance during the attempt to chase her off the nest. She lay with head held almost vertical, jaws slightly agape, uttering a deep throaty growl each time a missile landed nearby or actually hit her. Our attempts to dislodge her failed".

It seems almost certain that such crocodiles remain on the rookery until hatching time, without once visiting the water. The physiological condition

of these animals, especially in regard to dehydration, is doubtless comparable to that of torpid crocodiles which, under different circumstances, are known to survive long periods of drought, aestivating in caves and holes dug in dry pans or river-beds. Many observers have recorded such behaviour, as, for example, from Lake Rukwa (Swynnerton and Nicholson, in Cott, 1961); Abyssinia (Emin Pasha, 1890); Somaliland (Eliot, 1905); West Nile Province of Uganda (Kittenberger, 1929); and Mali (Lhote, 1948): the latter states that crocodiles inhabiting a temporary lake near Ménaka spend at least six months of the year aestivating in the mud after the lake has dried up.

Parental Care at Hatching Time

Calling of the young

When ready to hatch the young respond to airborne sounds and to terrestrial vibration by calling. Under artificial conditions -- if, for instance, eggs are stored in boxes indoors -- the human voice, a tape recording of a hatchling's grunt, the slamming of a door, or the shaking of an egg in the hand, will elicit the vocal response; and when one hatchling calls others may join in the chorus. In the field, a pat of the palm above the nest will stimulate calling, and this reaction provides a ready means of ascertaining the time when hatching is due. Under natural conditions the step of the mother or the sweep of her tail near the nest will doubtless have a similar effect. Hunt (1969) reports a like response in hatchlings of the Spectacled caiman: when he lightly brushed the roof of the nest so as to simulate a mother crawling on the ground, croaking was heard.

Maternal reaction to vocalization

The sounds uttered by the unhatched young stimulate the guardian parent to visit the nest and open it, thus enabling the hatchlings to escape from the shells. Experiments to test the female's response to a tape recording of the cries of unhatched crocodiles were carried out on different rookeries below Murchison Falls in 1968 and 1969. At one site the recorder was concealed in an observation hide. The female that had been floating off shore when the recorded was switched on, soon submerged and promptly surfaced at the bank and climbed up towards the hide without hesitation. On another occasion when the recorder was hidden in grass on a sand-bar close to several nests, three crocodiles swam towards the sound. One of them hauled out and came to rest just short of the playing recorder. Modha (1967) had previously

obtained generally similar results on Lake Rudolf. There is, then, no doubt that the croaking of the unhatched brood does alert, and attract, the nesting mother to her brood.

Exhumation of the eggs

It is well known that the female unearths the eggs at hatching time, but details of the process have rarely been observed. Examination of nests that have been opened by the parent shows that alternative methods may be used, according to the situation of the nest. Normally, and where the brood-chamber is covered with hard, firm earth, the crocodile lies with her snout near the nest, and digs down to the eggs with the fore-limbs. At such nest sites one can often clearly see a platform, wedge-shaped in front where the throat had rested, with a trench on each side made by the fore-limbs, with two heaps of excavated spoil that had been thrown back beside the body, and claw-marks left in the wall of the egg-chamber.

On the other hand, where nests are in loose dry sand, liable to cave-in during excavation, the female scoops out a hollow from above the eggs with her body. Mr L.J. Sim, a crocodile hunter in Tanzania, informed me (pers. comm.; 13 March 1958) that just before sunset on 30 January 1956, he saw a crocodile wriggling and squirming on a bare patch of river-bank. On reaching the spot he heard the young croaking from beneath the shallow rimmed crater thus formed. An African assistant told Sim that he had witnessed the same method of liberation, and he was most insistent that the crocodile's feet were not used. This method is certainly consistent with the appearance of shallow basin-like excavations -- some over four yards (3.70 m) in diameter -- such as I found in 1952, in two colonial rookeries at the south end of Lake Albert (Cott, 1961). Loveridge (1953) saw similar crater-like excavations on dune-sand near Mtimbuka, Nyasaland; and a photograph by Adamson (1955) illustrates a rookery of nest-craters on Lake Rudolf sands.

At hatching time the young are absolutely dependent upon maternal assistance. The eggs are covered by many inches of earth: in some soils, such as loamy clay which packs hard, a man would have to use a panga (machete) to chip the covering away and there is no question of the hatchlings escaping unaided. Unless the parent is at hand to expose the eggs, the young perish in the shell. In the course of surveys carried out below Murchison Falls in 1968 and 1969, when some 350 nests were under observation, I have no record of hatching except from nests that had first been excavated. Modha (1967) made similar observations on Lake Rudolf: he reports that from not one of 150 nests had any hatchlings managed to escape without maternal help. In cases where the female fails to revisit her croaking young, the subterranean chorus may continue for four or five days. When the release is overdue, the surviving hatchlings burst the shell and emerge almost

explosively immediately the eggs are unearthed, though a moment before the shells were not even chipped.

Release of the hatchlings

The remarkable determination of the female to reach and liberate her young has been observed on a number of occasions. This was first demonstrated experimentally by Voeltzkow (in Gadow, 1901), who had a nest surrounded with a fence. When the mother had returned several times and partly destroyed the fence, this was replaced by a stronger one. The mother then dug a deep ditch beneath the fence in her efforts to reach the nest. In Zululand, Pooley (1969a) isolated a nest with a structure of stout poles 15 cm in diameter, supporting an 8-gauge wire fence, the latter firmly bound with sacking, and the nest roofed over with the same material. At hatching time the parent was found to have smashed her way through the barrier and to have opened the nest. Pooley (1969b) also reports that screens of heavy wire mesh, laid over nests to protect clutches from predators, were easily displaced by the parent at hatching time, some of the screens being found 3 m from the nest in a twisted heap of wire and pegs. Jones (in Cansdale, 1955) records that in the Bonthe District of Sierra Leone a nest was first discovered in a rest house only when the adult came one night to dig it oug.

Whether, in the field, the female assists her offspring in the actual hatching process is not known. But recent observations on crocodilians in captivity suggest that it may be so. Hadley (1969) has described hatchings witnessed by him in Livingstone Game Park in 1966. Having dug her eggs from the ground, the mother C. niloticus "carried three or four of them at a time to the water. They were held very lightly in her mouth and she moved her head from side to side slowly in the water as though washing the eggs. She then applied pressure to the eggs and cracked them. One young crocodile emerged from the egg and swam out of her mouth, and a second dropped to the bottom of the pool and shortly afterwards the young crocodile surfaced. This I witnessed twice".

Even more surprising is the parental care of the Spectacled caiman, witnessed at Tuxtla Gutierrez Zoo and described by del Toro (1969). "After 70 days of incubation ... the male started to break the nest, scratching at it with his hind legs and tossing mouthfuls aside ... Now something very unexpected happened: the male rolled over several of the eggs, crushing them with his hind legs and tail until the young were free. He also took hold of several eggs with his teeth, one at a time, and crushed the shell carefully till the young could escape". The female stayed in the water while this was happening, called to the young, and took them around the pool "just as a hen takes her chicks around the yard".

In the light of these observations, the comment by Vansleb, who wrote of the Nile crocodile in 1678, is of interest. He states that at hatching time the female "then goes and opens the hole and breaks the shell with its Musle for the young to creep out".

Post Natal Maternal Care

Early reactions of hatchlings

Observations on clutches of eggs excavated at hatching time show that, as soon as they have broken out of the shell, hatchlings tend to make for a near-by object affording shade and shelter. For example, when in 1968 at Murchison Falls I placed a crude dummy of a crocodile a few yards from eggs that were about to hatch, most of the young, on emergence, made their way to the dummy, some immediately, eagerly and at a run, dragging the umbilical cord and still-attached shell behind them, and took cover beneath the lower jaw and along the flanks of their 'mother'. When in 1969 my African assistant lay down motionless close to an excavated clutch, he likewise became a centre of attraction, and soon had many baby crocodiles sheltering under his chin, arms and sides.

Transit from nest to nursery

This behaviour raises the questions: how do the emergent young react to the presence of the female in a wild state; and what part does the female play at this phase of the breeding cycle? Transit from nest to nursery has never been witnessed. Whether the young are conducted, or carried from the one to the other, is not yet certainly known.

Factors favourable for the nursery site are shallow, confined or still water, with for cover plentiful marginal or floating vegetation such as Pistia stratioides, Cyperus articulatus or Leersia hexandra. The site may be in the lee of a fallen tree, in a creek leading from the main body of water, or inland in a shallow mere. Such nurseries can often only be reached by travel of several hundred yards across country, and in a direction away from the waterside rookery.

As to how the journey is accomplished, accounts vary. An early observation is given by Goldsmith (1805) who states that on being set free the brood "quickly avail themselves of their liberty; a part run unguided to the water; another part ascend the back of the female, and are carried thither

in greater safety". Young have been seen on a number of occasions following the parent. Thus, in Madagascar, Voeltzkov (1899) was reliably informed by his taxidermist that he had seen a large crocodile with a tribe of about twenty young ones travelling over a stretch of sand to the water: the parent was in an excited state -- "Das alte Tier sei auffällig wild gewesen". In Basotseland, Livingstone (1865) was told by his companions that the female leads her brood to the water. Mr F. Wilson (pers. comm., 1952) once saw a crocodile with a brood of newly-hatched young sunning on a bank in Lake Victoria: on being disturbed the parent went into the water, followed by her hatchlings.

With other species, the parent-offspring relationship appears to be similar. In his account of a primeval nesting ground of A. mississippiensis on St John River in northern Florida, Bartram (1792) frequently saw the female "leading about the shore her train of young ones". One alligator which passed close to the side of his boat had young following after her: "they kept close together in a column, without straggling off to the one side or the other". Mitchell (in Kellog, 1929) states that the mother on watch calls the hatchlings to her den, which then becomes their home.

There are other records which suggest that the female may sometimes carry her brood to their new quarters. Chadwick (1931), who witnessed a hatching, states that as each young one crawled from the shell "it swarmed upon the mother and clung to her". In Nigeria, Lamborn (1913) was informed by natives that the young crocodiles, immediately after hatching, attach themselves to the dorsal fringe of the tail of the mother and are thus conveyed by her to the water. Mr J.L. Sim (pers. comm., 13 March 1958) was given similar information in Tanzania: "when the young emerge, they mount the back of the mother, and as soon as it is dark, she transports them through shallow water to a patch of reeds". In Lake Rudolf, Modha (1967) was told by natives that the young are carried to the water on the snout, neck and back of the female. A launch coxwain with long experience of the Victoria Nile at Paraa assured me that in 1967, he personally saw a crocodile on land transporting hatchlings on its back. Similar behaviour has been recorded of the American crocodile C. acutus (Ulloa, in Brehm, 1885). Once established in the nursery site, the young -- over a period of several weeks -- constantly clamber on to their parent's head and back as she lies half-submerged: this I have witnessed and photographed at close range on many occasions in Uganda.

Predatory enemies of the young

Unguarded hatchlings, like the eggs, are very vulnerable and are preyed upon by many enemies. In the Victoria Nile these are known to include Nile monitor, Great White egret Casmerodius albus, marabou, Saddle-bill stork

Ephippiorhynchus senegalensis, Fish eagle Cuncuma vocifer, Black kite, Ground hornbill Bucorvus leadbeateri and African civet Viverra civetta (Cott, 1968). Records of other species that prey upon hatchlings are: in Egypt (formerly) Egyptian mongoose Herpestes ichneumon and Soft-shelled turtle Trionyx triunguis (Anderson, 1898); on Lake Rudolf, pelican, Sacred ibis, Pied crow Corvus albus and the catfish Clarias lazera (Modha, 1967 and pers. comm.); and in Zululand, Goliath and Grey heron, Little egret Egretta garzetta, Spotted eagle owl Bubo africanus and Rusty-spotted genet Genetta tigrina (Pooley, 1969a).

The situation is closely similar for hatchlings of other crocodilian species. For example, of the American alligator Le Buff (1957) records otters, skunks, raccoons, large wading birds, turtles, snakes and other alligators as enemies. Audubon (1827) referred to White ibis Guara alba (= Eudocimus albus) and Sand-hill crane Grus canadensis as eaters of the young. The American bullfrog Rana catesbiana has the same habit (Wettstein, 1954).

Maternal defence of the young

The female in charge of her brood becomes an aggressive and dangerous animal -- alert and ready to attack any adversary, both by day and night. During two seasons' work on the Victoria Nile I witnessed defensive behaviour on many occasions. The female at one nursery was seen to make a tremendous leap out of the water and over a fallen tree trunk, to drive away a Vervet monkey that had come down to drink. When we approached another nursery that was sited in a creek forty yards (37 m) from the river, the female on more than one occasion came directly for the boat, porpoising and threshing the water with its tail. At a riverside nursery the female unobtrusively submerged, coming up beneath the patrol-launch and striking it a tremendous blow with its head. A fourth female guarding her brood in a ditch was unusually bold: during days of observation this animal made repeated attacks whenever I approached her closely -- hissing, growling, and making lunges, jaws agape, with incredible agility. Seen at point-blank range, such demonstrations are most impressive.

Descourtilz (1809) has an account of C. acutus making a determined attack on two men when surprised at her nest. Dharmakumarsinji (1947) who watched a female Marsh crocodile for a whole day "maintaining a scrupulous guard" over her newly-hatched young, writes: "I saw this crocodile rush out of the water, at least a dozen times, to drive away Black-necked storks Xenorhynchus, herons Ardea and large white egrets Egretta when they ventured to alight near the young which were lying helpless at the water's edge". The crocodile was afterwards shot and confirmed to be a female. Neill (1946) relates that the calling of a juvenile C. novae-guineae that had

been caught by hand at night, provoked the adult into charging savagely in the direction of the sound. Hartwig (1873) described an attack made under somewhat similar circumstances upon Richard Schomburgk by Melanosuchus niger on the Essequibo: "The mother, a creature of prodigeous size, suddenly emerged with an appalling roar, making desperate efforts to reach her wriggling and screeching offspring ... Having been wounded with an arrow, she retired for a few moments, and then again returned with redoubled fury, lashing the waters into foam by the repeated strokes of her tail". McIlhenny (1934) relates how a female American alligator had to be restrained from attacking him when he was handling her young at a nest on Avery Island, Louisiana.

Recent observations have shown that the young remain gregariously with the mother for several weeks, learning to feed and fend for themselves while under close maternal supervision. Thus, on 8 April 1969, a female with her brood was found occupying a waterhole in a narrow ditch opposite Paraa. The hatching date of the clutch was not known. Subsequently this nursery was under observation, at first daily, and later at intervals of a few days. The mother crocodile continued to guard her hatchlings until 28 June -- the last date she was seen in the nursery. Her duties had extended over at least 81 days -- a period about equal to the incubation period. In other words, it appears that for about six months in the year the breeding female is continuously engaged in pre-natal and post-natal care.

Knowledge of the vital part which parental care plays in the successful rearing of offspring has important implications in the field of management and conservation. Disturbance of females on the nesting grounds causes high mortality both through hatching failure and predation. Protection from interference during the successive phases of the reproductive cycle is therefore essential for recruitment and long-term survival of the population (Cott, 1968, 1969).

References

Adamson, Joy. 1956. The Island of No Return. Country Life 1040-2.

Anderson, John. 1898. Zoology of Egypt. I. Reptilia and Batrachia. London: Bernard Quaritch.

Audubon, J.J. 1827. Observations on the Natural History of the Alligator. Edinburgh new Phil. Journ. 2: 270-280.

Barrett, Charles. 1939. Koonwarra: A Naturalist's Adventures in Australia. London: Oxford University Press.

Bartram, William. 1792. Travels through East and West Florida. Philadelphia: James and Johnson.

Boake, Bancroft. 1870. The Nest of the Crocodile. Zoologist (2)5: 2002-4.

Brehm, A.E. 1885. Merveilles de la Nature. Les Reptiles et les Batraciens. Ed. E. Sauvage. Paris: Lib. Baillière.

Buff, Charles R. le. 1957. Observations on captive and wild North American Crocodilians. Herpetologia, 13: 25-8.

Chadwick, W.S. 1931. Hunters and the Hunted: some Glimpses of Man and Beast in the African Bush. London: H.F. and G. Witherby.

Clarke, S.F. 1888. The Nest and Eggs of the Alligator: A. Lucius Cuv. Zoo. Anz. 11: No 290: 568-70.

Cott, Hugh B. 1961. Scientific Results of an Inquiry into the Ecology and Economic Status of the Nile Crocodile (Crocodilus niloticus) in Uganda and Northern Rhodesia. Trans. zool. Soc. London, 29: 211-358.

1968. The Status of the Nile Crocodile below Murchison Falls. IUCN Bulletin, N.S. 2(8): 62-64.

1969. Tourists and Crocodiles in Uganda. Oryx, 10(3): 153-60.

Cresswell, Richard. 1862. Aristotle's History of Animals. London: Bohn.

Deraniyagala, P.E.P. 1939. The Tetrapod Reptiles of Ceylon. Colombo: Dulau Co.

Descourtilz, M.E. 1809. Voyages d'un Naturaliste, et ses Observations. Paris: Dufart père, Lib. 3: 71-92.

Dharmakumarsingi, K.S. 1947. Mating and the Parental Instinct of the Marsh Crocodile (C. palustris Lesson). J. Bombay Nat. Hist. Soc. 47: 174-76.

Eliot, Charles. 1905. The East Africa Protectorate. Edward Arnold.

Emin Pasha und Stuhlmann, F. 1890. Zur Biologie des afrikanischen Krokodile. Zool. Jahrb. Syst. 5: 546-8.

Gadow, Hans. 1901. Amphibia and Reptiles. London: Macmillan.

Golding, Arthur. 1587. The excellent and pleasant works of Julius Solinus. London: Thomas Hacket.

Goldsmith, Oliver. 1805. A History of the Earth and animated Nature. V. London.

Hadley, D. 1969. Breeding of Crocodile in Livingstone Game Park. The Puku, No 5: 226-8

Hartwig, G. 1873. The Tropical World: Aspects of Man and Nature in Equatorial Regions of the Globe. London: Longmans, Green.

Hippel, E.V. 1946. Stomach Contents of Crocodiles. Uganda J. 10: 148-9.

Holland. 1601. The Historie of the World. Commonly called the Naturall Historie of C. Plinius Secundus. London.

Hunt, R. Howard. 1969. Breeding of Spectacled caiman Caiman c. crocodylus at Atlanta Zoo. Int. Zoo Yb. 9: 36-7.

Kellog, R. 1929. The Habits and Economic Importance of Alligators. U.S. Dept Agr., Washington, Tech. Bull. 147: 1-36.

Kittenberger, Kálmán. 1929. Big Game Hunting and Collecting in East Africa. 1903-1926. London: Edward Arnold.

Lamborn, W.A. 1913. Notes on Habits of certain Reptiles in the Lagos District. Proc.Zool.Soc.London, 1913: 218-24.

Lavauden, Louis. 1934. Les grands animaux de chasse de l'Afrique Française. XII. Crocodiles. Fauna Colon. Franc., Paris, 5: 472-7.

Lhote, Henri. 1948. Au sujet des tanières à crocodiles des falaises nigériennes et quelques observations biologiques sur le crocodile. Notes Africaines, Dakar, 40: 1-2.

Livingstone, David & Livingstone Charles. 1865. Narrative of an Expedition to the Zambesi and its Tributaries. London: John Murray.

Loveridge, Arthur. 1946. Reptiles of the Pacific World. New York: Macmillan.

1953. Zoological Results of a fifth Expedition to East Africa: Reptiles from Nyasaland and Tete. Bull. Mus. comp. Zool. Harvard, 110(3): 143-322.

McIlhenny, E.A. 1934. Notes on Incubation and Growth of Alligators. Copeia, 1934: 80-88.

Medem, Federico J. 1958a. The Crocodilian genus Paleosuchus. Fieldiana, Zool. (Chicago Nat. Hist. Mus.) 39: 227-47.

1958b. Informe sobre Reptiles Colombianos. III Investigaciones sobre la Anatomia craneal, Distribucion Geografica y Ecologia de Crocodylus intermedius (Graves) en Colombia. Caldasia, 8(37): 175-215.

Modha, M.L. 1967. The Ecology of the Nile crocodile (Crocodylus niloticus Laurenti) on Central Island, Lake Rudolf. E. Afr. Wildlife J., 5: 74-95.

Neill, W.T. 1946. Notes on Crocodylus novae-guineae. Copeia, 1946: 17-20.

Pitman, C.R.S. 1930. Ann. Rep. Game Dept, Entebbe.

1941. About Crocodiles. Uganda J., 8: 84-114.

Pooley, A.C. 1969a. Preliminary Studies on the Breeding of the Nile Crocodile Crocodylus niloticus, in Zululand. The Lammergeyer, 3(10): 22-44.

1969b. Some Observations on the Rearing of Crocodiles. The Lammergeyer, 3(10): 45-57.

Reese, Albert M. 1907. The Breeding Habits of the Florida Alligator. Smiths. Misc. Coll., 48: 381-7.

Robinson, St.J. 1948. The Crocodile at the Nest. North Queensland Nat. Cairns, 16(88): 3-4.

Shelford, Robert W.C. 1916. A Naturalist in Borneo. London: Fisher Unwin.

Stevenson-Hamilton, J. 1954. Wild Life in South Africa. London: Cassell.

Toro, Miguel Alvarez del. 1969. Breeding the Spectacled caiman Caiman crocodylus at Tuxtla Gutierrez Zoo. Int. Zoo Yb. 9: 35-6.

Vansleb, F. 1678. The Present State of Egypt. London: John Starkey.

Voeltzkow, A. 1899. Beiträge zur Entwicklungsgeschichte der Reptilien. Biologie und Entwicklung der äusseren Körperform von Crocodilus madagascariensis Grand. Abh. Senck. Naturf. Gesell., 26: 1-150.

Waytialingham, S. 1880. Notes on the Breeding of C. palustris. Proc. zool. Soc. London, 1880: 186-7.

Wettstein, O. v. 1954. Sauropsida: Allgemeines -- Reptilia. In Kükenthal, Handbuch der Zoologie, 7: 321-424. Berlin: Walter de Gruyter.

Paper No 19

THE SENSES OF CROCODILIANS

A. d'A. Bellairs
St Mary's Hospital Medical School, London

Introduction

Crocodilians, like most active predators, are alert animals, well endowed with sensory equipment, and for their zoological station in life seemingly intelligent in the sense of being able to profit from experience. There is, however, little evidence that their brain structure is more advanced than that of reptiles in general (Goldby & Gamble, 1957).

On the behavioural side, it seems likely that the nesting habits and faculty for maternal care of eggs and newly hatched young are more complex in crocodilians than in other reptiles (Cott, 1961, and in these Proceedings). Reliable field accounts indicate that crocodiles show considerable cunning in stalking and capturing their prey; for example, Cott writes that "adult crocodiles often lurk off-shore near game trails and watering places. On sighting an animal that has come down to drink, the reptile quietly submerges, and cruises under water to the precise spot from which it can make its fatal upward rush". When ambushing prey a crocodile may use its tail to give a disabling blow, or to throw the victim into the water. I have heard it suggested that crocodiles may co-operate in driving fish into the shallows where they are easier to catch, but am uncertain how much truth there is in the idea.

It is well known that crocodiles become increasingly wary in places where where they are extensively hunted. This applies even to nocturnal hunting; the reptiles become 'light-shy' and can no longer be easily approached in the water when a light is shone at their eyes. The ability of the animals to learn very quickly to avoid enemies has been demonstrated by Bustard (1968), who studied a wild population of young, previously undisturbed Crocodylus porosus in an isolated lake in eastern Papua. On the first night when the lake was visited it was possible to approach 11 individuals on the surface and to capture five by hand. On the second night a further ten animals were approached but it was only possible to catch one; on a further patrol an hour later eight specimens were seen but only one permitted close approach and none at all were caught. The captured crocodiles were kept until the end of the investigations.

Despite the fact that many species of crocodilians can be kept fairly easily in captivity and are suitable for certain types of experimental study (Coulson & Hernandez, 1964), no laboratory investigations of their learning ability (as, for example, to learn their way through a maze) or powers of memory appear to have been undertaken. There has been a similar lack of study of their sensory physiology, except perhaps where hearing is concerned, and for the most part our knowledge of their senses is based on the inferences which can be drawn from anatomical structure. This is basically similar in all the 23 or so existing species of this very conservative group.

The Nose and Sense of Smell

The nasal passages of crocodilians show various specializations which will be briefly described, although they seem to be primarily associated with the peculiar type of amphibious predatory mode of life which these animals pursue, rather than directly with the sense of smell. The nostril openings, like the eyes, face upwards and are situated on an elevation at the front of the snout (see Fig. 1A). Each nostril has the shape of a crescentic slit, concave posteriorly, and is opened and closed by a pair of muscles which seem unique to crocodilians. Opening of the nostril is effected by the contraction of a muscle with longitudinal fibres attached to the posterior wall of the bony external nasal opening. The nostril is closed mainly by a circular muscle whose fibres surround the longitudinal muscle like a sleeve. When this contracts it squeezes the longitudinal muscle like a piston against the back of the nostril, closing the aperture. These muscles are of unstriped character and are innervated by the sympathetic nervous system (Bellairs & Shute, 1953). Cavernous tissue, consisting of blood vessels which can be dilated and press against the walls of the nasal vestibule, provides an ancillary method of narial closure. This type of mechanism is found also in certain aquatic chelonians and in desert lizards, both of which lack the more specialized crocodilian narial muscles. In terrestrial forms it helps to keep sand out of the nose.

Each external nostril of the crocodile leads downwards into a short tube or vestibule which opens in turn into the main nasal chamber or cavum proprium nasi. This chamber is more complicated than the corresponding part of the nose in other reptiles. Medially, of course, it is bounded by the nasal septum, which separates it from its fellow of the opposite side. On the lateral wall there are no less than three projections or conchae which bulge out into the basal cavity; they are composed of cartilage covered by mucous membrane. From front to back these projections are called the preconcha, concha and postconcha (see Fig. 1B). In other existing reptiles only a single conchal projection is usually present. Membrane-lined recesses or

paranasal sinuses open into the nasal cavity on either side, while the naso-lachrymal duct enters the nose beneath the posterior part of the preconcha (Parsons, 1970).

The long nasopharyngal tube begins beneath and behind the preconcha and passes posteriorly to open near the back of the skull; in its course it is invested by various bones, i.e. the palatines, vomers and pterygoids; the internal narial openings traverse the pterygoids in the bony palate. The significance of this arrangement is, of course, well known. The internal narial opening is guarded by two flaps of soft tissue, one extending downward from the palate and the other projecting upwards behind the tongue (see Fig. 1B). This latter flap can be thrust upwards by muscular action and, together with the palatal flap forms a kind of valve which prevents water from entering the trachea when the jaws are open. Consequently the crocodile is able to drown its prey without taking water into its own respiratory passage.

Only a part of the nasal cavity is lined by sensory epithelium containing olfactory cells with hair-like processes or cilia; the olfactory nerves arise from these cells, become collected into bundles and pass back to the olfactory bulbs of the fore-brain. This olfactory epithelium is restricted in crocodiles to the posterior and dorsal part of the cavum proprium, and to the dorsal parts of some of the paranasal sinuses. The rest of the nose is lined with epithelium of non-sensory, 'respiratory' type.

It is clear that the olfactory organs of crocodilians are by reptilian standards well developed, although the organ of Jacobson (a specialized and more or less separate olfactory organ which is of great importance in lizards and snakes) is absent, disappearing during embryonic life. The importance of smell in the life of crocodilians is suggested by the presence of two pairs of large musk glands, one beneath the throat on either side, the other just within the cloaca. These are said to be particularly active in the breeding season and Gadow (1901) suggests that the sexes are able to find each other by following scent trails in the water. As a rule, however, the nostrils appear to be closed when the snout is submerged and it is possible that the animals cannot smell under water.

It also seems likely that crocodilians rely on their sense of smell to locate prey, and in particular, carrion. They readily assemble, especially at night, to feed on a carcass, even when this is some distance from the water (Cott, 1961). It should not be difficult to devise experiments on captive animals which throw some light on their olfactory powers.

Eyes and Vision

The eyes of crocodilians are relatively large and possess the usual reptilian

complement of accessory structures: upper and lower eyelids (the former being supported by a distinct supraorbital bone), a well developed nictitating membrane with its own musculature, and lachrymal and Harderian glands discharging into the conjunctival space. In many species the eye colour is greenish-yellow, but in Osteolaemus it is a dark, liquid brown. Crocodilians have some degree of binocular vision, the fields of the two eyes overlapping by some 25°.

Although crocodiles are often active in the daytime and bask at certain times of the day, many features of their eyes suggest adaptation to nocturnal habits (Walls, 1942; Underwood, 1970). For example, the scleral ossicles present in most reptiles (other than snakes) and in birds are absent, though they were present in certain extinct crocodilians. These little plates of bone apparently play an important part in the typical sauropsid method of accommodation. They help to maintain the inward convexity of the corneo-scleral junction and hence facilitate the exertion of pressure on the lens by the ciliary body; this results in increasing the lens curvature in a manner appropriate for close vision. It is generally believed that crocodilians have only poor powers of accommodation so that images of objects close to them are necessarily crude. Moreover, their eyes appear to be correctly focussed for distance vision in air, and it is very unlikely that they can accommodate sufficiently well to see with any precision under water, with its different refractive index (Walls, 1942; Tansley, 1965).

The retina is duplex, containing both rods and cones (see Fig. 2). The rods, which are concerned with vision in dim light, are more numerous; as in many other vertebrates the purple visual pigment rhodopsin is found in the rods when the retina has adapted to dark. There is a small region of special sensitivity (area centralis) where the power of optical resolution is probably greater than elsewhere.

Another interesting feature of the retina is the presence of a well developed tapetum layer which is situated outside the neuro-sensory layers of the retina but internal to the choroid, and contains reflecting crystals of guanine. Tapeta of various types are found in many other nocturnal animals and have the function of reflecting light back on to the visual cells (rods and cones) and so increasing their sensitivity. The presence of the tapetum is responsible for the phenomenon of 'eye-shine', as when the eyes of a cat are illuminated at night by the headlights of a car. A crocodile's eyes reflect light in a similar way and the reddish eye-shine elicited often betrays the presence of the animal to the torch of the nocturnal hunter.

The crocodilian pupil has the form of a vertical slit in bright light. In his fascinating book, The Vertebrate Eye, Walls has pointed out that the vertical pupil is not diagnostic of nocturnal habits as such, but is characteristic of nocturnal animals which also like to bask in bright sunshine; here again, the domestic cat affords a parallel. A slit-like pupillary opening can

be closed more effectively than a circular one, and hence gives a better protection for a retina which is basically suited for vision in dim light.

One might imagine from the conditions described that the crocodilian eye only worked efficiently at night, but it is by no means certain that this is so. Many field accounts suggest that the animals can perceive both enemies and prey at a considerable distance. Moreover, they appear to be capable of precise judgement when stalking and seizing prey in the daytime and have been known to spring out of the water to capture leaping fish or flying insects. Their skilful use of such tactics is surprising in view of their reputedly feeble powers of visual accommodation and seems to merit further investigation.

It is thought that crocodilians, unlike many chelonians and lizards, are unable to perceive colours (Walls, 1942). There are no obvious colour differences between the sexes nor are there other indications that colours are important in crocodilian life. Nevertheless, in view of the relatively close relationship between crocodilians and birds, experimental observations, based perhaps on attempts at colour training, would be welcome.

Ear and Hearing

The outer and middle ears of crocodiles show many interesting features, but it is questionable how far these are significantly related to the function of hearing. The outer ear structure is considerably more elaborate than that in other groups of reptiles (see Fig. 3A). Behind the eye there is a well developed superior ear-flap or 'pinna'; this is covered with scaly skin and conceals a fairly shallow meatal space at the bottom of which lies the tympanic membrane. Beneath and in front of the superior ear-flap is a less well defined inferior flap continuous with the tissues of the 'cheek' region. At the front of the ear region there is a slit-like opening between the upper and lower ear-flaps which is generally dilated when the head is in air and closed when it is submerged. These movements are effected by muscular action and appear to constitute the normal method whereby the tympanic membrane is exposed to sound waves. The whole superior ear-flap can also be moved up and down by a further pair of muscles situated near its posterior edge. Wever and Vernon (1957), in their valuable study of the crocodilian ear, state that the superior ear-flap is often raised slightly when the animal is on land, but pronounced movements of this flap can seldom be observed. They can be elicited, however, if a few drops of water are squirted under the flap on to the tympanic membrane; while an author on big-game hunting (Lake, 1953) has written that if a crocodile is frightened or angry its superior ear-flaps move up and down like hummingbirds' wings, an apt description. One would like further observations on the use of these ear-flaps in nature.

Wever and Vernon suggest that the main function of the ear-flaps is to exclude water from the auditory meatus, but they do not seem to be completely water-tight; there may be some seepage between them when the head is submerged (Shute & Bellairs, 1955). Since the pressure of the water would tend to close the superior flaps more tightly during diving, it is possible that they may to some extent protect the delicate tympanic membrane from pressure; they would certainly guard it from injury against underwater snags. The auditory sensitivity is reduced considerably when the flaps are tightly closed, but hardly reduced at all if they are even slightly opened.

The conducting apparatus of the middle ear is of the usual reptilian type; there is a single ossicle, the stapes or columella, and a cartilaginous extrastapes, part of which is applied to the tympanic membrane. The middle ear cavities and Eustachian tubes are remarkably complicated, for there are both lateral and median tubes; the membranous tympanic system eventually communicates with the pharynx by a common opening in the midline behind the internal nostrils (see Fig. 3B). There is also a connection across the midline from one tympanic cavity to the other, and an extension from each cavity into the lower jaw through a membranous tube called the siphonium.

It would seem that a rather similar though less elaborate type of tympanic pneumatisation occurs in many birds, and it is possible that this feature is part of a common archosaurian heritage. Its function is obscure, though it has been suggested that the branched air passages of crocodilians, with their transverse communication, provide a method of very rapidly equalizing the pressures within the two middle ear cavities (Colbert, 1946; Simonetta, 1956). Wever and Vernon (1957) have shown that sounds are conducted very readily through the transverse passage so that vibrations stimulating one ear stimulate the other 'about equally well'. The benefits, if any, of this cross-passage are not clear, since it would apparently make it more difficult for the animal to localize the source of sound impinging on both ear drums on the basis of differences in their intensity. We know that alligators can localize sounds, however (Beach, 1944), and it is possible that there is some very sensitive mechanism for detecting a minute time-lag between the stimulation of one ear and the other.

The cochlea or lagena of crocodiles is extremely well developed by reptilian standards, and though not coiled like the mammalian cochlea, is bent halfway along its length, as in some birds (Baird, 1970). Wever and Vernon investigated the auditory capacities of caimans by recording electric potentials set up in the ear when this is exposed to sounds of different frequency. It was found that auditory sensitivity was greatest for sounds with a range of 100 to 3000 cycles per second and fell off rapidly for lower and higher tones. These figures are comparable with those obtained by Wever and his colleagues for certain lizards, and it is not really clear whether the Crocodilia have better powers of hearing than lizards such as geckos, which also have a well developed cochlear apparatus.

Evidence for the importance of sounds in daily life is much better documented for crocodilians than for other reptiles. Young Nile crocodiles croak as a signal for maternal help before or after hatching, while older individuals may hiss or growl in threat. During the breeding season male (and at least in some species, female) crocodilians roar; Cott suggests that this may be a mating call rather than a threat directed towards rivals, but it is very possible that it has some territorial significance. The roar or bellow of the American alligator has been described as 'one of the great animal voices of the world' (Carr, 1963). Some people have apparently been able to attract wild crocodilians by making noises of various kinds, which may perhaps simulate sounds made by the animals themselves, or even by potential prey. Joy Adamson (1961, p.38) writes that crocodiles in East Africa invariably respond to a certain man-made sound which can be roughly represented by 'imn, imn, imn'; if there were any crocodiles within 400 yards they would come to the water's edge "as though drawn by a magnet ... If we moved, and our noises then came from a different place ... (the crocodiles) would follow them". The Adamsons learnt the trick from African fishermen on Lake Baringo. In the laboratory, Beach (1944) studied the reactions of captive male alligators to sound and elicited roaring, hissing and aggressive display by blowing a French horn to them at a frequency of 57 Hz. Other noises such as thunder, blasting or gunfire which perhaps resemble the roars made by rivals, may also provoke a vocal response from an alligator.

It therefore seems clear that crocodilians have good hearing, at least by reptilian standards, and that auditory stimuli are important in their social behaviour; such stimuli may well play a part also in predatory and defensive activities.

Other Senses

Taste buds are present in the mucous membrane covering the pterygoid region of the palate (Wettstein, 1931-54).

The scales of the upper and lower jaws are furnished with conspicuous pigmented elevations. These have a rich nerve-supply, and are organs of touch (Laidlaw & Murray, 1933); organs of this type are not uncommon in the integument of reptiles, but seem particularly well developed in the Crocodilia. Perhaps they have some special significance here -- for instance the detection of disturbances under water made by fish.

An interesting idea, mentioned during the course of this meeting, is that crocodilians might possess some system of underwater echolocation comparable with that of cetaceans. Could the complexities of the middle ear play any part? I do not know of any evidence for anything of this kind, and Dr R.H. Chabreck has told me that a blind alligator which he kept bumped repeatedly

into obstacles in its tank until it learnt its way around.

Our ignorance about so many aspects of the biology of these impressive and fascinating reptiles is one of the best reasons for ensuring that they do not become extinct.

* * *

References

Adamson, J. 1961. Living free. The story of Elsa and her cubs. Collins & Harvill Press: London.

Baird, I.L. 1970. The anatomy of the reptilian ear. In Gans & Parsons (1970), pp. 193-275.

Beach, F.A. 1944. Responses of captive alligators to auditory stimulation. Am. Nat. 78: 481-505.

Bellairs, A. d'A. & Shute, C.C.D. 1953. Observations on the narial musculature of Crocodilia and its innervation from the sympathetic system. J. Anat. 87 : 367-378.

Bustard, H.R. 1968. Rapid learning in wild crocodiles (Crocodylus porosus). Herpetologica 24 : 173-175.

Carr, A. & the Editor of Life. 1963. The Reptiles. Time Inc.: New York.

Colbert, E.H. 1946. The Eustachian tubes in the Crocodilia. Copeia, 12-14.

Cott, H.B. 1961. Scientific results of an inquiry into the ecology and economic status of the Nile crocodile (Crocodylus niloticus) in Uganda and Northern Rhodesia. Trans. zool. Soc. Lond. 29: 211-356.

Coulson, R.A. & Hernandez, T. 1964. Biochemistry of the alligator. A study of metabolism in slow motion. Louisiana State University Press: Baton Rouge.

Gadow, H. 1901. Amphibia and Reptiles. Macmillan: London.

Gans, C. & Parsons, T.S. (Editors). 1970. Biology of the Reptilia. Morphology B, Vol. 2. Academic Press: London & New York.

Goldby, F. & Gamble, H.J. 1957. The reptilian cerebral hemispheres. Biol. Rev. 32 : 383-420.

Laidlaw, G.F. & Murray, M.R. 1933. Melanoma studies III. A theory of pigmented moles. Their relation to the evolution of hair follicles. Am.J.Path. 9 : 827-838.

Lake, A. 1953. Killers in Africa. W.H. Allen ; London.

Parsons, T.S. 1970. The nose and Jacobson's organ. In Gans & Parsons, pp. 99-191.

Shute, C.C.D. & Bellairs, A. d'A. 1955. The external ear in Crocodilia. Proc.zool.Soc.Lond. 124 : 741-749.

Simonetta, A. 1956. Organogenesi e significato morfologico del sistema intertimpanico dei Crocodilia. Arch.Ital.Anat.Embriol. 61 : 335-372.

Tansley, K. 1965. Vision in Vertebrates. Chapman & Hall : London.

Underwood, G. 1970. The eye. In Gans & Parson, pp. 1-97.

Walls, G.L. 1942. The Vertebrate Eye and its adaptive radiation. Cranbrook Institute of Science, Michigan.

Wettstein, O. 1931-54. Sections on Crocodilia in Handbuch der Zoologie ("Kukenthal") (a work issued in many parts over many years). De Gruyter : Berlin & Leipzig.

Wever, E.G. & Vernon, J.A. 1957. Auditory responses in the Spectacled caiman. J. cell. comp. Physiol. 50 : 333-339.

Figure 1

A Diagram showing action of crocodilian narial muscles, the external nostril being shown open on the left, and almost closed on the right. The muscles are shown as if in horizontal section, the arrows indicate direction of pull or thrust.

B Diagram of head of crocodilian in longitudinal section to show nasal cavity (lateral wall) and conchae, internal nostrils and flaps or valves guarding them. (Partly based on Parsons.)

CM, circular muscle (closes nostril). CO, concha. IN, internal nostril. LA, region of larynx. LM, longitudinal muscle (opens nostril). N, (external) nostril. NT, nasopharyngeal tube. OE, oesophagus. PC, preconcha. PO, postconcha. R, recess of nasal cavity (others also present). T, tongue. TR, trachea. V, valvular flaps (upper and lower) guarding airway when mouth is open under water.

Figure 2

Visual cells from retina of American alligator, from near centre of tapetum. A, single cone. B, double cone. C, rod. (After Underwood.)

Figure 3

A Diagram of external ear structures of a crocodilian. The superior ear-flap has been turned up to show the tympanic membrane, and its muscles have been dissected out; the action of the levator muscle is not obvious from the figure. Arrows show movements of inferior ear-flap. (After Shute & Bellairs.)

B Diagram of membranous Eustachian tube system in a crocodilian. The broken lines indicate the position of the skull base. (After diagram in Wettstein.)

DM, depressor muscle of superior ear-flap. E, extension of tympanic cavity which leafs into quadrate and ultimately into lower jaw. IEF, inferior ear-flap. LM, levator muscle of superior ear-flap. LT, lateral Eustachian tube. MT, median tube. O, anterior, slit-like opening of outer ear. OP, common opening of membranous Eustachian tube system into pharynx. SEF, superior ear-flap. T, transverse communication between tympanic cavities. TC, tympanic cavity. TM, tympanic membrane.

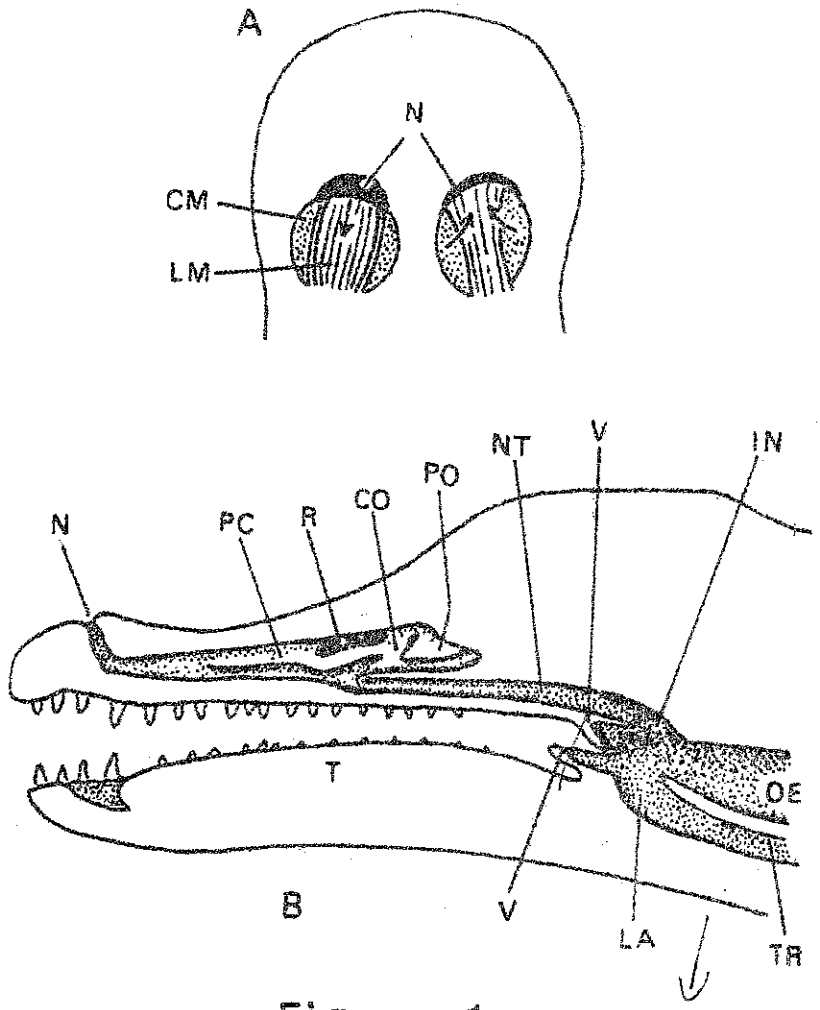


Figure 1.

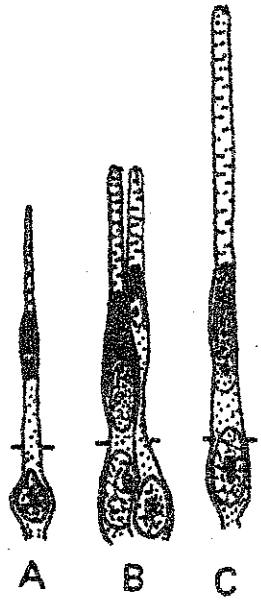


Figure 2.

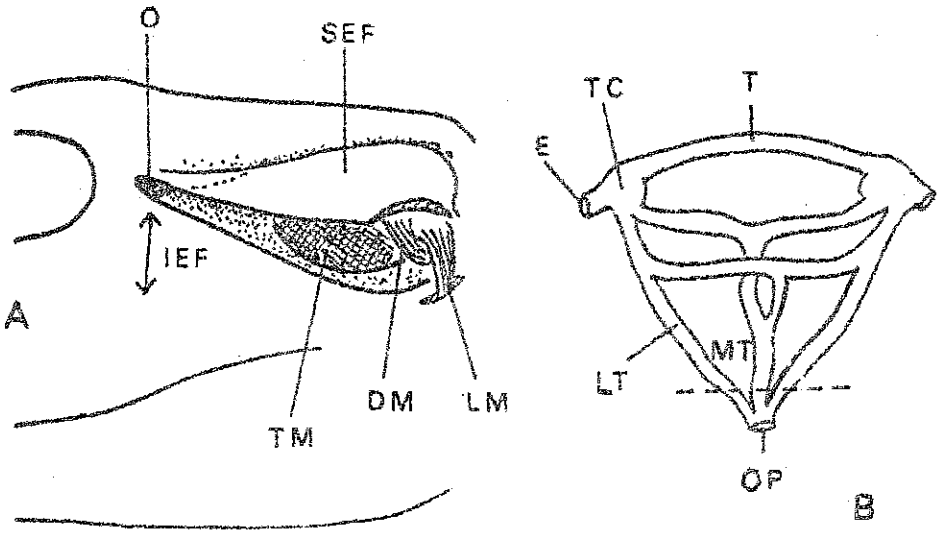


Figure 3.