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Feasibility of the Establishment of a Captive-Breeding Population of the American Crocodile

NATIONAL PARK SERVICE
DEPARTMENT OF THE INTERIOR

Everglades National Park, South Florida Research Center, P.O. Box 279, Homestead, Florida 33030

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FEASIBILITY OF THE ESTABLISHMENT OF A CAPTIVE-BREEDING POPULATION OF THE AMERICAN CROCODILE

A Report

Prepared for the

National Park Service

United States Department of the Interior

Report T-509

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numbers of young to maintain a stable population. According to recent experimental work, C. acutus hatchlings may not be able to tolerate the now normally high salinity rates they face during the hatching season (Evans and Ellis, 1977; Dunson, 1970).

Dredge and fill operations in the Keys, commercial fishing in crocodile nesting areas, nest robbing by humans, hurricanes, introduced plant species (especially Casurina), development of highways, marinas, and housing in former crocodilian habitat, prolonged droughts, and general increase in human activities within American crocodile habitat, are additional factors which have undoubtedly been negative influences on C. acutus populations (Craighead, 1968; Dasmann, 1971; Ogden, 1976, 1978; Lang, 1975). Raccoons were found to destroy 17% of south Florida crocodile nests (Ogden, 1978). This figure compared favorably with other reported crocodilian nest predation rates. Lang (1975) remarked that raccoons have become very abundant in south Florida since many of their predators have been reduced. The author assumes that disease will replace predator control in south Florida raccoon populations as it has in other regions and populations will experience greater fluctuations in population size. It should be pointed out that investigators have ignored the relationship between nest examination by

researchers and subsequent predation rates. Hines and Dietz (pers. comm.) found that raccoons prey upon alligator nests investigated by humans significantly more often than they do undisturbed nests. Thus, persons monitoring nests in the past may well have contributed to nest failure due to raccoon predation.

Current evidence suggests that there is something drastically wrong with the Florida American crocodile population. Population estimates indicate there may be fewer than 20 breeding females. Recruitment into the population appears very low. While the answers to the precise causes of the population's decline may be answered in the next several years, corrective action most likely will take years. In the interim, the author considers that a captive propagation program would insure the survival of Florida *C. acutus* stock against catastrophic loss, provide animals for restocking and research purposes, and be consistent with national and international efforts to conserve crocodilians. The following report examines the feasibility of establishing a captive, self-reproducing stock of genetically pure Florida crocodiles, potential sites for development, and considers topics relative to the implementation of the program.

CURRENT POTENTIAL FOR BREEDING CROCODILIANS IN CAPTIVITY

Although crocodilians have long been popular exhibit animals at zoological parks and aquariums, relatively few institutions have been successful in propagating them. Most institutions, because of space limitations, geographical location, lack of interested or qualified staff, inadequate revenues, and the demands of the visiting public, have simply not become involved in crocodilian conservation and propagation programs.

A review of zoo inventories often shows that a large diversity of species are maintained in a given collection with a correspondingly high incidence of single or unpaired specimens. Thus, it is not unusual to see several species of crocodilians displayed in a community enclosure which provides the minimal needs of the inhabitants, a shallow concrete pool and several basking areas. Such enclosures are designed to avoid the expense of heating large volumes of water and to allow easy viewing of the crocodilians by the public. In these situations, as Honegger (1971) points out, reproduction is practically impossible with crocodiles, frequently of remarkable longevity records, kept in large groups composed of various species and size classes

maintained in more or less unbiological enclosures.

Additional problems were revealed in King and Dobbs' (1975) recent survey of crocodilians maintained in American zoos and aquariums. Questionnaires returned indicated that some zoo staffs had difficulty in identifying and accurately sexing their crocodilians. This problem was due in part to the lack of collection data accompanying specimens purchased through animal dealers and to the paucity of pertinent scientific literature generally accessible to zoo staff members. This latter situation has been somewhat remedied by the availability of Brazaitis' (1973) key to living crocodilians and Chabreck's (1967) and Brazaitis' (1969) descriptions of a definitive sexing technique.

Of the approximately 500 worldwide zoos and aquariums, less than 1/10 have bred crocodilians. Between 1960 and 1975 inclusively, 47 institutions reported breeding one or more crocodilian species in their collections (see Table 1), of these three were alligatorids and 8 were crocodylid species. *Crocodylus acutus* was only reproduced twice by one reporting institution, the Atlanta Zoological Park in 1973 and 1974. Examination of Table 1 data clearly indicates most crocodilians are bred in institutions which are located in warm climates or fall within the species' geographical

distribution. Of 32 successful Alligator mississippiensis breedings, 30 occurred in institutions located in the southern half of the United States, and the majority of breedings took place within the historic range of the species. The Indian mugger crocodile (Crocodylus palustris) was bred twenty times; nineteen of these breedings occurred within the boundaries of the species' natural distribution, the remaining event took place in Thailand under similar climatological conditions.

The reader should understand that while geographical location of a propagation facility plays an important role in breeding a given crocodilian species, it doesn't have to be the overriding factor. It is understandable that Crocodylus palustris is, for the most part, bred in India, for that is by far the most common crocodilian in captivity there. On the other hand, it is rare in crocodilian collections outside of India. Although there are facilities located in the United States which could provide the environmental needs for a breeding group of C. palustris, no such breeding group exists. In many instances, the breeding successes reported were not the result of a carefully developed and monitored propagation scheme. But rather, the events occurred because the institution was favorably located (climatologically), provided enough three dimensional space for

reproductive activities, and they had accumulated enough animals of the right species, sex, and age class to make successful breeding a possibility.

During the past half dozen years, an increasing number of institutions have recognized the plight of the world's crocodilians and taken steps to develop propagation programs for these vanishing forms. Most zoological parks are now willing to send their unpaired specimens on breeding loan to parks which have developed a breeding program for the particular species. Others have reduced the number of crocodilian species exhibited and improved their facilities. The results -- planned or otherwise -- have been gratifying, as recorded breeding figures (Table 1) have doubled in each five year period from 1961 to 1975.

The Atlanta Zoo has the finest zoological park record for a sustained crocodilian propagation program. This program (Hunt, 1973) had its origins in July 1965 when they obtained a group of juvenile Morelet's crocodiles (C. moreletii) from the Mexican State of Yucatan. The females first nested in 1969 and have done so each year since that time. Fertile eggs have been produced each year and hatchings occurred from 1971 to 1977. The adult Morelet's crocodiles are situated in a large solarium with a 1,100 gallon pool and

maintained at 32°C. Many of the offspring have been liberated back into Mexican waters. Additionally, Atlanta Zoo has successfully bred Caiman crocodilus (Hunt, 1969) and Crocodylus acutus (Duplaix-Hall, 1975; Olney, 1976) under similar conditions.

King and Dobbs (1975) pointed out that the space available to crocodilians varies considerably. Basically, zoos which reproduced crocodilians provided more space than those which did not. Successful zoos provided 12-170 m^2/animal while those which were unsuccessful provided 3-16m^2/animal. They too noted that relative space may be more important than absolute space during the nesting period. Relatively small quarters can be designed or modified to provide a nesting female with a secluded nesting site which she can defend.

King (pers. comm.) notes that there is a positive correlation between water depth of zoo crocodilian pools and breeding success. Reproduction rarely occurs in parks which do not provide a maximum pool depth of 3 or more feet. Similarly, Joanen and McNease (1971) reported that mating in alligators occurs in open water more than 1 meter deep.

In 1974, the New York Zoological Park's Department of Herpetology staff abandoned its attempts to breed its pair of

Chinese alligators (Alligator sinensis) within the confines of the reptile house facility and looked beyond the Zoo's perimeters for a suitable breeding site. The staff explored the possibility of utilizing ponds or canals which receive heated water discharge from a nuclear power facility. Potential power plant sites were found in South Carolina, Florida and Texas. Investigations at the Savannah River Ecology Laboratory indicated that American alligators which inhabit ponds receiving waste heat discharge exhibited accelerated growth rates and larger body sizes than those found in unheated ponds in the vicinity of the South Carolina nuclear facility. Unfortunately, Alligator mississippiensis males were not synchronizing with females during the normal South Carolina breeding season and reproduction rates appeared very low (Brisbin, pers. comm.). While temperatures appeared suitable for tropical-occurring crocodilians, it did not appear to be so for temperate zone alligatorids which normally have an extended inactivity period. Thus the Department looked for a quasi-natural site which offered environmental conditions approximating those existing in the Chinese alligator's historic range.

The Rockefeller Wild Life Refuge, owned and operated by the Louisiana Wildlife and Fisheries Commission and located in the coastal marshes of southwestern Louisiana, offered suitable conditions. Comparison of meteorological

data of the two localities indicated roughly similar temperatures, amounts of precipitation, and seasonal changes. The staff of the Refuge has some of the most knowledgeable and experienced biologists studying the ecology, behavior, and reproductive biology of the American alligator. Their existing program included the propagation of A. mississippiensis in captivity and their knowledge and experience would be a valuable asset to an A. sinensis propagation effort.

The New York Zoological Society submitted a proposal for a joint propagation program to the Louisiana Wildlife and Fisheries Commission. It was approved in late November 1975 and construction of facilities at the Refuge began immediately under the direction of Ted Joanen, Research Leader, Refuge Division. The U.S. National Zoological Park joined the project by contributing the only other available pair of Chinese alligators in the United States.

On 22 March 1976, the four A. sinensis were transferred from the New York Zoological Park to their quarters at the Refuge. Each pair was located in a double-fenced, escape-proof, one-half acre enclosure. Each enclosure contains natural vegetation, two freshwater 400 square foot ponds, and one 1875 square foot (25' x 75') pond. All ponds are graded to a maximum depth of 5 feet. Maintenance of the

specimens parallels that developed for American alligators currently being bred at the Refuge.

The specimens that are being used in the initial phase of the program are long-term captives. The U.S. National Zoo pair had been in captivity (acquired as adults) for at least 37 years and the NYZS pair for 19 years. The U.S. National Zoo male apparently was in ill health as it did not survive the first summer. The remaining three appeared to acclimate rapidly and exhibited behavior we assumed parallel to that of wild A. sinensis. In the months ahead they were rarely seen. They constructed tunnels in the birm of their large earthen pools. The winter of 1976-1977 was the worst on record, with temperatures falling below 0°C and the question of whether long-term zoo maintained A. sinensis could survive these conditions was at issue. After five months of inactivity, the three animals emerged, and by the first week in May were feeding normally. They remained secretive and sought shelter when their quarters were approached.

In late June nesting activities were observed. On 26 June, eleven eggs were deposited. Although most were misshapen, several eggs appeared to be normal and viable. The first of two hatchlings pipped on 31 August and represented the first captive breeding of this crocodilian.

This breeding, as well as those previously mentioned, serve to illustrate that it is feasible to breed captively maintained crocodilians (even though they may have been kept for lengthy periods) when given appropriate conditions, and when the expertise is available to design and develop propagation programs.

Crocodilian rearing and breeding efforts are not limited to zoological parks and related institutions. As populations of the world's wild crocodilians have disappeared, there has been a proliferation of rearing and breeding programs for these threatened forms. Interest in farming crocodilians grew with the development of protective legislation. In some instances, the farming efforts were forced on hide-hunters and poachers as the big reptiles became too scarce to hunt. Consequently, most farms are planned as a source of hides. Very few of these institutions actually are farms that breed their own stock to produce the young that are the source of the hides. Instead, the eggs and young are collected and brought to the "farm" for hatching and rearing. Their commercial success depends on the continued existence of wild crocodilians. If the wild populations disappear, the rearing stations will disappear as well. Rearing stations are in operation in Singapore, Indonesia, Papua New Guinea, Rhodesia, Mozambique,

Venezuela, and El Salvador. True farms that produce young crocodilians bred and hatched from the farm stock exist in Thailand, South Africa, Florida, experimentally in Louisiana, and limitedly in Papua New Guinea (Behler, 1976; Blake, 1970; Downes, 1973; Joanen and McNease, 1971, 1974, 1975; King, pers. comm.; Pooley, 1969, 1971, 1973, pers. comm.; Yangprapakorn et al., 1971).

These rearing stations vary from elaborate, expensive, concrete and steel facilities to small, native cottage industries consisting of one or two enclosures constructed of bush materials or chicken wire. Many of the latter were started by people who have little or no biological understanding of what is needed to maintain crocodilians alive and in good health and to get them to breed. Many stations close down after their stock dies from infection or some dietary malady.

On the other hand, the successful farms, including the Papua New Guinea Government installations at Moitaka, Pagwi, and Lake Murray; the research station run by the Natal Parks Board in Ndumu, South Africa; the Samut Prakan Crocodile Farm in Thailand; and the research station operated by the Louisiana Wildlife and Fisheries Commission

at the Rockefeller Refuge; have greatly increased our knowledge of pen design and construction, stocking rates, breeding biology, egg handling and incubation, growth rates, disease control, and general crocodilian husbandry. Relevant information appears elsewhere in this report.

In addition to the Atlanta Zoological Park's successful C. acutus propagation effort, the species has nested at several Florida roadside attractions. These include: Everglades Wonder Gardens in Bonita Springs, Gatorama in Palmdale, and Gator Jungle in Christmas. Successful hatchings occurred sporadically in the past at Everglades Wonder Gardens and on a number of occasions within recent years at Gatorama. In Jamaica, J. Charles Swaby of Mandeville (at 2,000 feet in the hills) maintains approximately 50 American crocodiles and claims that he has had nesting the past few years and has, on occasion, released hatchlings back into Jamaican waters.

At the present time, however, there are no serious efforts to propagate the American crocodile within the United States. The Atlanta Zoo has sent its remaining American crocodiles to Central Florida Zoological Park in Sanford. Unfortunately, the single female won't be sexually mature for at least seven years.

Of the zoological parks in this country, only the Jacksonville Zoo, Philadelphia Zoological Gardens, and perhaps the New York Zoological Park (C. acutus on loan to Rio Grande Zoo) have at least one sexually mature pair of American crocodiles. None of these institutions have developed facilities spacious enough to accommodate a significant breeding program for C. acutus.

Facilities at Everglades Wonder Gardens are inadequate (see remarks elsewhere) for any serious propagation program. The few successful hatchings that were recorded there in past years occurred under the most marginal conditions. Any interest that the Piper Brothers had in breeding American crocodiles disappeared years ago as they have not given serious thought to hatching eggs in at least ten years. Further, it should be noted that the attraction has not been updated to any degree within recent years and, according to Les Piper, business has been very poor. Both owners are now in their 70's and are contemplating selling or closing down in the near future.

Of the Florida roadside attractions, Cecil Clemon's Gatorama appears to have been the most successful in reproducing American crocodiles. Although the facility is large enough for a serious propagation program, it is

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poorly designed and currently mismanaged, overstocked and in a state of disrepair (see additional remarks elsewhere). Mr. Clemons claims that his business has been crippled severely by the development of new attractions (i.e. - Disneyworld) and especially by the loss of his ability to advertise on billboards. (Virtually all billboards in his area have been removed in compliance with the Federal Highway Beautification Act.) He further remarked to the author that he is in financial difficulty (and appears to be in poor health) and wishes to sell his property and stock in the immediate future.

Herman Brooks, owner of Gator Jungle, informed the author that his crocodilians lay eggs each April but apparently he has not had a successful hatching since he plans (under conditions he has successfully employed for American alligator eggs) to artifically incubate eggs in 1978.

Frank Godwin, manager of Gatorland Zoo, reports that his Kissimmee facility holds thirty Jamaican C. acutus. No mention of egg laying or reproduction was made, however, in response to the author's inquiry about the facility and its crocodilians.

Clearly, it is feasible to establish a self-reproducing stock of C. acutus under captive conditions. The American crocodile has already been bred under marginal conditions at several facilities. It should be emphasized that there is no serious captive propagation program for C. acutus in existence at the present time. While some of the facilities which hold American crocodiles provide minimum requirements for propagation, the author does not consider any of them satisfactory for developing a captive propagation program as envisioned by the National Park Service, the American Crocodile Recovery Team, or himself.

Table 1. CROCODILIANS BRED IN CAPTIVITY BY INTERNATIONAL ZOOLOGICAL PARKS, AQUARIUMS, AND INSTITUTIONS (1960 - 1975).

	Institution/Locality	Year Bred	Reference	
Alligator mississippiensis	Crandon Pk Zoo, Miami	1960	Jarvis	1961:278
	Ross Allen Rep. Inst., Silver Springs	1960	Jarvis	1961:278
	Oklahoma City Zoo, Okl. Cty.	1961	Jarvis	1962:285
	Brookgreen Gardens, Murrells Inlet	1965	Jarvis	1967:348
	Phoenix Zoo, Phoenix	1966	Jarvis	1968:338
	Ross Allen Rep. Inst., Silver Springs	1966/67	Jarvis	1968:338
		1968	Lucas	1969:268
	Roeding Pk Zoo, Fresno	1967	Lucas	1969:268
			Chaffee	1969:34
	Jerusalem Univ., Israel	1968	Lucas	1970:304
	Brookgreen Gdns, Murrells In.	1969	Lucas	1971:316
	Houston Zool Gdns, Houston	1970	Lucas et al.	1972:371
	Phoenix Zoo, Phoenix	1970	Lucas et al.	1972:371
	Ft. Worth Zool. Pk., Ft. Worth	1971	Duplaix-Hall	1973:286
		1972	Duplaix-Hall	1974:332
	Houston Zool Gdns, Houston	1972	Duplaix-Hall	1974:332
	La. Purchase Zoo, Monroe	1972	Duplaix-Hall	1974:332
	Jungle Larry's Af. Safari at Carib. Gdns, Naples	1972	Duplaix-Hall	1974:332
	Ft. Worth Zool Pk, Ft. Worth	1973	Duplaix-Hall	1975:319
	Aust. Rept Pk, Gosford, Aust.	1973	Duplaix-Hall	1975:319
	Houston Zool Gdns, Houston	1973	Duplaix-Hall	1975:319
	La. Purchase Zoo, Monroe	1973	Duplaix-Hall	1975:319
	Jungle Larry's Af. Safari at Carib. Gdns, Naples	1973	Duplaix-Hall	1975:319
	Knowland Pk Zoo, Oakland	1973	Duplaix-Hall	1975:319
	Randolph Pk Zoo, Tucson	1973	Duplaix-Hall	1975:319
	Ft. Worth Zool Pk, Ft. Worth	1974	Olney	1976:337
	Houston Zool Gdns, Houston	1974	Olney	1976:337
	Jacksonville Zool Pk, Jacksonville	1974	Olney	1976:337

	Institution/Locality	Year Bred	Reference	
Alligator mississippiensis	Jacksonville Zool Pk Jacksonville	1974	Olney	1976:337
	Randolph Pk Zoo, Tucson	1974	Olney	1976:337
	Jacksonville Zool Pk, Jacksonville	1975	Olney	1977:257
	Busch Gdns Zool Pk, Tampa	1975	Olney	1977:257
Caiman crocodilus	Parque Zool. de Tuxtla Gut., Chiapas, Mexico	1961	Jarvis	1962:285
	Vivarium Kehl, Germany	1966	Hirschfeld	1966:308
	Tuxtla, Chiapas, Mexico	1966	Jarvis	1968:338
			del Toro	1969:36
	Atlanta Zool Pk, Atlanta	1967	Lucas	1969:269
	Tuxtla, Chiapas, Mexico	1968	Lucas	1970:304
	Atlanta Zool Pk, Atlanta	1969	Lucas	1971:316
	El Pinar, Caracas, Venezuela	1970	Lucas et al.	1972:371
	Tuxtla, Chiapas, Mexico	1970	Lucas et al.	1972:371
	Natura Artis Magistra, Amsterdam, Netherlands	1971	Duplaix-Hall	1973:286
	Atlanta Zool Pk, Atlanta	1971	Duplaix-Hall	1973:286
	Tuxtla, Chiapas, Mexico	1971	Duplaix-Hall	1973:286
	Atlanta Zool Pk, Atlanta	1972	Duplaix-Hall	1974:332
	Tuxtla, Chiapas, Mexico	1972	Duplaix-Hall	1974:332
	Atlanta Zool Pk, Atlanta	1973	Duplaix-Hall	1975:319
	Ft. Worth Zool Pk, Ft. Worth	1973	Duplaix-Hall	1975:319
	Crandon Pk, Miami	1973	Duplaix-Hall	1975:319
	Topeka Zool Pk, Topeka	1974	Olney	1976:337
	Atlanta Zool Pk, Atlanta	1975	Olney	1977:257
	Crandon Pk, Miami	1975	Olney	1977:257
Caiman latirostris	Thuringer ZooPk, Erfurt, Germany	1964	Jarvis	1966:424
	Jardim Zool do Rio de Janeiro, Brasil	1966	Jarvis	1968:338

Table 1 (Cont'd).

	Institution/Locality	Year Bred	Reference
Crocodylus acutus	Atlanta Zool Pk, Atlanta	1973	Duplaix-Hall 1975:319
	Atlanta Zool Pk, Atlanta	1974	Olney 1976:337
Crocodylus johnsoni	Melbourne Zool Gdns, Melbourne, Australia	1975	Olney 1977:257
	Melbourne Zool Gdns	1975	Dunn 1977:130
Crocodylus moreletii	Atlanta Zool Pk, Atlanta	1970	Lucas et al. 1972:371
	Atlanta Zool Pk, Atlanta	1971	Duplaix-Hall 1973:286
	Atlanta Zool Pk, Atlanta	1972	Duplaix-Hall 1974:332
	Tuxtla, Chiapas, Mexico	1972	Duplaix-Hall 1974:332
	Atlanta Zool Pk, Atlanta	1973	Duplaix-Hall 1975:319
	Tuxtla, Chiapas, Mexico	1973	Duplaix-Hall 1975:319
	Atlanta Zool Pk, Atlanta	1974	Olney 1976:337
	Atlanta Zool Pk, Atlanta	1975	Olney 1977:257
	Tuxtla, Chiapas, Mexico	1975	Olney 1977:257
Crocodylus niloticus	Tel Aviv Univ., Israel	1963	Jarvis 1965:364
	Jardin Zool., 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
	Aquarium Trop, Paris, France	1969	Lucas 1971:316
	Tel Aviv Univ., Israel	1969	Lucas 1971:316
	Kumasi Zool Gdns, Ghana	1971	Duplaix-Hall 1973:286
	Tel Aviv Univ., Israel	1972	Duplaix-Hall 1974:332
	Slaski Ogrod Zool, Katowice, Poland	1974	Olney 1976:337
	Tel Aviv Univ., Israel	1974	Olney 1976:337
	Akt. Zool Gtn, Cologne, Germany	1975	Olney 1977:257
	Sl Ogd Zool, Karowice, Poland	1975	Olney 1977:257
	Yakubu Gowan Pk, Maiduguri, Nigeria	1975	Olney 1977:257
	Tel Aviv Univ., Israel	1975	Olney 1977:257

	Institution/Locality	Year Bred	Reference	
C. niloticus x *C. acutus*	Hagenbeck's Tierpark, Hamburg, Germany	1970	Lucas et al.	1971:371
Crocodylus palustris	Municipal Hill Gdn Zoo, Ahmedabad, India	1960	Jarvis	1961:276
	Zool Gdn Jaipur, India	1960	Jarvis	1971:278
	Municipal Hill Gdn Zoo, Ahmedabad, India	1962	Jarvis	1963:254
	Zool Gdn Jaipur, India	1962	Jarvis	1963:254
	Zool Gdn Jaipur, India	1963	Jarvis	1965:364
	Maharaja Fatesingh Zoo, Baroda, India	1964	Jarvis	1966:424
	Dusit Zool Pk, Bangkok, Thailand	1965	Jarvis	1967:348
	Zool Gdn Jaipur, India	1965	Jarvis	1967:348
	Mun. Hill Gdn Zoo, Ahmedabad India	1966	Jarvis	1968:338
	Zool Gdn Jaipur, India	1967	Lucas	1969:268
			Yadav	1969:33
	Zool Gdn Jaipur, India	1968	Lucas	1970:304
	Mun. Hill Gdn Zoo, Ahmedabad India	1969	David	1970:116
			Lucas	1971:316
	Mun. Hill Gdn Zoo, Ahmedabad India	1970	Lucas et al.	1972:371
	Zool Gdn Jaipur, India	1970	Lucas et al.	1972:371
	Gdn Zoo, Ahmedabad, India	1972	Duplaix-Hall	1974:332
	Zool Gdn, Jaipur, India	1972	Duplaix-Hall	1974:332
	Gdn Zoo, Ahmedabad, India	1973	Duplaix-Hall	1975:319
	Gdn Zoo, Ahmedabad, India	1974	Olney	1976:337
	Gdn Zoo, Ahmedabad, India	1975	Olney	1977:257
	Zool Gdn Jaipur, India	1975	Olney	1977:257

Table 1 (Cont'd).

	Institution	Year Bred	Reference
Crocodylus porosus	Atagawa Trop Gdn, Higashi-Izu, Japan	1971	Duplaix-Hall 1973:286
	Singapore Zool Gdn, Singapore	1975	Olney 1977:257
Crocodylus rhombifer	Jardin Zool., Havana, Cuba	1965	Jarvis 1967:348
Osteolaemus tetraspis	Victoria Zool Gdn, Victoria Cameroun	1969	Lucas 1971:316
	Kumasi Zool Gdns, Ghana	1970	Lucas et al. 1972:371
	Ueno Zool Pk, Tokyo, Japan	1972	Duplaix-Hall 1974:332
	Ueno Zool Pk, Tokyo, Japan	1973	Duplaix-Hall 1975:319
	Kumasi Zool Gdns, Ghana	1975	Olney 1977:257
	Ueno Zool Pk, Tokyo, Japan	1975	Olney 1977:257
	Metro Tor Zoo, Toronto, Canada	1975	Olney 1977:257

CROCODYLUS ACUTUS PRESENTLY MAINTAINED IN CAPTIVITY IN THE UNITED STATES, GENETIC PURITY AND AVAILABILITY

Current review of census data of United States zoological parks, aquariums, and roadside attractions reveals that there are in excess of 150 crocodiles reported to be American crocodiles (*C. acutus*) maintained in captivity (see Table 2). Of the facilities tabulated, the reviewer is confident that only *one* facility (Everglades Wonder Gardens, Bonita Springs, Florida) maintains a group of *C. acutus* whose origin is south Florida waters.

For years Les and Wilfred Piper, owners of Everglades Wonder Gardens, advertised that they would purchase live crocodiles caught anywhere in south Florida. From the late 1930s to the fall of 1953, they answered these calls and accumulated approximately 50 adults and twice that number of juveniles. Most of the specimens reportedly came from the vicinity of Key Largo and the Cape Sable region (LeBuff, 1957; Moore, 1953). No additional specimens have been collected by the Piper brothers since 1953 (Piper, pers. comm.). A single *C. intermedius* or *C. acutus* (presumably the former) is currently maintained in a separate facility. Inasmuch as *C. acutus* was rarely imported by

animal dealers in any numbers prior to the late 1950s or early 1960s, it is the author's impression that the population maintained by the Pipers is genetically pure Florida stock.

Five additional C. acutus reportedly from Florida waters are recorded in Table 2, but at the time of writing documentary data was not available or is subject to question.

The author was able to ascertain that Gatorama (Palmdale, Florida), Gatorland Zoo (Kissimmee, Florida), and Gator Jungle (Christmas, Florida) all have substantive groups of C. acutus which were collected in Jamaica (Clemons, Godwin, Brooks, pers. comm.). Additionally, the Philadelphia Zoological Gardens has 0.1 C. acutus collected at Rocky Point, Jamaica, in 1957 (Bowler, pers. comm.) and Flamingo Grove has a pair of Jamaican specimens from Gatorama (Clemons, pers. comm.).

The majority of other tabulated captive C. acutus are without collection data. Although several of these are possible C. intermedius, the probability of significant error seems small, as suspect animals, for the most part, have been scrutinized by zoological park personnel or visiting herpetologists familiar with crocodile morphology.

The two species, as presently recognized, are separated by external characteristics discussed by Brazaitis (1973).

During the course of this evaluation, an overwhelming number of zoo curators expressed a willingness to give assistance to a federally sponsored (or otherwise funded) breeding program for C. acutus by making their animals available as outright donations or on a breeding loan basis. Les Piper was also positive about the effort and said that some of their remaining animals could be acquired. He stated that they would have to be reimbursed for catching, crating and transferring the animals in question. The terms of exchange would have to be worked out with both brothers. It appears, however, that they would be amenable to providing animals on breeding loan for the recognition of so doing. They positively would be willing to sell the specimens required. While the general health of Piper's crocodilians is less than desirable, most appear to be salvagable and their health would improve when situated in a less competitive situation and placed on an improved diet.

In considering acquisition of C. acutus from Everglades Wonder Gardens, the following observations should be taken into account:

1) The minimum age of the animals is 27 years.

2) A few individuals exhibit signs of senescence; no tooth replacement, losing weight.

3) According to Piper, the present attrition rate is about 2 animals per year -- causes: fighting (several individuals missing portions or entire limbs, or an eye, many had lesions on their tails), old age, disease (some may have steatitis, most individuals covered with algae).

4) Animals have been maintained on a diet largely, if not entirely, composed of fish. The diet appears to be lacking essential vitamins as most available marine fishes contain significant amounts of thiaminase.

Cecil Clemons of Gatorama is willing to part with a group of his Jamaican *C. acutus* on a cash basis. In recent years he has sold juveniles for $100 and adults for $1,000/animal. Gatorama is in trouble financially, and specimens could probably be obtained for less than $500/specimen.

TABLE 2. CROCODYLUS ACUTUS IN CAPTIVITY IN UNITED STATES ZOOLOGICAL PARKS, AQUARIUMS, AND ROADSIDE ATTRACTIONS, NOVEMBER 1977.

Institution	No./Sex	Size	Origin	Remarks
Baltimore Zoo Baltimore, Md.	0/1/0	42"	Unknown	Rec'd 16 June 1970 from Catoctin Mountain Zoo, Thurmont, Md.
Brookfield Zoo Chicago, Ill.	0/0/1	approx. 4'	Unknown	Rec'd 12 Oct. 1976 from private collector who had it since 1973.
Busch Gardens Tampa, Fla.	1/2/4	3' to 7'	Unknown	Male + 1 unsexed juvenile rec'd from Florida Game & Fresh Water Fish Comm. 12/74 and 10/13/75. Females on breeding loan from St. Louis Zoo. 3 unsexed adults from Tarpon Springs Zoo 1/15/76.
Central Florida Zoological Park Sanford, Fla.	2/1/0	male = 8' female = 3'	Unknown	Rec'd from Atlanta Zoo which has no data.
Cleveland Aquarium Cleveland, Ohio	0/0/1	2-2 1/2'	Unknown	Rec'd from animal dealer (Bill Chase) about 4 years ago.
Columbus Zoo Columbus, Ohio	2/0/0	6'6" + 8'6"	Unknown	Came to zoo in 1968 and 1970 from private donor.

TABLE 2 (Cont'd.) CROCODYLUS ACUTUS IN CAPTIVITY IN UNITED STATES ZOOLOGICAL PARKS, AQUARIUMS, AND ROADSIDE ATTRACTIONS, NOVEMBER 1977

Institution	No./Sex	Size	Origin	Remarks
Crandon Park Zoo Miami, Florida	0/0/1	24"	Unknown	About 2 years old. Rec'd from Tamir Ellis, U. Miami.
Everglades Nature Center (Everglades Safari) Miami, Florida	0/1/0	6'	Florida waters (?)	Rec'd from Miami Serpentarium.
Everglades Wonder Gardens (Piper Bros.) Bonita Sprgs, Fla.	0/0/20 (approx.)	8'-14'	Florida waters	Collected in Florida waters from late 1930s to 1953. Specimens appear to be mostly females
Flamingo Grove Flamingo, Fla.	1/1/0	adults	Jamaica	"Borrowed from Gatorama," C. Clemons
Ed Froelich, Jr. W. Palm Beach, Fla.	1/1/0	male= 11 1/2' female= 8'	Florida waters (?)	Male rec'd as hatchling from New Orleans research facility in 1960s; female rec'd years ago - caught at Vero Beach. Froelich believes both are of Florida origin.
Gatorama Palmdale, Fla.	0/0/45 (approx.)	4' - 12'	Jamaica	"All specimens collected in Jamaica" - C. Clemons
Gator Jungle Christmas, Fla.	0/0/16	2 = 5-6' 14 = 8-12'	Jamaica	"Caught in Jamaica in 1970" - H. Brooks.

TABLE 2 (Cont'd.) CROCODYLUS ACUTUS IN CAPTIVITY IN UNITED STATES

ZOOLOGICAL PARKS, AQUARIUMS, AND ROADSIDE ATTRACTIONS, NOVEMBER 1977.

Institution	No./Sex	Size	Origin	Remarks
Gatorland Zoo Kissimmee, Fla.	0/0/30	6'-8'	Jamaica	"Originated from Jamaica" - F. Goodwin.
Homosassa Sprgs, Inc. Homosassa Sprgs., Fla.	1/0/0	12-13'	Florida waters (?)	Caught in Tarpon Lake, east of Tarpon Springs in 1947 by Bob Trotter.
Houston Zoo Houston, Texas	0/1/0	8'	Costa Rica	Collected 14 Aug. 1973 by Louis Porras.
Los Angeles Zoo Los Angeles, Calif.	0/1/0	4'	Unknown	Stunted animal found in settling tank by construction workers.
Miami Serpentarium S. Miami, Fla.	1/0/0	adult	Florida waters (?)	Did not respond to inquiries.
New York Zool. Park Bronx, New York	1/2/0	6'-8'	Male - Colombia Females unknown	Male rec'd from animal dealer, 9/68. Females rec'd 2/20/70 & 3/30/73 from Central Park & Assiniboine Park Zoo. Sent on breeding loan to Rio Grande Zoo 7/8/75.
Philadelphia Zool. Gar. Philadelphia, Pa.	1/2/0	male = 8' $female_1$ = 5'6" $female_2$ = 7'5"	$Female_2$ - Rocky Pt., Jamaica; Male, $female_1$ - unknown.	$Female_2$ purchased from James Lazell, 6/27/57; male, $female_1$ from Ross Allen, 10/15/71.

TABLE 2 (Cont'd.). CROCODYLUS ACUTUS IN CAPTIVITY IN UNITED STATES ZOOLOGICAL PARKS, AQUARIUMS, AND ROADSIDE ATTRACTIONS, NOVEMBER 1977.

Institution	No./Sex	Size	Origin	Remarks
Clyde Peeling's Reptiland Allenwood, Pa.	0/1/0	4'	Unknown	Rec'd from animal dealer about 4-5 years ago.
Oakland Zoo Oakland, Calif.	0/0/1	unknown	Unknown	Did not respond to inquiry.
Rio Grande Zoo Albuquerque, N.M.	0/0/1	3'	Unknown	Rec'd from private donor from New York.
St. Louis Zoo St. Louis, Mo.	1/0/1	male = 9' juvenile = 2'	Unknown	Male rec'd early 1960s; juvenile rec'd as public donation in 1975, stunted.
San Antonio Zoo San Antonio, Texas	1/0/0	7'6"	Unknown	Rec'd from Trinity Univ. graduate student prior to 1970.
Seminole (Okalee) Indian Village Hollywood, Fla.	Unknown	Unknown	Jamaica (?)	Did not respond to inquiry.
Staten Island Zoo Staten Island, N.Y.	1/1/0	3'	Unknown	Rec'd 10/74 from animal dealer.
Steinhardt Aquarium San Francisco, Calif.	0/0/2	5'; 1 1/2'	Unknown	Rec'd as public donations.
Waltzing Waters Aquarama Ft. Myers, Fla.	0/1/0	8'6"	Unknown	Rec'd from Crandon Park Zoo.

A COMMENT CONCERNING THE GENETIC PURITY OF THE WILD POPULATION OF FLORIDA *CROCODYLUS ACUTUS*

King and Krakauer (1966) and others have commented on the exotic herpetofauna which have been introduced in south Florida. In 1966, the spectacled caiman (*Caiman c. crocodilus* and *C. crocodilus fuscus*) occurred in the various canal systems in and adjacent to cities in south Florida. At that time this crocodilian did not appear to be reproducing but presumably was capable of overwintering.

Following the implementation of protective legislation for Florida alligators in the early 1950s, animal dealers began importing South American crocodilians for tourist sales and for use in their mail order businesses (Moore, 1954). In the two decades which followed the number of crocodilians imported each year reached staggering numbers. Importation figures available from the U.S. Fish and Wildlife Service indicate that 4,907,742 reptilians were declared for importation for the three year period 1969-1971. King (1974) determined that of the 2,109,571 reptiles that legally entered the United States in 1970, 112,402 were crocodilians; 105,903, or 94.2%, of them *Caiman crocodilus*. Extrapolating this figure to include the three year figures, it is presumed

that one quarter of a million caimans were imported in that time period.

The majority of crocodilian imports pass through the Miami port-of-entry and are received by south Florida based wildlife importers. It has long been an established practice of overstocked dealers to liberate unwanted animals. Animal escapes from outside holding quarters, too, is a recognized problem. Additionally, disenchanted crocodilian owners have been known to set their pets free in what they consider a suitable home for their unwanted animal. Thus, it is not surprising that many feral Caiman crocodilus have been observed living in the wild in south Florida. Today, a reproducing population occurs within the confines of the Homestead Air Force installation.

Although Crocodylus acutus has never been imported in numbers that in any way are comparable with those of Caiman crocodilus, hundreds have been imported from Jamaica, Colombia, Mexico, and Panama. Many releases of C. acutus are known to have occurred although their documentation is poor. Table 3 includes the information that was made available to the author during the course of the study. The majority of releases are specimens without collection data (their origins are most probably Jamaica,

Colombia, or Mexico) or from localities other than south Florida. For the most part, animals released came from zoological parks and were liberated in the Everglades National Park by Park personnel. There is, however, unsubstantiated evidence that dozens of other C. acutus releases were made by private individuals over the years. The following C. acutus captures and sightings in atypical situations have come to the author's attention and lend weight to the above thesis.

Naples County, 1977, 6' specimen observed vic. Naples on number of occasions by F. Dayhoff.

Indian River County, 1974, adult male caught at Vero Beach and taken to Lion Country Safari, Head, pers. comm.

Indian River County, 1960s, 8' female collected at Vero Beach, Froelich, pers. comm.

Sarasota County, 1953, adult collected near Osprey by Piper Brothers.

Pinellas County, 1947, adult male collected in Tarpon Lake by Bob Trotter, Hamlet, pers. comm.

It is impossible at this point to evaluate the success of these liberated specimens in terms of their ability

to survive and reproduce or to measure their effect on the resident C. acutus population. Ogden (pers. comm.) recalls that several of the zoo-raised American crocodiles which were released in West Lake were occasionally observed after their release. Further, he mentioned that one female nested several times, at least once successfully. Kroll (1977) released a number of zoo-raised American alligators equipped with radio transmitters back into the wild in Texas to study their ability to survive and compete with resident alligator populations. Although the study was troubled with malfunctioning transmitting equipment, it appears that at least a portion of the animals survived.

Considering that Caiman crocodilus has been successful in establishing a reproducing population in south Florida in a situation totally new to the species, the author cannot help but feel that at least some of the Crocodylus acutus specimens which were released in American crocodile habitat have survived and are interbreeding with native C. acutus.

Table 3. CROCODYLUS ACUTUS INTRODUCTIONS INTO FLORIDA WATERS

Date Released	No./Sex	Size	Release Site	Origin	Remarks
15 May 1969	0/3	♀1 7'8 1/2", 111 1/2 lbs.	West Lake	South America(?)	New York Zoological Soc. sent 3 specimens to E.N.P. 14 May 1969. ♀1 received from Carl Herman 1/26/62
		♀2 7'9 1/2", 112 lbs.	Coot Bay	Ecuador	♀2 collected by Herndon Dowling 1/16/62 in Guayas River near Guayaquil, Ecuador
		♀3 6'7", 93 lbs.	West Lake	Mexico	♀3 received from Chas. Chase 6/16/64.
					Info Source: NYZS files; Klukas, in litt.
Nov. 1969	1/0	6'6"	West Lake	Unknown	E.N.P. rec'd spec. from Louisiana State Univ. L.S.U. purchased specimen from animal dealer C.C. McClung, Snake Farm, Laplace, La. Info source: Klukas, in litt.; Coulson, in litt.

Table 3 (continued). CROCODYLUS ACUTUS INTRODUCTIONS INTO FLORIDA WATERS

Date Released	No./Sex	Size	Release Site	Origin	Remarks
1 April 1970	0/1	9'	West Lake	Unknown	E.N.P. rec'd from U.S. National Zoo - 30+ year zoo captive. Info Source: Johnson, pers. comm.; Klukas, in litt.
21 April 1970	0/1	3'6"	West Lake	Unknown	E.N.P. rec'd spec. from William A. Dunson, Penn. State Univ. NYZS spec. sent to Dunson 8/23/66. Originally purchased from Rider Animal Co. 5/6/66. Info Source: NYZS files; Klukas, in litt. Dunson, pers. comm.
6 Oct. 1970	0/0/1	8'-9'	West Lake	Key Largo - 1959 or 60	E.N.P. rec'd fr. Atlanta Zoological Park; released with spaghetti tag #1279 placed in anterior dorsal scute of tail. Info Source: Klukas, in litt.
8 Oct. 1970	0/0/9	610-710 mm, 785-1450 grams	Still Creek	Florida	Two from 1969 eggs and 7 from 1970 eggs. Were pen reared in freshwater pools near E.N.P. headquarters. All were code marked through clipping of tail scutes. Info Source: Klukas, in litt.

Table 3 (continued). CROCODYLUS ACUTUS INTRODUCTIONS INTO FLORIDA WATERS

Date Released	No./Sex	Size	Release Site	Origin	Remarks
15 Nov. 1971	1/1	adults	Creek off Little Madeira, Site #4	Florida(?)	Detroit Zoo originally obtained specimens from Tarpon Zoo which claimed to have collected them in Keys in 1950s. Observed for a couple of months post-release. Info Source: Castle, pers. comm.
1970s	0/0/2	juveniles	unknown	Jamaica	Unknown individual obtained 2 C. acutus from Gatorama in exchange for 2 American alligators. These crocs were released in Fla. waters. Site not mentioned. Info Source: Clemons & Crutchfield, pers. comm.
1970s	unknown	adults	Fisheating Creek	Jamaica	Gatorama has lost many acutus in recent years, have been observed miles from escape site. Info Source: Clemons, Garrick, Hines, pers. comm.

Table 3 (continued). CROCODYLUS ACUTUS INTRODUCTIONS INTO FLORIDA WATERS

Date Released	No./Sex	Size	Release Site	Origin	Remarks
Sept. 1972	1/1	subadults	Florida Bay	Unknown	U.S. National Zoo released spec. in company of E.N.P. staff. Specimens obtained from animal dealer C. Chase (?) in 1968 and thought to be from Jamaica. Info source: Johnson, pers. comm.
1976/77	1/0	14'	Upper Keys	Unknown	Florida Game & Fresh Water Fish Commission released Lion Country Safari long-term captive late in 1976 or early 1977. Info Source: Head, pers. comm.

Crocodylus acutus: PROTECTIVE LEGISLATION AND PERMIT REQUIREMENTS

In the FEDERAL REGISTER of 25 September 1975 (40 FR 44149-44151), the United States population of the American crocodile (*Crocodylus acutus*) was listed as an Endangered Species, as defined by the Endangered Species Act of 1973 (16 U.S.C. 1531-1543; 87 Stat. 884). Regulations which implement the Act appear in the Code of Federal Regulations, Title 50, Chapter 1, Subchapter B. Pursuant to Section 7 of the Act, the Director of the U.S. Fish and Wildlife Service, upon review of relevant comments and information obtained by the Service, determined Critical Habitat for the American crocodile (41 FR 41914-41915) on 24 February 1976.

The Endangered Species Act of 1973 supplants the previous Endangered Species Conservation Act of 1969 (16 U.S.C. 668cc-1 to 6, 83 Stat. 275). This Act serves to provide a means whereby the ecosystems upon which Endangered and Threatened species depend may be conserved, to provide a program for the conservation of Endangered and Threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions in which the United States has pledged its support for the conservation of wild flora and fauna worldwide.

With respect to Endangered Species (ex. Crocodylus acutus), the regulations governing the Act declare that it is unlawful for any person to import, export, sell or ship in interstate or foreign commerce, or harass, harm, or capture, any such species. These restrictions apply to both living and dead specimens, as well as products made from them. However, the Director of the Fish and Wildlife Service may issue a permit authorizing any activity otherwise prohibited by the Act, for scientific research or for enhancing the propagation or survival of endangered wildlife. Applications for permits must be submitted to the Director on an official application form (Form 3-200) provided by the Service.

American crocodiles held by a public zoo (municipal, county, state or federal zoo, or non-profit institution) on 28 December 1973 are excluded from the prohibitions. Endangered species held on 28 December 1973 by commercial zoos (those operated for profit) are, however, subject to the prohibitions. When American crocodiles which are exempt from the prohibitions of the Act are shipped interstate, documentary evidence supporting their pre-Act status should be included with the shipment. Pre-Act American crocodiles, may be shipped in interstate commerce where the purpose of such shipment is to place the animal on loan to another individual, agency, or institution. If the recipient later obtains a permit under the Act, the animal may be legally

purchased. Institutions may likewise ship pre-Act animals as bona fide gifts to another party without a permit.

The reviewer's survey of Crocodylus acutus in captivity in the U.S. indicates that all known captive specimens of Florida origin are pre-Act specimens and are presently found in commercial roadside attractions in the State of Florida. As such, they can be moved within the State of Florida, whether the transaction is commercial or not, without a Federal Endangered Species Permit. Such activity, however, is subject to the issuance of a state permit by the Director of the Florida Game and Fresh Water Fish Commission. If Florida C. acutus are found in a captive situation outside of the State, permits may be required to export the animal from the state in question. The legislatures of numerous states have introduced bills or have passed laws affecting animal transactions; California, Connecticut, Florida, Georgia, Hawaii, Illinois, Maryland, Massachusetts, Michigan, New York, Pennsylvania, South Carolina, and Texas are among the states that do so.

Although it is unlawful to take wild American crocodiles in Florida waters, employees of the National Park Service, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and Florida Game and Fresh Water Fisheries Commission, who are designated by their agency for such purposes, may, when acting in the course of official duty,

take injured or sick specimens or remove nuisance animals without obtaining a Federal Permit. Such activity must be reported in writing to the Fish and Wildlife Service within five days after capture. The specimens may only be retained in accordance with directions from the Service.

REVIEW OF EXISTING FACILITIES -- THEIR SUITABILITY AND AVAILABILITY -- AND SITE, PLAN AND MANAGEMENT RECOMMENDATIONS FOR A CAPTIVE PROPAGATION FACILITY FOR AMERICAN CROCODILES

During the course of the study, the author received a multitude of suggestions concerning potential sites for implementing an American crocodile captive breeding program. All suggestions were evaluated. Basic considerations for reviewing the candidacy of a site included geographical locality, climate, security from severe tropical storms, quantity and accessibility of land available and the structure of its present ownership, developmental and operational expenses, availability of inexpensive crocodilian food supply, and the logistics of moving crocodilians to and from the program site. For purposes of site review, the author presupposed that a given site had to be able to accommodate a minimum of four breeding pairs of American crocodiles.

The review of crocodilians bred in captivity in the previous section serves to illustrate that the overwhelming majority of successful breedings occurred within a given species' natural range or under similar climatological conditions. Except for Atlanta Zoo's two *Crocodylus acutus* breedings, all other known successful breedings have occurred in south Florida or elsewhere with the species' natural range. While it appears that satisfactory breeding facilities could be developed in situations other than in south Florida, very few U.S. localities have climates satisfactory for maintaining a breeding group of American crocodiles without prohibitively expensive environmental modifiers.

With respect to thermoregulatory requirements, Florida *C. acutus* are most likely near the lower limit of their activity range and existing temperatures have prohibited their dispersal northward. Circumstantial evidence suggests that crocodylids (Pooley, 1969; Neill, 1971) are more sensitive to low temperatures than alligatorids (Kennedy and Brockman, 1965; Parsons and Huggins, 1965; Lowe, et al. 1971; Medem, 1971b). Under suboptimal temperatures, zoos experience greater difficulty maintaining crocodiles than they do alligators and caimans (Brazaitis, pers. comm.; Behler, pers. obs.). Thus, the author feels very strongly that any program for

breeding C. acutus should take full advantage of the climatological offerings of south Florida.

In addition to temperature advantages, water, land, construction and manpower expenses in Florida are substantially less than those in more temperate situations. All captive American crocodiles of known or suspected Florida origin are currently found within Florida's borders and may move intra-state without a Federal Endangered Species Permit. And, quality crocodilian food is readily available and inexpensive.

For the above-mentioned reasons, facilities located north of Florida Route 70 (running east-west immediately north of Lake Okeechobee) were not seriously considered. Those sites which merited consideration included three roadside attractions, a zoological park, a national reserve, a breeding center for primates, a Dade County Port Authority facility, and a nuclear power plant. The suitability of each is briefly reviewed below:

1) Everglades Wonder Gardens, located on U.S. 41 in Bonita Springs, Lee County; owned and operated by Bill and Les Piper.
   Size of Property: approximately 4-5 acres.
   Present facility: A single spring-fed, cement pool with a square concrete haul-out area in center housing about 20 American crocodiles. A 20' x 20' sand pit is situated adjacent to

the pool. Several small display facilities are scattered about attraction.

Present potential: With modification, present pool can accommodate a single pair of breeding C. acutus.

Future potential: While the site offers considerable security from hurricane waters, an ample supply of spring water, approximately 20 Florida American crocodiles, and is in close proximity to an abundant crocodile food source; modification of the attraction into a propagation facility to accommodate a minimum number of breeding crocodiles would be extremely difficult, impractical and unjustifiably expensive.

Remarks: The attraction has not been improved or updated in recent years, and Les Piper remarked that they planned to close the attraction in the near future.

2) Everglades Nature Center (Everglades Safari), located at 26700 Tamiami Trail, 20 miles west of Palmetto Expressway on south side of Rt. 41, Dade County; owned by Rick Farace, operated by Joe Wasilewski.

Size of property: 10 acres of which approximately 4 would be available.

Present facility: Includes a vacant 18' deep 1 acre pond, a small inexpensively fenced enclosure holding a breeding pair of American alligators, a small building with reptile displays. Owner manages air boat ride and restaurant on same property. Property bordered by canal.

Present potential: With perimeter fencing, pond can probably accommodate 1/2 adults.

Future potential: The site offers an ample water supply, security from severe tropical storms, and an available supply of crocodile food, modification of existing pond would have to be extensive to accommodate a minimum number of breeding crocodiles. Dividing the modified pond into management units would be difficult. Additionally, the owner envisions putting a monorail around the perimeter of his acreage. While the owner expressed a great desire to provide space for an American crocodile breeding program, it is not offered altruistically, since he would expect the facility to increase his

attendance. The public disruption factor would be great, management difficult, and the program handicapped by a multitude of interactions between program supervisor and landowner.

3) Gatorama, located on U.S. Rt. 27 in Palmdale, Glades County; owned and operated by Cecil Clemons.

Size of property: 16+ acres.

Present facility: Includes a deep well-fed pond approximately three acres in size and divided into two sections (one side housing perhaps 150 American alligators, the other perhaps 40 Jamaican American crocodiles). Approximately one dozen, various sized, cinder block walled enclosures house assorted adult and juvenile crocodilians. Large facility surrounded by an unburied, chain-link fence. The existing perimeter fence does not restrict animals to their enclosure as a number have escaped over and under fencing into adjacent facilities and into Fisheating Creek. Owner claims his facility housed about 200 American crocodiles in recent years. If so, the number which may have escaped is substantial.

Future potential: The site offers a sufficient water supply, security from tropical storms, and

a readily available supply of inexpensive crocodile food. Modification of existing facility to accommodate a significant breeding program (6/8 animals) would require replacement of existing fencing with escape-proof materials, drainage and some dredging of ponds, and creation of nesting areas. The existing collection of crocodilians would have to be relocated (unless a small group of Jamaican American crocodiles was retained for breeding purposes). This may prove to be quite difficult.

While Gatorama does not provide excellent management facilities now, the size of the facility is sufficient to improve the majority of existing deficiencies. The property also includes residential quarters and space for research work and is available.

Remarks: It appears that, for reasons of health, very low attendance, and lack of hired help, Cecil Clemons will be forced to close Gatorama in the near future. Clemons claims that he is in financial trouble and plans to sell the attraction as soon as he finds a buyer. He has offered the farm to various persons for $100,000 to $500,000 and claims to have been offered $1 million for his "farm" about five or so years ago. Realistically,

an appraisal of the property and facilities will show that its value does not exceed $85,000. No value has been placed on the animal stock. Disposal of the majority of crocodilians (i.e. - Jamaican American crocodiles and American alligators) would be difficult. The state of Florida would be reluctant to have pen-raised alligators released because of their potential threat to humans. There is no real market for adult Jamaican C. acutus and, while a reintroduction (in Jamaica) scheme is possible, the financial burden would be great. Under no circumstances should liberation into Florida waters be considered.

4) Dade County Zoo development site, located 16 miles west of central Miami and bordered by S.W. 152nd Street, S.W. 184th St., S.W. 122nd Ave., and S.W. 137th Ave., southern Dade County (unincorporated). The land is a portion of the former Richmond Naval Air Station.

Size of property: 740 acres.

Present facility: park, although slated for completion several years ago, is in early stages of development. Among the few facilites which have been constructed are ten 40' x 40' enclosures to house crocodiles. Approximately 50% of each enclosure is a pool 8'-10' deep. Facilities are insufficient for breeding purposes and poorly designed for maintenance. At

present, only 1 pool/day can be drained and filled. Site is part of the Atlantic coastal or pineland ridge, 9'-12' above sea level, and secure from hurricane waters. Water supply not well developed and antiquated, very low water pressure. Dade County's water and sewer service connections will not be completed until the end of 1979 at the earliest. Wells are to be dug later so that untreated ground water can be used for animal pond and irrigation usage.

Present potential: The existing facilities do not offer a realistic opportunity to breed American crocodiles.

Future potential: Sufficient water should be available from constructed well. Zoo site is located on flat land which currently supports the largest remaining stand of Dade County pine (*Pinus elliotti hardwoodi*) and several disturbed soil sites would seemingly offer an excellent opportunity to develop a crocodilian propagation project. It is doubtful whether housing would be available on county property. Housing in nearby residential communities would be expensive. The history of the new parks development is cluttered with political problems. The present staff (i.e. Crandon Park) which would be available for an on-site crocodile breeding program are not suitably trained and conflicts would arise between program and non-crocodile program personnel.

Remarks: Confidentially, several of Crandon Park's administrative staff expressed doubt that the new zoo would ever become a reality. A chief administrator is, despite public claims to the contrary, not interested in an American crocodile breeding program. The development of the "Dade County Zoo" is fraught with problems and does not presently represent a health environment for developing additional programs.

5) Big Cypress National Reserve, offices located at 850 Central Avenue, Naples, Collier County.

Size of property: 280,000+ acres, includes approximately 15,000 tracts; ultimate size 570,000 acres.

Development potential: Numerous sites of sufficient size suitable for developing a significant crocodile breeding facility, which have an ample supply of water on a year-round basis, are hurricane water secure, and have housing facilities in close proximity (Schell and Dayhoff, pers. comm.). Potential sites situated along U.S. 41, state roads 839 and 841, Turner Road. Attention was also drawn to Ochopee area. Advantages to developing a federally-sponsored crocodile breeding program on Big Cypress lands are: use of previously purchased property and accommodations for housing. Any modification of land would require a NEPA statement.

Remarks: It is the opinion of the author that the development of an American crocodile propagation project within Big Cypress boundaries would be in concert with the Reserve's operating philosophy. Reserve personnel were very positive to the idea of such a program within the Reserve.

6) Florida Primate Center, 1319 San Mateo, Ft. Myers, Lee County; sponsored by University of Georgia, George Huggins, co-director.

Size of property: 60 acres.

Present facility: abundant water supply, a complex canal system dividing primate breeding areas.

Development potential: At present there is no opportunity to develop a crocodile breeding program of any description at the Center, Huggins, pers. comm.

7) Dade County Port Authority Jetport Training Facility, located north of U.S. 41 and west of canal L-28.

Size of property: not determined.

Present facility: property has a number of scattered quarry pits partially filled with water; five offer some potential for housing crocodilians. No housing facility available on site.

Development potential: Utilization of pits not considered practical for both monetary and management reasons. Availability of land not determined.

8) Florida Power and Light Company, Turkey Point cooling canals, located 1/2 mile north of Card Point, Card Sound, Dade County.

Size of property: several square miles -- not determined.

Present facilities: Turkey Point plant has an intricate cooling canal system as well as several isolated canals immediately north of the cooling system.

Development potential: the cooling canals appear to be unsatisfactory because of size and environmental conditions for development of a program. Isolated canals to the north of the system are approximately 400 m x 65 m and 1-2m in depth. Salinity rates are 1-4 ppt. Developing a management program would present some obstacles but could be overcome. Site does not appear to offer adequate protection from hurricane waters. Crocodilian food supply locally available.

Remarks: Florida Power and Light has not been receptive to crocodilian breeding project proposals in the past. The author was informed that while Turkey Point's isolated canals could be available to use of a crocodile program, they saw only intangible benefits. The attitudes expressed are summarized in the statement: "If you can assist us in demonstrating that implementation of such a program would work positively towards the licensing of the site

(FPL's proposed power plant - south Dade site) then I could argue very persuasively in your behalf," Wilcox, in litt.

Of the aforementioned sites, only two, in the opinion of the author, should be considered as suitable sites for a federally sponsored program to establish a captive propagation facility for American crocodiles. Logistically, a tract within Big Cypress National Reserve stands out above the others for it appears to meet all the criteria used for evaluation of potential sites. Gatorama, because of its size, availability, and present facilities for crocodilians as well as for managerial quarters, ranked second. If, however, a tract within Big Cypress cannot be utilized, the best alternative would be acquisition of property equalling five acres, or preferably larger, with an existing residence of management staff.

During the course of the study, the author considered existing bodies of water such as the numerous pits, canals and other man-made water reservoirs within Big Cypress as potential sites for developing a facility for maintaining a breeding stock of Crocodylus acutus. Unfortunately, the development of a facility around any one of these bodies of water cannot be justified in terms of cost effectiveness or in animal management logistics. The best option is to totally develop a facility on a property of suitable size with a good source of water and with existing accommodations

for management personnel. Figure 1 (Theoretical American Crocodile Propagation Facility) illustrates a theoretical crocodilian breeding facility which makes maximum use of space and allows for an intensive management program.

The facility is designed to accommodate 14 adult animals as well as to provide spacious quarters for rearing offspring to a size deemed suitable for restocking. Each of the four breeding pens equals approximately .52 acres and has a water surface measuring in excess of .15 acres. Stocking rates are one male and two females per enclosure.

Working with adult American alligators (Alligator mississippiensis) at Rockefeller Refuge, Joanen and McNease (1975) achieved successful stocking rates of one male to 2-4 females in three .5 acre enclosures. Water area in the .5 acre enclosures ranged from .09 - .18 acres (x = .12) with approximately .04 acres available per stocked female. All enclosures supported natural vegetation.

Examination of their stocking data for six experimental pens, measuring 1/2 acre to two acres in size, indicates that a safer stocking rate (in terms of fighting/mortality risks) is 1.2 animals/enclosure. When crowded, both males and females engaged in fighting or escape attempts. Stocking rates became fixed in all enclosures (eg. 1.2 to 1.4 animals/

Figure 1.

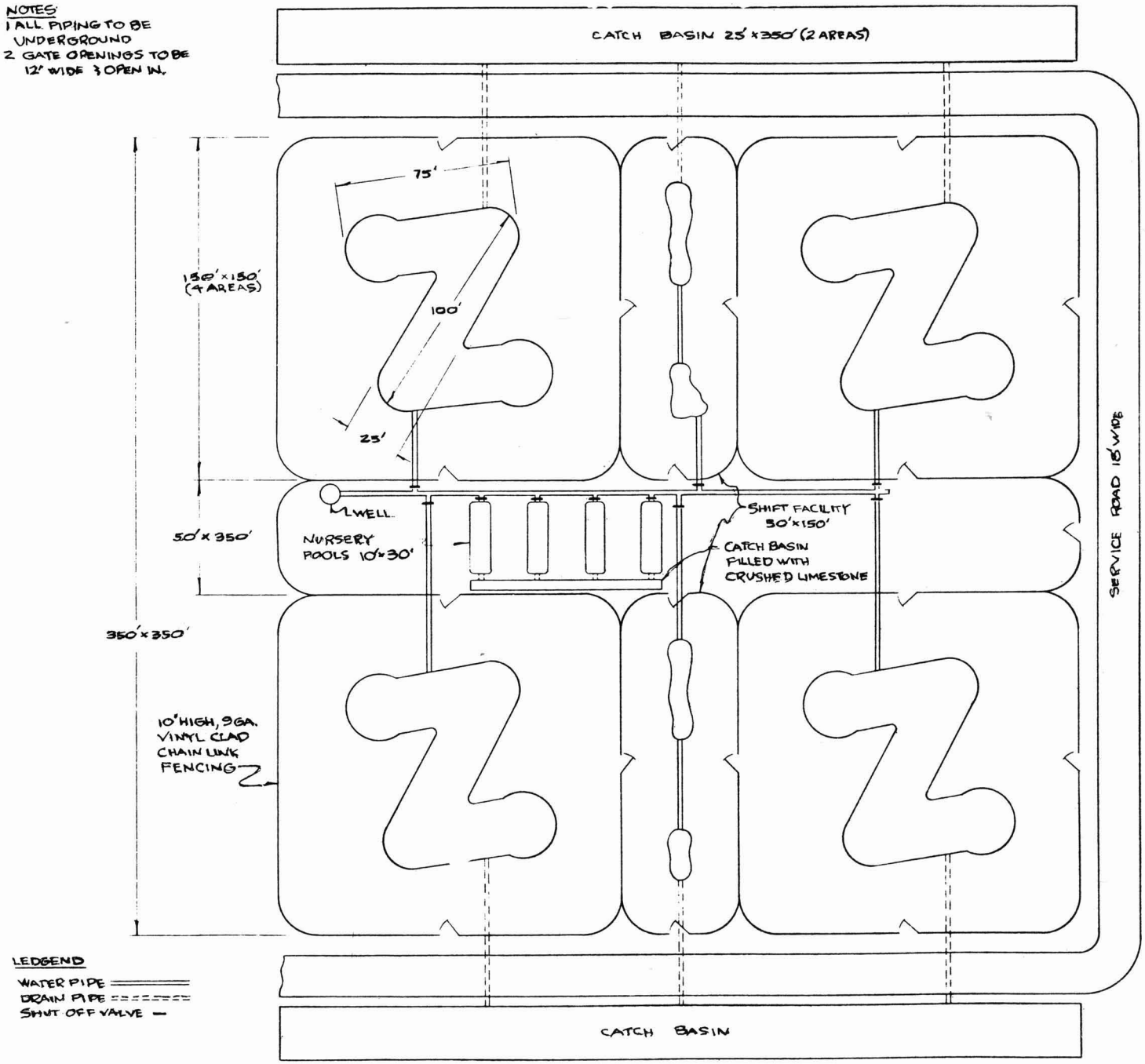

FIG 1 THEORETICAL AMERICAN CROCODILE PROPAGATION FACILITY

SCALE: 3" = 100'

.5 acre enclosure) and any additions to the group resulted in fighting and death or escape of introduced animals. Only the largest enclosure, measuring 2.07 acres, supported two males. Captive male alligators required seven times more area than females and two males successfully housed together required four times the area as a single male. Joanen and McNease's (1971) earlier studies with .25 acre enclosures indicated a maximum stocking rate of 1.1 American alligators.

Similar successful stocking ratios have been found for crocodylids. At Papua New Guinea's Moitaka Crocodile Farm, nesting of saltwater crocodiles (Crocodylus porosus) and New Guinea crocodiles (Crocodylus novaeguineae) has occurred in enclosures ranging from less than .25 acre to more than 2 acres. Only one adult male is able to be successfully housed per enclosure (Behler, pers. obs.) during the nesting season. Pooley (1977) observed considerable fighting between two adult male Nile crocodiles, C. niloticus, sharing a .79 acre enclosure with an adult female and six subadults (3 males, 3 females). The subordinate adult male was killed. Subadult males were also repeatedly attacked and were forced to seek refuge in the smallest of the three ponds within the enclosure. Lang (1975) reports that three dominant American crocodiles divide Gatorama's three acre

lake into three territories during the breeding season. He notes that while fighting is rarely seen, subordinate males are often excluded from the territories of the dominant males. Females were observed to move from one territory to the next with impunity.

Crocodilians, discussed in an earlier section, occasionally nest under crowded zoological park conditions and within enclosures significantly smaller than .5 acres. Essentially, however, multiple nesting is not taking place within these limited confines. Joanen and McNease (1975) report a nesting rate of 50% among their captive female American alligators. Other crocodilian "farms" cannot boast of similar successes. Under the crowded conditions at Gatorama, Clemons (pers. comm.) mentions that he gets a couple of American crocodile and American alligator nests each year. Nesting success does not exceed 20%.

To reliably breed crocodiles sufficient land and aquatic space must be provided for animals to socialize in a normal fashion. One-half acre enclosures with .15 acre of water/female is recommended. Pools should be designed so that females may visually separate themselves from one another and graded to a maximum depth of at least 1.5 m. Large crocodilians, for the most part, breed in open water which is

a meter or more in depth (King and Dobbs, 1975; Yangprapakorn et al., 1971; Joanen and McNease, 1970, 1972). The 6' pool depth figure given in the specifications for the theoretical crocodilian facility provides sufficient depth for breeding activities and provides the crocodiles with a secure retreat during adverse weather conditions or when disturbed by humans.

In addition to the four breeding pens, the theoretical facility provides two 150' x 50' shift units to accommodate an injured animal, a new arrival being conditioned, an extra male, or any adult animal which must be segregated from others, All pens are designed to be escape-proof and require very low maintenance (see specifications). Note that two feet of fencing is buried, above ground-level the fencing is equipped with a galvanized sheet metal guard and has rounded corners. Specified fencing is extremely resistant to south Florida's weather conditions and should not need replacement for at least twenty-five years.

Nursery and incubation facilities should be developed within the interior of the complex in the space provided. Design of the facility should incorporate the suggestions of Pooley (1969, 1971) as well as pertinent information contained in the crocodilian husbandry references cited by Downes (1973).

THEORETICAL AMERICAN CROCODILE PROPAGATION FACILITY

Specifications for facility to accommodate 6/8 adult animals (stocking rate/large enclosure = 1/2 animals).

1) Land requirements: breeding facility as designed requires approximately 5 acres of land.

2) Enclosures: (4) 150' x 150' breeding pens equalling approximately .52 acres; (2) 50' x 150' holding or shift pens equalling approximately .17 acres; (4) 10' x 30' rearing or nursery pens.

3) Pools: all earth-bottomed; pools in the four breeding pens each to equal 250' in length (as shown in Fig. 1), 25' in width, and tapered to a maximum of 6' in depth; 2 pools in each of the 2 holding facilities to equal 60' x 25' x 4' and 20' x 25' x 4'; one pool in each of the four nursery pens to equal approximately 6' x 20' and tapered to 2' in depth.

4) Fencing: 10' high #9 gauge Anchor Permafused vinyl-coated wire (chain-link); to prevent escapes, bottom 2' buried and top 2' covered with #24 galvanized sheet metal (wired to inside surface of fencing);

all fence angles rounded to prevent crocs from gaining purchase in enclosure corners; 45° angle extension arms (angled outward) with 3 strands of barbed wire attached to top of fence to thwart human intruders (optional). Each enclosure serviced through 12' wide swing gates as illustrated in Fig. 1.

5) Water supply: 4" well approximately 50' deep, equipped with a 4" submersible pump rated at 250-770 gph. All plumbing pvc. 2" main feed line; 1 1/2" lines to pools in large enclosures; 3/4" lines to nursery pools. All distribution lines fitted with pvc ball shut-off valves.

6) Waste water disposal: carried from breeding and holding facility ponds via 4" pvc drain lines to shallow tapered catch basin (size of which is relative to existing conditions); 2" pvc overflow piping to drain nursery pools to stone-filled catch basin (size determined after percolation test).

7) Service road: dirt, 12' to 18' wide, around 3 sides of facility as figured.

serve as a model around which other crocodilian conservation programs could be developed.

8) Selection of breeding stock: The Florida population of American crocodiles is not considered to be taxonomically distinct from populations occurring elsewhere. Various populations, however, do exhibit some morphological differences which merit investigation. Until such time as a thorough review of the taxonomic status of *Crocodylus acutus* has been undertaken, the only breeding stock which should be considered for recruitment are those animals derived from the Florida population. Potential commercial sources appear elsewhere in this report. To initiate the breeding scheme, it is recommended that 4.8 animals be purchased from available long-term, captive Florida *Crocodylus acutus* stock. Extreme care should be taken in selecting healthy stock which do not exhibit signs of senescence. Female stock selected for a given enclosure should be of similar size and mass; males should be larger than the females.

9) Equipment needs: A pickup truck (used) is required for transporting stock, food supplies, and needed materials. additional equipment needs include several heavy-duty, nylon cargo nets, ropes, canvas tarps, incubator media, assorted shovels, maintenance tools, and environmental monitoring equipment. Five thousand dollars should be

budgeted for equipment for the first year's operation.

10) Crocodile food requirements: The diet of wild American crocodiles has not been closely scrutinized. Neill (1971) notes that its principal food is fishes and reports that the stomach of a Honduras specimen contained assorted fishes, hair, hooves, and turtle shell fragments, while a Jamaican animal was found to contain fishes, crabs, birds and dogs. Clemons (pers. comm.) stated that crocodile stomachs which he examined in Jamaica contained primarily crabs and lesser amounts of fish. Additionally, he observed many crabs, a raccoon, and a few mullet in the stomach contents of an 11' Florida Bay male killed years ago. Ogden (pers. comm.) related that *C. acutus* were blue crab-eaters and remarked that East Creek fishermen told him they observed crocodiles hitting schools of mullet. In captivity, American crocodiles have been maintained in good health on a diet of rough fishes, road-kills consisting mainly of raccoon, opossum, armadillo and chicken refuse (Clemons, pers. comm.). At the New York Zoological Park, American crocodiles fed eviscerated fish, rats, horse liver, beef ribs, occasionally small chickens, a multi-vitamin and vitamin E supplement grew rapidly.

South Florida has excellent sources of suitable and inexpensive crocodile food. In addition to animal remains from laughtering facilities, rough fish may be purchased inexpensively from salt and freshwater fisheries as well as shrimp fleets operating out of Homestead, Tavernier, Key West, Naples, Fort Myers, and Lake Okeechobee. Additionally, fresh roadkills can and should be utilized. Joanen and McNease (1975) reported feeding their captive breeding American alligators at a rate of 7-8% body weight/week during the summer months. South Florida-maintained crocodiles should require lesser amounts of food because of the higher average temperatures and resulting increased efficiency of digestion. For purposes of calculating annual food costs, the following figure (considered very generous) is based on a 7% body weight figure (assuming average adult weight equals 180 lbs.), food averaging $.10/lb., and fed 48 weeks/year.

Annual crocodile food budget = (180) x (.07) x (12) x (48) x (.10) = $725.76.

11) Annual egg production: Assuming a population of eight females with a 50% nesting rate the second year of the program, total egg production would be expected to equal 176

(4 x 44 eggs/clutch) (Ogden, 1978). Ogden reports an approximate hatch rate of 47% for nests which were not preyed upon by predators or subjected to adverse environmental factors. Inasmuch as egg mortality is high in natural or quasi-natural situations, artificial incubation should be employed to advert predation and extreme environmental condition losses. Bustard (1971), Chabreck (1971), Chaffee (1969), Joanen (1975), Pooley (1971), Kimura (1972, and others have commented on satisfactory methods for incubating crocodilian eggs. Assuming a 40%-50% hatching success for all eggs (including infertile eggs), the program would yield 70-80 hatchlings or 17.5-20% of the highest current estimate of the total American population.

12) Rearing. Rearing American crocodiles, like most hatchling crocodilians, present no special problems and mortality rates can be kept to less than 10%/year. Pooley (1971), King and Dobbs (1975), Joanen and McNease (1974), Coulson, Coulson and Hernandez (1973), and numerous others have commented on successful rearing techniques.

Assuming that the bulk of the hatchling population is being reared for release back into the wild, specimens should be retained in a controlled situation until they are large enough to cope with their principal predator, the raccoon.

At the same time, serious consideration should be given to potential release situations and environmental conditions which juveniles would face. Preconditioning to anticipated conditions should be a significant part of the rearing schedule.

13) Salinity requirements: Wild populations of American crocodiles are found in waters which exhibit dramatic differences in salinity rates. Noble (1923) found American crocodiles in Lago Enriquillo, Dominican Republic. Salinity here is 50% greater than seawater. Neill (1958) observed the same species in the freshwaters of Cuba's Cienaga de Zapata. Other freshwater populations are known to occur on Barro Colorado Island, Canal Zone; near San Blas, Nayarit, Mexico; and numerous rivers through the species' range in South America.

Grant's (1940) contention that young *Crocodylus acutus* would not survive in freshwater is obviously in error. Dunson (1970) and Evans and Ellis (1977) present evidence that hatchling American crocodiles do not tolerate sea water and lose weight relatively quickly. Accordingly, Underwood (1950) found that *C. acutus* maintained in saltwater perished within a few days and animals kept in freshwater survived.

On the other hand, recent telemetry studies of hatchlings by Lang (1975, in litt.) indicated that they tolerated salinities of 36-41 ppt well and weight loss was negligible.

While it is not within the purposes of this report to add to the existing controversy over the hatchling crocodilians' ability to handle salt loads or to be directly concerned with the physiological mechanisms involved in dealing with excess sodium, the author recognizes the need for exposing juveniles to a salinity gradient in which they could auto-regulate. The size at which animals should be exposed or the duration has not been determined. Florida Power and Light's Turkey Point facility has several isolated canals north of their cooling system which are approximately 400 m x 65 m and 1-2m in depth. Current salinity rates are 1-4 ppt. Several earthen dikes could be constructed and saltwater pumped from the nearby canal system to create a significant salinity gradient (Wilcox, in litt.). Smaller canals in Homestead Air Force Base are also known to have a salinity gradient (Campbell, pers. comm.). The availability of each and logistics of developing a head start program there would have to be determined. It is essential that current studies investigating the salt handling mechanisms in crocodiles continue so that missing information can be incorporated into the pre-release program.

14) Staffing requirements:

Facility Manager: Implementation and direction of the American crocodile propagation facility as described requires a full-time "facility manager" to initially oversee construction activities, finalize arrangements for transport of program animals, and supervise the station's day-to-day operations. He should take direction from the institutional authority supervising the project and expenditure of funds. Suggested salary is $14,000/year, fringe benefits equalling approximately 30% addition to salary ($4,200), housing and vehicle (pick-up truck) required for facility operations.

Assistant to Facility Manager: The facility manager would require the part-time assistance of a competent crocodile maintainer to help with feeding and routine chores within the confines of the propagation or shift enclosures. The assistant would have to be available on a two day/week basis and on short notice to assist manager with emergency situations. Suggested salary is $6,000/year, no fringe benefits or housing allotment.

Additional manpower: On occasion, the manager would require additional manpower for facility operations. During the initial stages of operation, he should recruit potential part-time help with the necessary talents required to assist with structured operations as well as emergency situations. Allocations for additional part-time services -- $3,000.

Institutional supervision: The manager of the American crocodile facility should be supervised by a recognized institution with crocodilian biologists on its staff. Project funds would be administered by the institution. Appropriate staff would have to be available to consult with the facility manager with respect to animal management and all aspects of research activities carried on at the facility. A minimum of six visits per year by institutional crocodilian management experts is recommended. Visitations to the propagation facility by recognized crocodilian experts are to be encouraged and accommodations should be provided at the institution's expense during their stay at the facility. Allocation for institutional supervisory services including travel, telephone, clerical, contingency and administration of funding expenses -- $4,500.

Availability of personnel

Institutional Supervisor

The New York Zoological Society supports a large, international conservation program. One of its primary interests is stemming the decline of the world's crocodilians. To this end, the Society has played an integral role in bringing the desperate plight of crocodilians to the attention of wildlife managers, legislators, conservation groups, and the general public on an international basis. As a result, many pieces of protective legislation have been passed, parks created, conservation programs of many descriptions initiated, meaningful ecological studies undertaken; and the plight of crocodilians is now publically recognized. The Society has been more deeply involved in crocodilian affairs than any other institution and is the logical choice to develop and execute the program. Three full-time staff members of the Society have extensive backgrounds in various aspects of crocodilian work. Numerous notable wildlife managers and biologists have received funding from the Society and could be called upon to provide input to the development of a captive propagation program for American crocodiles.

Facility Manager

Candidates for the facility manager position should hold a bachelor's degree in biological sciences, have a history of working with crocodilians, and be familiar with standard reptilian maintenance and propagation procedures. The candidate would have to share the philosophy of the supervisory institution. If the New York Zoological Society should direct the program, it would assume the responsibility of screening potential candidates and provide a training program for the selected individual.

Qualified candidates are presently available from among the curatorial staffs of zoological parks. Several curators have expressed interest in the project and would apply for the position should it become available. Additional candidates would be recruited through advertisement in the monthly newsletter of the American Association of Zoological Parks and Aquariums, from federal and state wildlife management personnel, and from colleges and universities offering herpetological training.

DISCUSSION

Crocodilians, like the majority of the world's large carnivores, are endangered. Through the efforts of the International Union for the Conservation of Nature and Natural Resources, The World Wildlife Fund, New York Zoological Society, and the diligent work of a handful of crocodilian experts, nations have become increasingly aware of the role crocodilians play in their ecosystems and the economic benefits -- either direct or indirect -- derived from these vanishing forms. Despite their endangered status, it is possible to restore wild crocodilians to levels which permit them to perform their normal role in the ecosystem.

Protective legislation is a logical first step in restoring the resource. The American alligator, considered to be an endangered species in the recent past, has recovered as a result of legislative measures instituted in the late 1960s and early 1970s. Today, the species no longer is considered endangered. A combination of management schemes and protective legislation effected this recovery.

Clearly there is no effective single-solution approach which will rescue any endangered crocodilian. A successful conservation program may well involve a combination of

rigorous enforcement of protective legislation; establishment of national parks or sanctuaries; creation of management and recovery plans; development of captive propagation facilities for rearing animals for restocking depleted habitat; basic autecological studies; commercial farming to supply hides to the international trade; a moratorium on hunting; and an intensive regional education program.

Recognizing the declining status of the Florida population of the American crocodile, U.S. authorities listed the crocodilian as an Endangered Species and shortly thereafter determined its Critical Habitat. These actions received the endorsement and support of the International Union for the Conservation of Nature and Natural Resources' Survival Service Commission's Crocodile Specialist Group. This Group has requested that all populations of the American crocodile be transferred to Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora; action which would prohibit any trade in the species except under special permit. Recently, the Crocodile Specialist Group has given the American crocodile and other marine and estuarine crocodilians special priority by developing a sub-programme for their conservation under the IUCN/WWF SEAS MUST LIVE campaign. Specific programs currently being

developed include a survey of the extant populations of Crocodylus acutus and distribution of suitable habitat in the Dominican Republic which should yield data on restocking areas and designating new sanctuaries; a conservation program for C. acutus and C. rhombifer in Cuba and the Isle of Pines; a survey of C. acutus in the Pacific coast estuaries of Central America for the purpose of protecting remaining populations and recommending new management programs for wild populations; a survey of C. acutus in Peru and Ecuador; and a two year ecological study of C. acutus and C. moreletii for the purpose of designating populations and habitat which could be protected in sanctuaries, to develop and expedite a management program for the wild populations, and advising on the establishment of farms for the species.

Captive propagation, long an accepted wildlife management method for assisting vanishing mammals and birds, is playing an increasingly important role in crocodile conservation and management programs initiated by private as well as state and national governments. The IUCN, WWF, UNDP, FAO and other environmental and developmental organizations have captive breeding or rearing schemes which are part of a broad-based conservation effort for crocodilians in Africa, Papua New Guinea, India, the United States, and several Central and South American countries. The establishment of a federally sponsored Florida American crocodile propagation

(whether it assumes the dimensions of a simple rearing station for hatching wild eggs and raising young for release, or a full-fledged captive breeding facility for holding and protecting a genetic reserve of the Florida population and producing young for restocking and research) will unquestionably be consistent with the international efforts to conserve crocodilians. It, too, will augment the aforementioned developing programs for the American crocodile.

The ultimate objective of the National Park Service and the American Crocodile Recovery Team's programs for Crocodylus acutus is to prevent the extinction of the species in south Florida. It appears that the development of a secure facility housing a self-reproducing stock of Florida American crocodiles is a logical secondary step toward meeting this objective. In addition to providing animals for restocking and research purposes, a propagation facility would serve as a center to relocate problem or injured crocodilians and eggs from doomed nests could be relocated to the station for incubation. Opportunities for investigating reproductive biology, behavior, diet and growth, and captive management would be open. Perhaps later, the operation could be expanded, through numerous funding channels, to provide quarters for

breeding groups of other endangered crocodilians. The captive propagation program for south Florida crocodiles would achieve world recognition and serve as a model around which other countries could develop parallel crocodilian conservation programs.

SUMMARY

- Current evidence suggests that there is something drastically wrong with the Florida American crocodile population. While answers to causes may be forthcoming within the next several years, corrective action will undoubtedly take years. An interim captive propagation program would insure the survival of Florida *Crocodylus acutus* stock against catastrophic loss, provide animals for restocking and research purposes, and be consistent with national and international efforts to conserve crocodilians.

- South Florida, in terms of climatological considerations, availability of freshwater and land, construction and manpower expenses, presents the best opportunity to develop a captive propagation facility for American crocodiles.

- Three roadside attractions, a national reserve, a breeding center for primates, a Port Authority facility, and a nuclear power plant were reviewed for their suitability as potential sites to develop a captive propagation facility. Logistically, a tract within the Big Cypress National Reserve appears to be the most suitable. The best

alternative is acquisition of a parcel of undeveloped land equalling 5 or more acres in size. Gatorama is available for acquisition and clearly has potential but it also has recognizable drawbacks.

- There does not appear to be an opportunity at existing zoological park facilities to develop a significant captive breeding program for American crocodiles.

- Development of a new facility to accommodate and intensively manage twelve adult C. acutus (4.8) is recommended. Plans describing a theoretical physical plant; its development and initial operating costs; staffing needs, and management scheme are provided.

- The author recognizes the need for exposing juveniles slated for restocking to a salinity gradient in which they can autoregulate. While several existing sites offer potential, their availability has not been determined.

- At the present time there are no serious efforts to propagate the American crocodile within the United States.

- The present level of captive propagation of crocodilian technology indicates that Florida crocodiles may be

successfully bred on an annual basis at a properly designed and located facility.

- American crocodiles have previously been bred at the Atlanta Zoological Park, Gatorama in Palmdale, Florida and at Everglades Wonder Gardens in Bonita Springs.

- While more than 150 American crocodiles are present in U.S. zoological parks, aquariums, and roadside attractions, all known captive Florida C. acutus specimens occur within the state of Florida.

- All known captive specimens of Florida American crocodiles are pre-Endangered Species Act specimens and are presently found in commercial roadside attractions in the state of Florida. As such, they can be moved within the state of Florida, whether the transaction is commercial or not, without a Federal Endangered Species Permit. A state permit issued by the Director of the Florida Game and Fresh Water Fish Commission is required.

- Designated federal and state officials may take injured or sick specimens or remove nuisance animals without obtaining a federal permit.

- To initiate a captive propagation program sufficient numbers of long-term captive Florida C. acutus are available from Everglades Wonder Gardens. Purchase price is negotiable. Minimum age of animals exceeds 27 years and selection of animals must be done with the utmost care. It appears that these animals represent genetically pure Florida stock.

- The genetic purity of the wild Florida population of C. acutus is suspect as there has been numerous releases of adult specimens of Central and South American origin.

- The New York Zoological Society supports a large, international conservation program and has a special interest in vanishing crocodilians. This institution is available to develop and execute a funded captive propagation program for American crocodiles.

- Qualified staff personnel are available from among the curatorial staffs of zoological parks and state or federal wildlife management agencies.

- A captive propagation program for American crocodiles would be consistent with recognized crocodilian management practices and would compliment national and international efforts to conserve C. acutus as well as other crocodilian populations. Such a program would provide an opportunity for behavioral, reproductive, diet and growth, and management studies and

serve as a model around which other crocodilian conservation programs could be developed.

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LITERATURE CITED

ALLEN, E.R. AND W.T. NEILL. 1952. The Florida crocodile. Nature Mag. 45(2):77-80.

BARBOUR, T. 1922. An annotated list of the Amphibia and Reptilia of Jamaica. Handbk. of Jam. for 1922.

_____, 1923. The crocodile in Florida. Occ. Pap. Univ. Mich., Mus. Zool. 131:1-6.

_____, 1945. That vanishing Eden: a naturalist's Florida. Little, Brown and Co. Boston.

_____, AND C.T. RAMSDEN. 1919. The herpetology of Cuba. Mem. Mus. Comp. Zool. 47:69-213.

BEAN, N.M. 1953. Crocodile nest at Trout Creek. Everglades Nat. Hist. 1(3):100-103.

BEHLER, J.L. 1976. The crocodile industry in Papua New Guinea. U.N.D.P. Report. 119 p.

_____, 1977. A propagation porgram for Chinese alligators (Alligator sinensis) in captivity. Herp. Rev. 8(4):124-125.

BLAKE, D.K. 1970. Crocodile farming in Rhodesia. Dept. Nat. Parks and Wildl. Mgmt. 48 p. mimeo.

_____, AND J.P. LOVERIDGE. 1974. The role of commercial crocodile farming in crocodile conservation. Biol. Cons. 8:261-272.

BRAZAITIS, P. 1969. The determination of sex in living crocodilians. Brit. J. Herp. 4(3):54-58.

_____, 1973. The identification of living crocodiles. Zool. 58(3-4):59-101.

BUSTARD, H.R. 1971. Temperature and water tolerances of incubating crocodile eggs. Brit. J. Herp. 4(8):198-200.

CARR, A.F. 1940. A contribution to the herpetology of Florida. U. Fla. Publ. Biol. Sci. Ser. 3(1):1-118.

CHABRECK, R.H. 1967. Alligator farming hints. La. Wild Life and Fish. Comm. Report.

_____, 1971. Alligator nest materials -- moisture and temperature levels for hatching alligator eggs. In 14th Bien. Report, La. Wild Life and Fish. Comm.

CHAFFEE, P.W. 1969. Artificial incubation of alligator eggs (Alligator mississippiensis) at Fresno Zoo. Intern. Zoo Yrbk 9:34.

CORY, C.B. 1896. Remarks on some of the Floridian snakes. In Hunting and Fishing in Florida. Boston.

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(4):211-357.

COULSON, T.D., R.A. COULSON, AND T. HERNANDEZ. 1973. Some observations on the growth of captive alligators. Zool. 58(2):47-52.

CRAIGHEAD, F.C. 1968. The role of the alligator in shaping plant communities and maintaining wildlife in the southern Everglades. Fla. Nat. 41(1):2-7 and 41(2):69-74.

DASMANN, R.F. 1971. No further retreat: the fight to save Florida. MacMillan Co., N.Y.

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

DAVIS, J.H. 1943. The natural features of southern Florida especially the vegetation, and the Everglades. Fla. Dept. Cons., Geol. Bull. No. 25:1-311.

DEL TORO, M.A. 1969. Breeding the spectacled caiman, Caiman crocodilus, at Tuxtla Gutierrez Zoo. Int. Zoo Yrbk. 9:35.

DE SOLA, C. 1935. Herpetological notes from southeastern Florida. Copeia, 1935:44-45.

DICKINSON, W.E. 1953. In quest of an adult crocodile. Everglades Nat. Hist., 1(4):151-156.

DIMOCK, A.W. 1918. The Florida crocodile. Am. Mus. Jour. 18(6):447-452.

_____, A.W. AND J. DIMOCK. 1918. Florida enchantments. Outing Publishing Co., N.Y.

DOWNES, M.C. 1973. The literature on crocodile husbandry. In Crocodiles. Suppl. Pap. No. 41, Int. Union Cons. Nat. New Ser.:93-115.

DUNN, R.W. 1977. Notes on the breeding of Johnstone's crocodile. Int. Zoo Yrbk., 17:130-131.

DUNSON, W.A. 1970. Some aspects of electrolyte and water balance in three estuarine reptiles, the diamondback terrapin, American and "saltwater" crocodiles. Comp. Biochem. Physiol. 32:161-174.

DUPLAIX-HALL, N. (ed.) 1973-1975. Reptiles bred in captivity. In Int. Zoo Yrbk. Vols. 13-15. Zool. Soc. London.

EVANS, D.H. AND T.M. ELLIS. 1977. Sodium balance in the hatchling American crocodile, Crocodylus acutus. Comp. Biochem. Physiol. 58(A):159-162.

FITTKAU, E.J. 1970. Role of caimans in the nutrient regime of mouth-lakes of Amazon affluents. Biotropica 2(2):138-142.

_____. 1973. Crocodiles and the nutrient metabolism of Amazonian waters. Amazonia, IV(1):103-133.

GRANT, C. 1940. The herpetology of Jamaica. II. The reptiles. Bull. Inst. Jamaica, Sci. Ser. No.1:61-148.

HEALD, E.J. 1970. The Everglades estuary: an example of seriously reduced inflow of freshwater. Trans. Amer. Fish. Soc. 99:847-848.

HIRSCHFELD, K. 1966. Zucht von krokodilkaiman (Caiman crocodilus) in Vivarium Kehl. Die Aqarien Terrar. Zeit 19(10):308-310.

HOFMANN, R.K. 1970. La distribucion actual del cocodrilo Americano (Crocodylus acutus Cuvier) en el Departamento de Tumbes. Informe Tecnico, No. 25, 1-6. mimeo. Lima.

HONEGGER, R.E. 1971. Zoo breeding and crocodile bank. In Crocodiles. Suppl. Pap. No. 32, Intl. Union Cons. Nat. New Ser. I:86-97.

_____, 1975. The crocodilian situation in European zoos. Int. Zoo Yrbk. 15:277-283.

HORNADAY, W.T. 1875. The crocodile in Florida. Amer. Nat. 9:498-504.

HUNT, R.H. 1969. Breeding of spectacled caiman (Caiman c. crocodilus) at Atlanta Zoo. Int. Zoo Yrbk. 9:36-37.

_____, 1973. Breeding Morelet's crocodile, Crocodylus moreletii, at Atlanta Zoo. Int. Zoo Yrbk. 13:103-105.

JARVIS, C. (ed.) 1961-1968. Reptiles bred in captivity. In Int. Zoo Yrbk., Vols. 2-8. Zool. Soc. London.

JOANEN, T. AND L. MCNEASE. 1971. Propagation of the American alligator in captivity. Proc. Ann. Conf. S.E. Assoc. Game Fish Comm. 25:1-23.

_____. 1974. Propagation of immature American alligators in controlled environmental chambers. Proc. Am. Assoc. Zool. Parks and Aquariums. Reg. Conf. 1974:262-268.

_____. 1975. Notes on the reproductive biology and captive propagation of the American alligator. Proc. Ann. Conf. S.E. Assoc. Game and Fish Comm. 29:1-25.

KENNEDY, J.P. AND H.L. BROCKMAN. 1965. Open heart surgery in Alligator mississippiensis Daudin. Herpetologica 21:6-15.

KIMURA, W. 1972. Study on the artificial incubation of crocodiles, report no. 2. Bull. Attagawa Inst. Trop. Gard. and Allig. Farm (3):2-9.

KING, F.W. 1974. Trade in live crocodilians. Int. Zoo Yrbk. 14:52-56.

____, AND J.S. DOBBS. 1975. Crocodilian propagation in American zoos and aquaria. Int. Zoo Yrbk. 15:272-277.

____, AND T. KRAKAUER. 1966. The exotic herpetofauna of southeast Florida. Quart. Jour. Fla. Acad. Sci. 29(2): 144-154.

KROLL, J.C. 1977. A radiotelemetric study of movements and behavior of captive reared alligators (Alligator mississippiensis) released in east Texas. U.S. Fish and Wildl. Serv. Report. unpubl.

KUSHLAN, J.A. 1974. Observations on the role of the American alligator (Alligator mississippiensis) in the south Florida wetlands. Copeia, 1974:993-996.

LANG, J.W. 1975. The Florida crocodile: wil it survive? Field Mus. Nat. Hist. 46(8):4-9.

LEBUFF, C.R. 1957. The range of Crocodylus acutus along the Florida Gulf coast. Herpetologica 13:188.

LOWE, C.H., P.J. LARDNER, AND E.A. HALPERN. 1971. Supercooling in reptiles and other vertebrates. Comp. Biochem. Physiol. 39(1A):125-135.

LUCAS, J. (ed.). 1969-1971. Reptiles bred in captivity. In Int. Zoo Yrbk. Vols. 9-11. Zool. Soc. London.

_____, AND N. DUPLAIX-HALL (eds.). 1972. Reptiles bred in captivity. In Int. Zoo Yrbk. Vol. 12. Zool. Soc. London.

MARSHALL, A. 1972. Alligators and cities: lessons from the Everglades. Fla. Nat. 45(4):107-109.

MAYNARD, C.J. 1876. [Chapter 1]. In Charles Hallock (ed.), Camp life in Florida.

MEDEM, F. 1971a. Situation report on crocodilians from three South American countries. In Crocodiles. Suppl. Pap. No. 32. Int. Union Cons. Nat. New Ser. I:54-71.

_____, 1971b. Biological isolation of sympatric species of South American crocodilians. In Crocodiles. Suppl. Pap. No. 32, Int. Union Cons. Nat. New Ser. I:152-158.

MOORE, J.C. 1953. The crocodile in the Everglades National Park. Copeia, 1953:54-59.

NEILL, W.T. 1958. The occurrence of amphibians and reptiles in saltwater areas, and a bibliography. Bull. Marine Sci. of the Gulf and Carib. 8(1):1-97.

_____. 1971. The last of the ruling reptiles. Columbia U. Press, N.Y.

NOBLE, G.K. 1923. Trailing the rhinoceros iguana. Nat. Hist. 23:541-558.

OGDEN, J.C. 1976. Crocodilian ecology in southern Florida. In Research in the Parks: Trans. Nat. Park Centennial Symp. U.S.D.I. Nat. Park Serv. Symp. Ser. No. 1:117-130.

_____. in press. Status and nesting biology of the American crocodile, Crocodylus acutus (Reptilia, Crocodylidae) in Florida. J. Herp.

OLNEY, P.J.S. (ed.). 1976-1977. Reptiles bred in captivity. In Int. Zoo Yrbk. Vols. 16-17. Zool. Soc. London.

PARSONS, L.C. AND S.E. HUGGINS. 1965. Effect of temperature on the electroencephalogram of the caiman. Proc. Soc. Exp. Biol. Med. 120:422-426.

PETERS, J.A. 1954. The amphibians and reptiles of the coast and coastal Sierras of Michoacan, Mexico. Occ. Pap. Mus. Zool. U. Mich. No. 554:1-37.

POOLEY, A.C. 1969. Some observations on the rearing of crocodiles. Lammergeyer III(10):45-57.

_____. 1971. Crocodile rearing and restocking. In Crocodiles. Suppl. Pap. No. 32. Int. Union Cons. Nat. New Ser. I: 104-130.

_____. 1973. Conservation and management of crocodiles in Africa. J. South Afr. Wildl. Mgmt. Assoc. 3(2):101-103.

_____. 1977. Nest opening response of the Nile crocodile, Crocodylus niloticus. J. Zool., Lond. 182:17-26.

POWELL, J.H. 1971. The status of crocodilians in the United States, Mexico, Central America, and the West Indies. In Crocodiles. Suppl. Pap. No. 32. Int. Union Cons. Nat. New Ser. I:72-82.

SCHMIDT, K.P. 1924. Notes on Central American crocodiles. Field Mus. Nat. Hist. Publ. 220. Zool. Ser. Vol. 12(6).

SMITH, H.M. 1896. Notes on Biscayne Bay, Florida. From the report of the U.S. Comm. of Fish and Fisheries for 1895. U.S. Govt. Print. Off., Washington, D.C.

UNDERWOOD, G. 1950. Natural history notes. Nat. Hist. Soc. Jamaica, No. 44:161-163.

YADAY, R.N. 1969. Breeding the mugger crocodile, Crocodylus palustris, at Jaipur Zoo. Int. Zoo Yrbk. 9:33.

YANGPRAPAKORN, U. E.W. CRONIN AND J.A. MCNEELY. 1971. Captive breeding of crocodiles in Thailand. In Crocodiles. Suppl. Pap. No. 32. Int. Union Cons. Nat. New Ser. I:98-101.

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