CROCODILE MANAGEMENT IN ZIMBABWE

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INTRODUCTION

The Nile Crocodile *Crocodylus niloticus* Laurenti, 1768, is the only crocodile native to Zimbabwe. Though within the tropics, Zimbabwe's climate, and as a result the distribution of crocodiles, is strongly influenced by altitude (Hutton 1984). Prior to 1900 the range of the crocodile in Zimbabwe was not documented, but the animal probably occurred along all perennial and many annual rivers below 1800 m, with reliable breeding below 900 m. Despite a high level of crocodile/human conflict, this range has not been greatly affected by Zimbabwe's burgeoning population. Numbers were markedly reduced in the 1950s, but have recovered and although there has been some loss of habitat, crocodiles have benefitted from the proliferation of dams. In particular, the construction of Lake Kariba created particularly favorable conditions for crocodiles at the time when their numbers were poised to recover as a result of new conservation policies.

The Department of National Parks and Wild Life Management of Zimbabwe (hereafter, the Department) recognizes wildlife as a renewable natural resource and considers that conservation is encouraged when the resource is used for the benefit of the people who live with it. It is impractical to attempt to safeguard a species through legislation and law enforcement unless people are at least tolerant towards it. This is especially true of a large predator like the Nile crocodile which seriously competes with legitimate human interests. Although non-consumptive uses may be preferred, there is not always a choice and benefits can often only be realized through the marketing of animals or their products. This philosophy towards the conservation and use of wildlife is well illustrated by the sustained-yield utilization of *C. niloticus* in which, for 20 years, eggs have been collected from the wild and hatchlings raised for their skins on licensed rearing stations.

Unfortunately, in Zimbabwe and elsewhere, management of the Nile crocodile along these lines has been hammered by politics. *C. niloticus* is classified by the IUCN as "vulnerable" (Groombridge 1982). Trade in its products was restricted when *C. niloticus* was placed on Appendix I of CITES prior to the acceptance of the "Berne Criteria" (CITES Conf 1.1, 1.2 and 1.3, 1976) for listing, delisting or transferring species between appendices. Many African Parties to the Convention questioned this classification and at least four, including Zimbabwe, entered a reservation against it. An inability to trade in the species would have represented a major setback for its conservation, with every likelihood of irresistible demands for the extermination of crocodiles outside protected areas. The success of Zimbabwe's policy of conservation through utilization led to the country's *C. niloticus* population being acknowledged as "out of danger" and transferred from Appendix I to Appendix II of CITES in 1983 (CITES 1984). This was followed, in 1985, by its downlisting in 9 other countries, each agreeing to an annual export quota.

This chapter describes the conservation of *C. niloticus* in Zimbabwe and for completeness includes information on the animal's biology, its conflict with humans and the history of its exploitation, its present utilization (together with associated legislation and technology) and, perhaps most importantly, the present status of the wild population and its response to exploitation.

LIFE HISTORY

The life history of *C. niloticus* is markedly affected by the environment. In Zimbabwe, hatchlings measure about 0.3 m total length (TL) and grow at a rate largely dependent on temperature. Puberty is more influenced by size than age. Females mature at approximately 2.6 m TL which has been recorded as taking from 8-30 years (Hutton 1984). Females rarely exceed 3.2 m TL, but males longer than 4 m TL are common and individuals greater than 5 m TL have been recorded from the Zambezi River in recent years (M. Ellerment pers. comm.).

Courtship and mating occur in July and early August (cool-dry season). Nest chambers are excavated and most clutches laid in late September (hot-dry season).

Both clutch and egg size increase with the increasing age and size of the female (Hutton 1984). The average clutch size of the Lake Kariba population is 45 (Blake and Loveridge 1975). Although dependent on temperature, the incubation period is about 90 days, during which most females remain in nest attendance. Incubation temperatures also determine the sex of embryos (males at high temperatures) and as a result, the sex ratio of the population (Hutton 1987b).

The extent and causes of nest failure vary between localities, but losses can be as high as 77% where incubation temperatures are sub-optimum. In warm areas predation is usually the largest single factor accounting for losses. At Ngezi predation averaged 40% over 10 years (Hutton 1984). The main natural predator is the Nile monitor *Varanus niloticus*.

Hatching usually takes place in December (hot-wet season) and is invariably assisted by the female.

Juveniles are highly susceptible to predation until they reach 1.2 m TL which can take from 3 to 8 years. In cool localities, where growth is slow, juvenile mortality becomes a bottle-neck to population growth (Hutton 1984). In warmer localities, where nest success and juvenile survivorship are high, the reproductive potential of the species begs some form of density-dependent regulation. Though there are few data from the wild, the intra-specific predation of one size class by another is implicated in the regulatory process. Cannibalism is common in captivity and ecological separation of size classes has been recorded in some wild populations. The home ranges of adults and their offspring (< 1.2 m TL) coincide, but are completely separate from those of larger juveniles and subadults (Hutton 1984).

As a result of the various environmental factors which affect life history processes, crocodiles are demographically most successful in areas of Zimbabwe below 600 m (Fig. 1).

Nile crocodiles are opportunistic predators though their prey target size increases with body size (Cott 1961, Hutton 1987a). Large mammals comprise the main diet of crocodiles larger than 2.5 m TL and in populated areas this may lead to the death of people and their livestock.

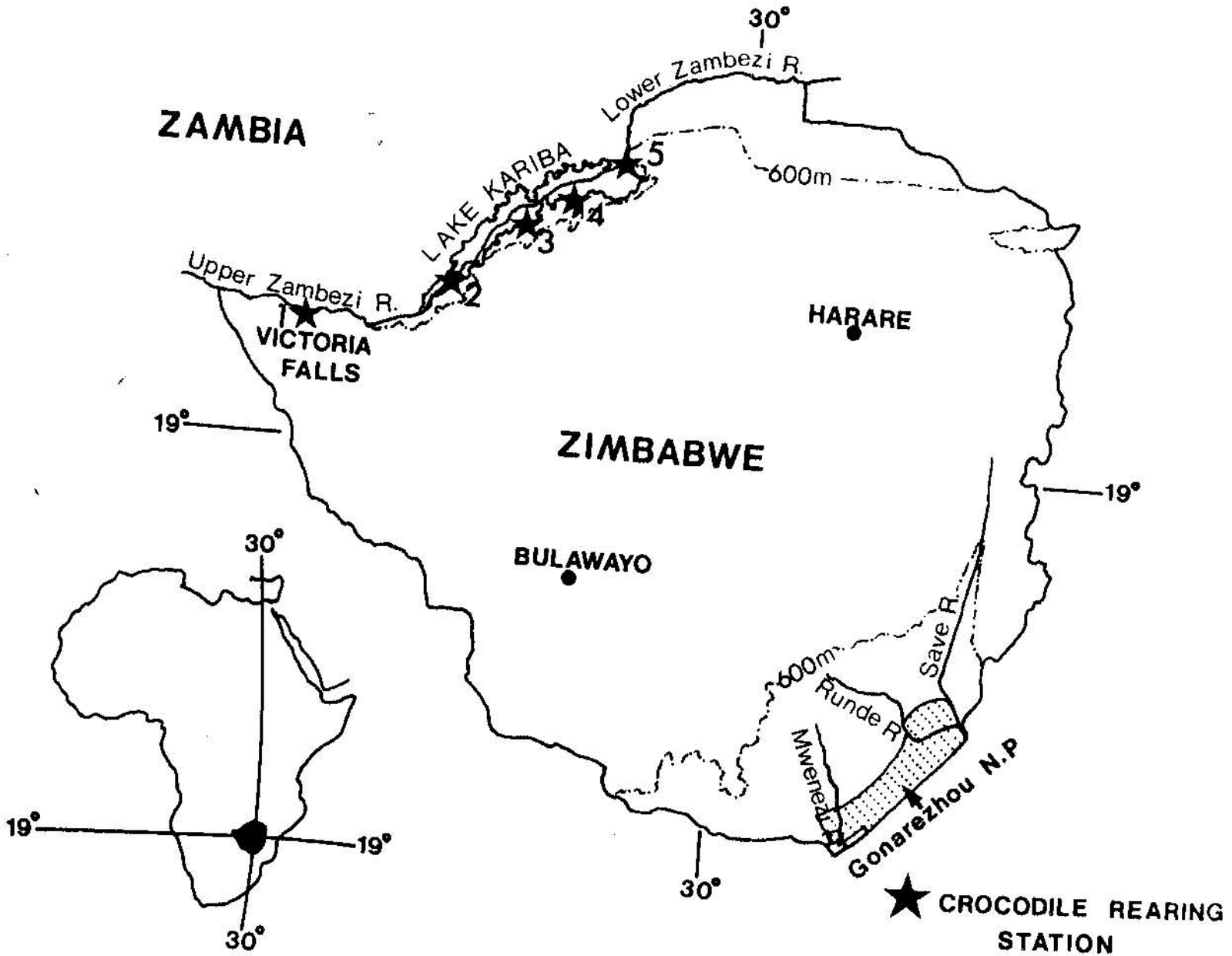

Figure 1. Zimbabwe, showing major rivers with crocodiles in areas below 600 m and the five crocodile rearing stations which currently have egg collection permits.

MANAGEMENT

Perspective - There has always been conflict between crocodiles and rural people dependent on natural water supplies for their domestic and livestock needs, but this has intensified since the 1940s when human numbers entered a phase of exponential increase. Zimbabwe has no tradition of crocodiles or their eggs being used as food, but their destruction has always been viewed as a service to the community. Originally this hunting probably had little effect on either crocodile numbers or distribution. However, soon after the Second World War the commercial hide hunting of *C. niloticus* commenced. This peaked in the 1950s, bringing many accessible populations to the point of extinction (G. Hall pers. comm.). At that time, Zimbabwe's crocodiles were only protected within National Parks which covered less than 5% of the country and contained little habitat suitable for the animal. Unprotected populations were affected badly by uncontrolled exploitation. For example, few large crocodiles survived along those reaches of the middle Zambezi which are now submerged by Lake Kariba (G. Child unpubl. data).

As a result of the Wild Life Conservation Act, crocodiles first received a measure of legal protection throughout Zimbabwe in 1961. At the same time the foundations were laid of the present Parks and Wild Life Estate which recognizes six classes of protected area, includes 12.7% of Zimbabwe and has substantial prime crocodile habitat. Mainly due to the control of skin hunting, crocodile numbers responded immediately.

Although crocodiles occur virtually throughout Zimbabwe, the country is divided by a central watershed which separates the two main river basins with crocodile habitat below 600 m. It is therefore convenient to consider that the recovery took place in two distinct populations, one in the northern Zambezi basin, the other in the southern Save/Limpopo basin - better known as the lowveld (Fig. 1). There are important physical and developmental differences between the two. The Zambezi valley has poor agricultural potential and is poorly developed. The Zambezi River is perennial and a 300 km section was flooded by the construction of the Kariba dam in the late 1950s. The resultant lake and most of the remaining river are part of the Parks and Wild Life Estate. By contrast, the region of the Save and associated rivers supports a dense human population. Large areas are irrigated and virtually the only undisturbed crocodile habitat occurs as relatively short stretches of the Save, Runde and Mwenezi Rivers in the Gonarezhou National Park (Fig. 1). All rivers in the area are annual and although they previously had large perennial pools, many of these, especially in the east, have been modified by impoundments, irrigation and resultant siltation. The crocodile population in this area is restricted by its dry season water requirements and may have always been much smaller than that of the Zambezi. Unfortunately, although most undesirable interactions between humans and crocodiles occur in the lowveld, the Zambezi population has the greater harvesting potential.

As recorded by Zimbabwe's newspapers, at least twenty persons were killed by crocodiles during the period 1982 until 1986 (Hutton 1986). In addition, many deprivations on livestock were reported to the Department's problem animal control units which respond to all serious crocodile problems by capturing or, occasionally, destroying the offending animals.

Rationale - The Parks and Wild Life Act of 1975 broke with traditional wildlife legislation in Africa and, in addition to consolidating the present system of protected areas, it effectively conferred ownership of most wildlife onto the landholder. Mechanisms exist to prevent abuse, but in general, landowners have the discretion of using their wildlife as they deem best and all benefits from such use accrue to them as there are no state hunting licenses or country-wide hunting seasons (Child 1977). The rationale behind this legislation is that the people best able to conserve wildlife are

those on whose land it occurs and that their motivation for doing so is increased with an economic incentive.

The possibility of a sustained-yield harvest of *C. niloticus* in Zimbabwe was first considered in the early 1960s, when crocodile populations were beginning to recover and calls for their control were becoming difficult to resist. The first permits allowing crocodile rearing stations to exploit the Lake Kariba population were issued in 1965.

It was argued that crocodile rearing stations would provide and make conspicuous an economic incentive to maintain Zimbabwe's wild crocodile populations and this has proved to be the case at the policy-making level. In 1985 hide and live sales earned Zimbabwe the equivalent of almost Z$1 million in foreign exchange, while Spencer's Creek Crocodile Ranch (one of the two stations which has visitor facilities) entertained approximately 40,000 tourists. As a result, crocodile welfare is a consideration when new development is planned. If this was not the case, many prime crocodile breeding sites would have disappeared by default already.

Unfortunately, despite its benefit to the national and local economies, the industry offers little direct advantage to the people of the Zambezi who have crocodile neighbors, and none to people in the lowveld. Every year numerous crocodiles and their eggs are destroyed in the lowveld, while in 1984 humans destroyed over 38 crocodile nests along the upper Zambezi River (R. Gee pers. comm.). Although little information is available, it appears that the Zambezi nests were destroyed by fishing communities (usually fishing illegally) in retaliation for net damage. Perhaps more serious for the crocodile population in this area is the entanglement and death of adult crocodiles in nets, though inadequate data are available on the magnitude of this problem.

Clearly, rural communities should be involved in Zimbabwe's conservation policy, but providing them with a tangible benefit is not simple. Crocodile eggs are delicate and their collection by largely uneducated rural people has been allowed, but has proved unsatisfactory. Suggestions that stations should pay for eggs have been resisted where the crocodile resource is on land with communal tenure because the benefits would not directly accrue to those most involved. In 1985 a number of people along the worst affected stretches of the Zambezi River were employed by stations to act as "wardens," locating and protecting nests for their collectors and this scheme shows promise. To tackle the problem in the lowveld, two new rearing stations are planned, one of which is to be run as a co-operative in a poor Communal Area (former Tribal Trust area in which all land is communally owned) with a high population of crocodiles and other wildlife.

Magnusson (1984) made a number of observations regarding the captive propagation of crocodilians and concluded that, for species with poorly valued commercial hide, such as *Caiman crocodilus*, neither farming (where adults are kept for the production of eggs) nor ranching (where eggs are collected from the wild) is likely to be economically viable. Unfortunately, the impression was given that the value of crocodile farming and ranching is dubious in all circumstances. In fact, with species which produce high quality "classic" hides, rearing is usually preferable to the hunting of wild animals.

Commercial rearing stations in Africa are privately funded and impinge little on limited government wildlife budgets. Capital investment in rearing facilities creates a commitment to sustained-yield harvesting, perennial employment and honesty in trade. If correctly managed, a harvest of eggs will yield many more skins than a harvest of live animals (mortality of wild eggs and juveniles can exceed 95% and the killing of adults erodes reproductive capital) and any mistake in the level of exploitation is less dangerous where eggs are being utilized. Hide size and quality can

be controlled on rearing stations and, where skins are "stored" as live animals, advantage can be taken of short-term market fluctuations.

The importance of rearing stations in displaying the economic value of crocodile conservation must again be stressed.

Mechanics - The mechanics of utilization are simple. Wild crocodiles and their eggs are protected throughout Zimbabwe by a special Statutory Instrument which makes it illegal to "injure, willfully disturb or remove the egg of any crocodile; or hunt or remove any crocodile" except by special permit available from the Department (Hutton 1986).

Egg collection permits are currently issued to only five commercial rearing stations. These produce skins from a mixture of ranching and farming. As noted above, two new stations are planned to utilize the lowveld population.

Permits for wild eggs are issued annually on the basis of each station's rearing success in the previous year. Overall egg quotas are set by the Department using data from monitoring of the wild population, but the Crocodile Farmers Association of Zimbabwe (CFAZ), in a self-regulatory role, recommends individual quotas for its members. These are subject to the Department's veto, but are usually accepted.

It is not intended that captive production should replace the wild harvest. Only from biological necessity, based on population monitoring, would wild quotas be reduced. However, farming allows stations to expand beyond the limit imposed by quotas.

Permits carry a number of standard conditions which include the requirement that stations submit monthly stock returns and cards as well as maps recording egg collection information (Hutton and Brennan 1985). Stations also have to make available to the Department, for restocking purposes, a number of juveniles of 1.2 m TL equivalent to 5% of the eggs collected (juveniles of this size appear to be free of interspecific predation). In reality, for a number of years the Department has taken only a few of these crocodiles, mostly for research. The wild population is large (Taylor, Loveridge, and Blake unpubl. data), making restocking an unnecessary (and unpopular) option. Nevertheless, the "5% requirement" is retained.

The sport hunting of a limited number of large crocodiles, especially on private land, is considered to have a conservation value and is permitted.

In accordance with Zimbabwe's obligations to CITES arising from its successful 1983 proposal to downlist the species, all crocodiles and their derivatives which enter international trade are marked with unique tags identifying their country of origin and their legality.

REARING INDUSTRY

Some technical aspects of crocodile production have been presented (Blake 1974, 1982), but ideas and technology are in a continual state of flux, being as much influenced by personalities as science. The following summarizes the rearing process as it stands today.

Egg collection - Blake (1974, 1982) has described egg collection where nests are found with a probe and the eggs recovered with great care. A similar system continues, but aircraft are used increasingly to locate nesting females.

Eggs are usually collected after 50 days because, though never rigorously tested, experienced collectors hold that the probability of embryonic mortality is highest in eggs lifted during the first few weeks after laying. However, although late collection has the advantage of allowing inviable eggs to be distinguished, by the time of collection a large proportion of nests have been lost to predation. Early collection would allow these eggs to be utilized. In addition, there is mounting evidence that incubation conditions strongly influence the subsequent growth and survival of hatchlings (Hutton 1987b). Under these circumstances, early collection would have advantages. Some stations, anticipating this possibility, are already lifting the eggs of captive stock shortly after oviposition (before the embryo has attached to the shell membranes) and artificially incubating them for the full period of development.

Because of the vast area over which wild eggs are collected it will never be possible to obtain them within a few hours of laying, but this may not be as critical as commonly believed. Although flooding of Zambia's Luangwa River necessitates that eggs are collected early, within a few weeks of laying, in 1985 hatching success was 85% (C. Beukes pers. comm.). Further investigation may show that earlier collection is practical in Zimbabwe and, if so, it will be encouraged.

Until 1985 the quota of eggs given to any station never exceeded 2500 and was commonly less. However, inviable eggs did not count against quotas (Hutton and Brennan 1985). From 1985 all eggs counted against permits and to compensate for this quotas were increased by 10%. As a result, the mean percentage of eggs rejected as inviable, which had risen to 14.5% by 1984, immediately fell to 7.4%. Incubation success did not decline (88.8% in 1984 and 90.5% in 1985) and thus it appears that eggs were more efficiently selected.

Incubation - Broadly similar incubation technology has evolved on each station. Eggs are packed in moistened vermiculite or sand within styrofoam boxes (Blake 1982). These are stacked, approximately 30 cm apart, on wooden shelves in a room in which, by various means, the temperature is maintained between 28^{o} and 34^{o} C. Experience has shown that heating is easier and more accurately controlled than cooling.

With the exception of one or two notably poor seasons, since 1979 the rearing stations have regularly achieved 80-90% success when hatching wild eggs (Fig. 2). The average hatch over the period 1981-85 was 89%. While eggs are spending most of their incubation under natural conditions it is unlikely that better success can be achieved. Under the present system, precise temperature control is difficult and short term extremes are prevented by the vermiculite or sand used as packing. One station, planning to artificially incubate eggs for their full term to influence hatchling survival, has built a simple, inexpensive, but more efficient incubator in which hatching success has been better than 90% (R. Lowe pers. comm.). This incubator compromises a small ($10m^2$), well insulated room which is plastered and enamel-painted for hygiene. The eggs are stacked, without packing medium, in shallow plastic trays. A high humidity may be maintained either by a continuous flow of, or standing, water. Temperatures are maintained within 0.5^{o}C by a fan heater with a sensitive thermostat. It seems likely that all stations will eventually switch to a similar design and opt for early collection.

Hatching - When wild eggs are collected it is common for the embryos within a single clutch to be at different stages of development (Pooley 1969, Hutton 1984) and hatchlings, if allowed to emerge undisturbed, may do so over a period of several days or even weeks. Blake (1974) considered that the "croaking" of emerging hatchlings stimulated neighboring embryos to hatch, but Magnusson (1980) disagreed. Some stations prudently isolate boxes of "croakers" to avoid premature hatching, others leave them amongst developing clutches.

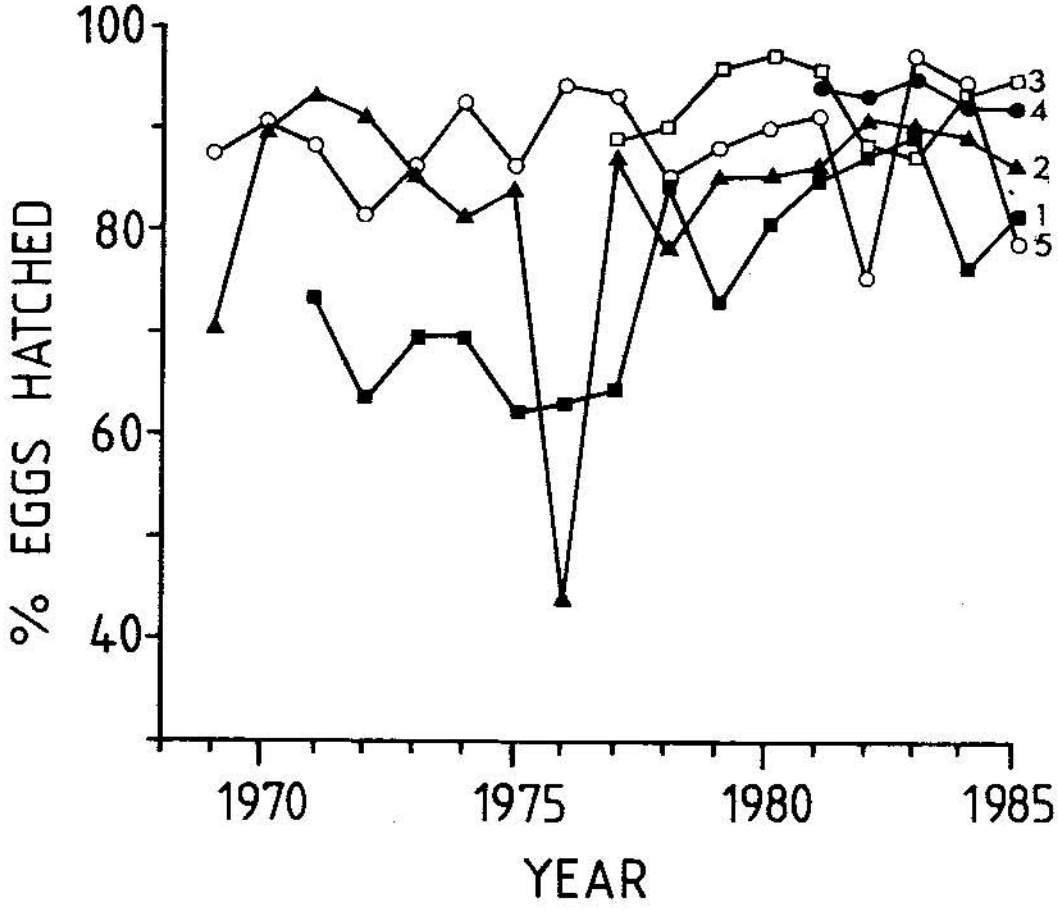

Figure 2. Hatching success of wild eggs on each of the five rearing stations from the first issue of their permits (station 1 since 1971; station 2, 1967; station 3, 1977; station 4, 1981; station 5, 1965).

Ideally, hatchlings which emerge unaided are washed and toe clipped in a clutch specific sequence. Each clutch is placed in a dry concrete pen or plastic tray of approximately 1 m , within a hygienic, well ventilated room where hatchlings are allowed to "harden-off" for 24-48 hours at 34°C.

Assisted hatching is done under strict hygienic conditions. Premature hatchlings with poorly resorbed yolk may require extended "hardening-off". They are kept dry except for a short daily swim in clean, shallow water dosed with tetracycline at 20 mg/l. The holding area is disinfected daily.

Care of hatchlings - The quantity and quality of crocodiles surviving to the end of their first year has shown great variation both between and within stations; mortality on the most successful station has ranged from 5 to 55% in consecutive years while on the poorest station it has been consistently greater than 30% and was 100% in one year (Fig. 3). The average from all stations during the period 1981-85 was 28.2%.

Hatchling crocodiles are very susceptible to handling and other stresses as Garnett (1983) clearly demonstrated with *Crocodylus porosus*. Though unquantified, the following are considered to cause stress, contributing to mortality on Zimbabwe's stations: unsuitable temperatures, poor hygiene, overcrowding, rough handling, poor size grading (resulting in a dominance hierarchy), inadequate attention to routine in feeding and cleaning and poor nutrition.

Mortality is clearly temperature related. More hatchlings have died in September, at the end of the cool season, than in February, immediately prior to the cool season, or November when the hot season is well advanced (Hutton and Brennan 1985). Low cool season temperatures suppress appetite, digestion and growth. Heating of ponds can substantially reduce mortality and increase food intake and growth (Blake and Loveridge 1975).

All stations appreciate that they have a temperature problem and have tackled it in some way, some by covering the pens at night, others by pumping water, which never falls below 18^{0} C, direct from Lake Kariba. Unfortunately, it is not certain how effective these efforts have been because stations have usually underestimated the optimum temperature for growth (Hutton and Brennan 1985). The only hatchling rearing system with precise temperature control is that at Spencer's Creek, the most temperate station, which has pens incorporating thermostatically controlled coal-fired heating.

Extremely high temperatures also stress crocodiles, and death is recorded as occurring at temperatures approaching 40° C (Hutton and Brennan 1985).

It is clear that, although the ultimate cause of death is usually disease, temperature or other stress is commonly the predisposing factor and a great number of deaths could be avoided with appropriate management.

Enclosure design is by no means standardized on stations, but small, outdoor, concrete pens, approximately $3m^2$, each with a saucer-shaped pond holding 50 hatchlings are currently preferred to larger pens holding 200 to 300 animals at the same density. Temperatures are more easily regulated, hygiene strictly maintained and disease controlled in small enclosures. Insulating the concrete of the pool, and covering pens with black plastic sheeting, when the ambient temperature begins to fall, can maintain high temperatures at night (Siziba 1985). Overheating during the day can be prevented by artificial shade. Feeding and cleaning routines are strictly maintained. Pens are best cleaned and disinfected after every feeding and always refilled with clean borehole or purified water.

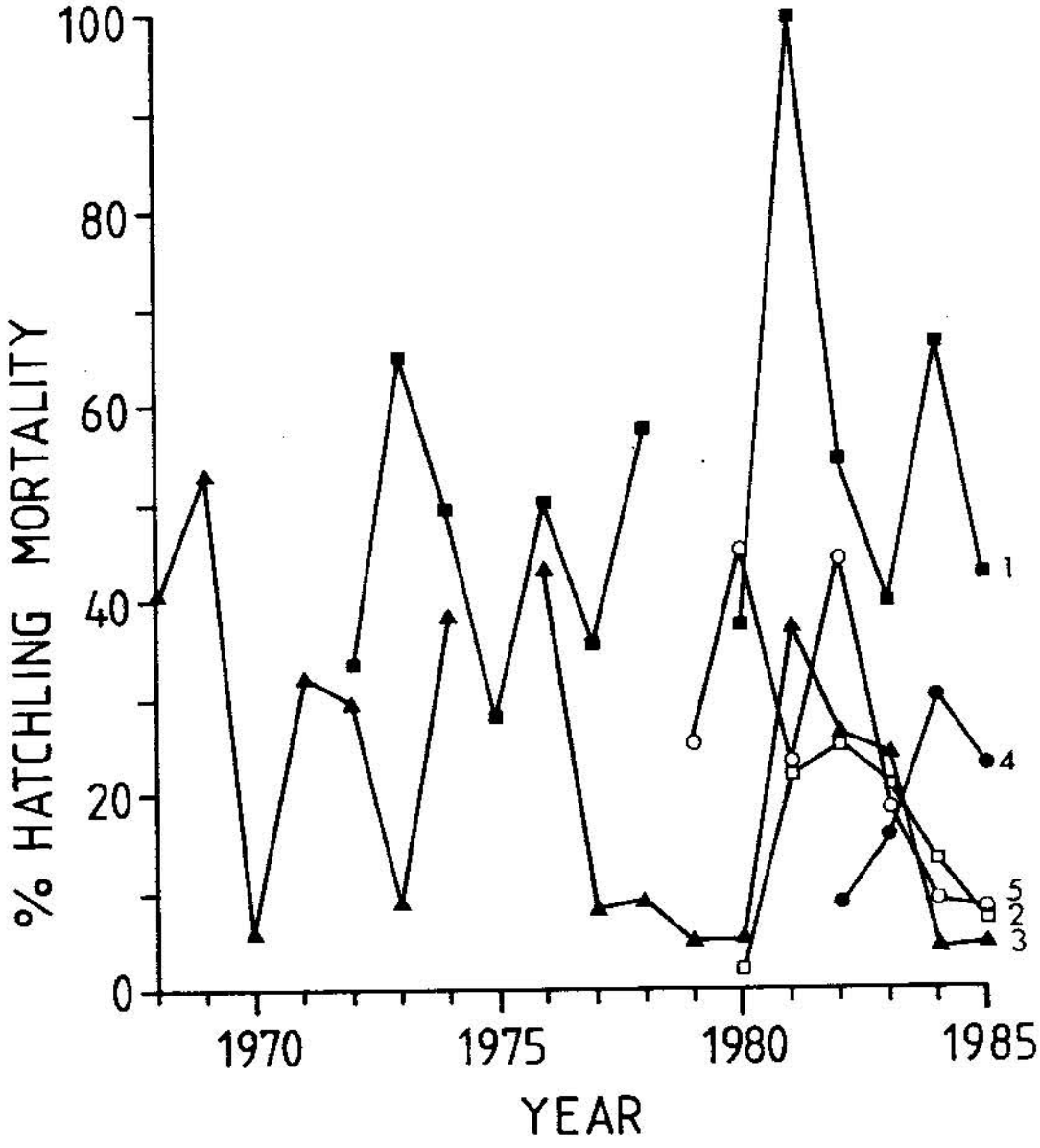

Figure 3. Annual percentage hatching mortality on each station since the issue of their permits.

Hatchlings are moved into these pens in early January after the "hardening-off" period. They are graded in March/April before the onset of the cool season, and again in October, when the new hot season is well advanced and before they are moved to new accommodation. Pens are then sterilized with formalin and sun-baked for as long as possible before the next season's hatchlings are introduced.

Environmental chambers, of a similar kind to those successfully used with *Alligator mississippiensis* in Louisiana (Joanen and McNease 1974) are currently being tested at temperatures of 34°C by a member of the CFAZ and the preliminary results are more encouraging than those recorded from Australian crocodiles under similar conditions (Webb et al. 1983).

Experience has shown that irrespective of the quality of facilities, information and extension services, the raising of crocodiles requires stringent management.

Care of rearing stock - On four stations, mortality among rearing stock (yearlings and older) commonly has been below 5% per annum. On the coolest station, however, rearing stock mortality has been as high as amongst hatchlings (Fig. 4). The overall mean mortality in the period 1981-85 was 3.3%.

Blake (1974) described the variety of pens used for rearing stock. Each design has proved adequate, but a double concrete pond results in an equal distribution of animals and a minimum of stress during cleaning. Adjacent ponds are drained, cleaned and refilled on alternate days and the crocodiles are thus never denied access to water. Corners and vertical sides are avoided, oval ponds with a saucer-shaped profile are considered most effective. As with hatchling pens, a mosaic of shade is provided. Separate feeding platforms are being built on some stations. These allow the crocodile to retreat into a trough of shallow water with their food, preventing contamination of the main pond. At least one station has completely concreted the area around ponds, others maintain a surround of closely cropped grass.

Some stations have earth "finishing" ponds, but the belief that these promote better growth than concrete pens has still to be verified. However, earth ponds are inexpensive and when properly managed do not appear to be less successful than those of concrete. If management is inadequate, efficient cropping is difficult and problems of hygiene, burrowing and escape may be encountered.

Feeding - Blake (1982) noted that the diet of captive crocodiles in Zimbabwe is virtually restricted to kapenta (*Limnothrissa miodon*), a sardine-like fish, and game meat (particularly elephant) from controlled hunting and on-going population reduction exercises.

On most stations, fresh kapenta is favored for hatchlings. Where only red meat is fed, deficiency syndromes soon appear and a supplement of vitamins, calcium, trace elements etc. is always added, often in the form of dried kapenta. Continual monitoring of food quality is encouraged, and some stations even supplement kapenta with calcium, trace elements and vitamins.

As noted by Magnusson (1984), the political climate of Zimbabwe has changed and the human population is rapidly growing. Although the financial justification is unlikely to change, social pressures against the continued feeding of crocodiles with game meat are anticipated and alternative sources of protein are being examined. One established station is diversifying into

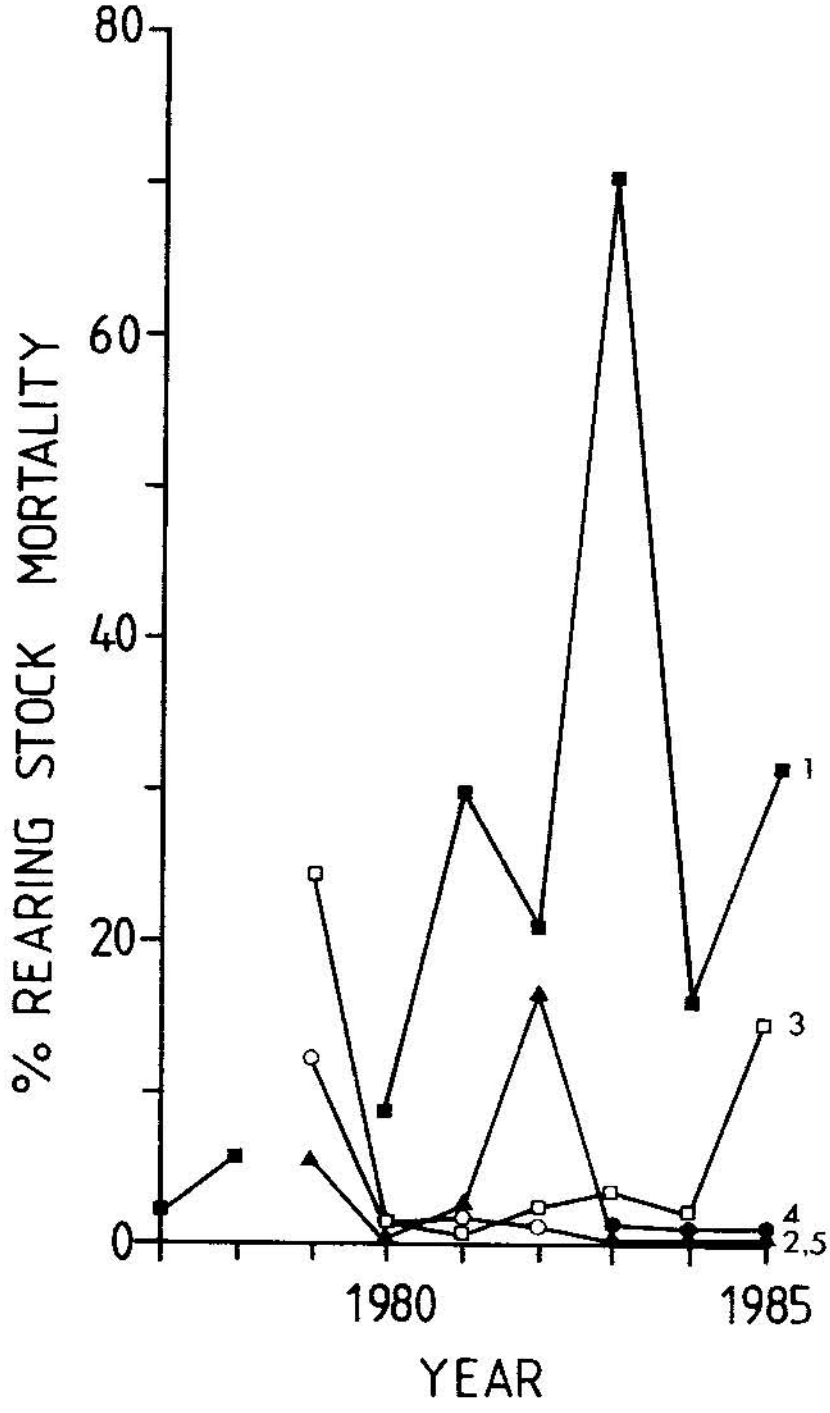

Figure 4. Annual percentage rearing stock mortality on each station since the issue of their permits.

ostrich production for hides (for the luxury leather trade) and meat to maintain crocodile production, another is experimenting with the large-scale production of bream fry (*Tilapia* spp.) in tanks.

Additional stations will only be allowed if, in addition to other requirements, they can show that they have access to an adequate and reliable source of food.

Disease - Disease has affected seriously the viability of crocodile farming in Zimbabwe and there are ethical objections to a system of conservation and management in which large numbers of animals succumb to disease (Foggin 1987). The fact that there is considerable variation in the occurrence and severity of disease between farms depending on climate, management, egg incubation, diet and housing suggest that these factors play a major role in the development of disease and that severe losses are a secondary manifestation of poor husbandry.

The main causes of death are major infectious disease syndromes including bacterial septicemia (*Aeromonas* and *Salmonella* species), viral hepatitis and coccidiosis. Runting, the causes of which are unknown, usually leads to death and is a severe problem on some stations.

Less important syndromes have been caused by pox virus and fungal infections, parasites, over-feeding and dietary deficiencies.

While disease prevention through improved husbandry is being encouraged, disease treatment remains important and although considerable work on this subject has already been done on rearing stations (Foggin 1987) more research is required and planned.

Cropping, flaying and curing - Zimbabwe crocodile hide is marketed in commercial units based on the width of the belly and by tradition animals have been slaughtered when about 1.5 m TL and 30-35 cm belly width (BW). However, the optimum size for cropping depends on a combination of production and marketing factors and has been as low as 25 cm BW. All stations crop by shooting the required animals in the head with a .22 short bullet. To ensure quality control, the CFAZ encourages a standardized skin preparation based on international practices. After washing, the backskin is removed ahead of that on the belly and each is thoroughly cleaned before curing in wet salt. Skins are then graded, measured and tagged before being rolled and stored in a cold room prior to export (Van Jaarsveldt 1987).

Efficiency - The proportion of incubated eggs which result in saleable hides has varied greatly between stations and on some has been consistently low. As an example of the efficiency of the industry in recent years, it is notable that of the average total of 9,600 eggs available to four stations in each of the years 1978 until 1982 only 3,360 (35%) were successfully hatched and raised to cropping size, and of these 43% were on one station. In order to improve this performance, in 1985 the Department and the CFAZ together adopted minimum standards for each stage of the rearing process and any station which does not consistently achieve these standards may be penalized by having its quota of wild eggs reduced. An immediate improvement was recorded in the ensuing 1985-86 season with only one station falling short of requirements. By 1987 an efficiency of 65% is anticipated and by 1990, with more eggs from captive stock, the five existing stations should be producing 15,000 hides per annum.

All crocodiles and their derivatives are marketed to best effect under the auspices of the CFAZ.

Research and extension - The industry is provided with extension services by the Department (which has a full-time crocodile specialist) and the Department of Veterinary Services. However,

recommendations are often based on experience rather than research. Research has been hampered by a shortage of funds, a lack of experimental facilities, the remoteness of stations and a lack of scientific expertise on the part of station management. Recently, the CFAZ has provided central experimental facilities, including eight heated pens for hatchlings, and two stations presently have managers with scientific training. Critical problems have been identified and an extensive research program is underway. This includes investigations into the effect of incubation on subsequent growth and survival, the effect of stress on growth and susceptibility to disease, pathogenicity to disease, nutrition and the design and thermal dynamics of enclosures.

EFFECTIVENESS OF MANAGEMENT

Response of wild populations - The most heavily exploited populations are those of Lake Kariba and the upper Zambezi River between the lake and the Victoria Falls, but the brunt of increased egg collection in recent years has been borne by the Kariba population from which a total of 11,273 eggs were removed in 1985 (Fig. 5). As a result, survey and monitoring has focused on this population. Only about 8% of the Zambezi below the lake is exploited and there are virtually no census data for this stretch of water.

From virtual extinction in the 1950s, crocodiles in the upper Zambezi increased until, by 1971, they bred in sufficient numbers to support the collection of about 2,000 eggs each year. This was not necessarily the maximum number of eggs that could have been removed, but reflected the ceiling of one station's quota. From a peak of 1,974 in 1975, the number of eggs recovered had fallen by 40% to 1,305 (of which 275 had been destroyed by humans) by 1985 despite intensive searching. The decline is due to the uncontrolled expansion of settlement and fishing on the Zambian side of the river. The Department has accepted that, with the exception of a few small colonies within major tributaries, this population is severely threatened and some of the remaining animals are being captured and moved to rearing stations.

Very little is known about crocodiles along the Zambian shore-line of Lake Kariba, but on the Zimbabwe side only those in the extreme western headwaters are seriously affected by pressures from fishing and settlement. Most of the remaining shore-line has well protected crocodile habitat and controlled fishing. Annual aerial and spotlight surveys conducted since 1975 suggest that the population numbers some 30,000 animals, 5,000 of which are adults (Taylor, Loveridge and Blake unpublished data). In its present state, monitoring does not give any indication of trends, mainly because there is no good correction factor for the effect of fluctuations in lake level on the number of animals seen. However, it is clear that the population has risen to its present level in the 25 years since the lake filled, while being exploited for most of this period.

Aerial surveys are rapid and simple, but only give an index of the number of large crocodiles in an area. Correction factors for the size structure of a population are established from spotlight counts, the accuracy of which is commonly considered dubious (Hutton 1984). As a consequence, any demographic response to utilization may not be detected for several years, until they are reflected as changes in the numbers of large juvenile and adults. Because the present system of monitoring does not show trends, some concern has been expressed about the doubling, since 1980, of the number of eggs collected from the lake and the fact that all areas outside Matusadona National Park are now regularly exploited (Hutton and Brennan 1985). However, as only about 300 nests are being raided for eggs each year, while census data indicate that there are 5,000 adult crocodiles, it has also been suggested that the population may still be under-exploited and the quota

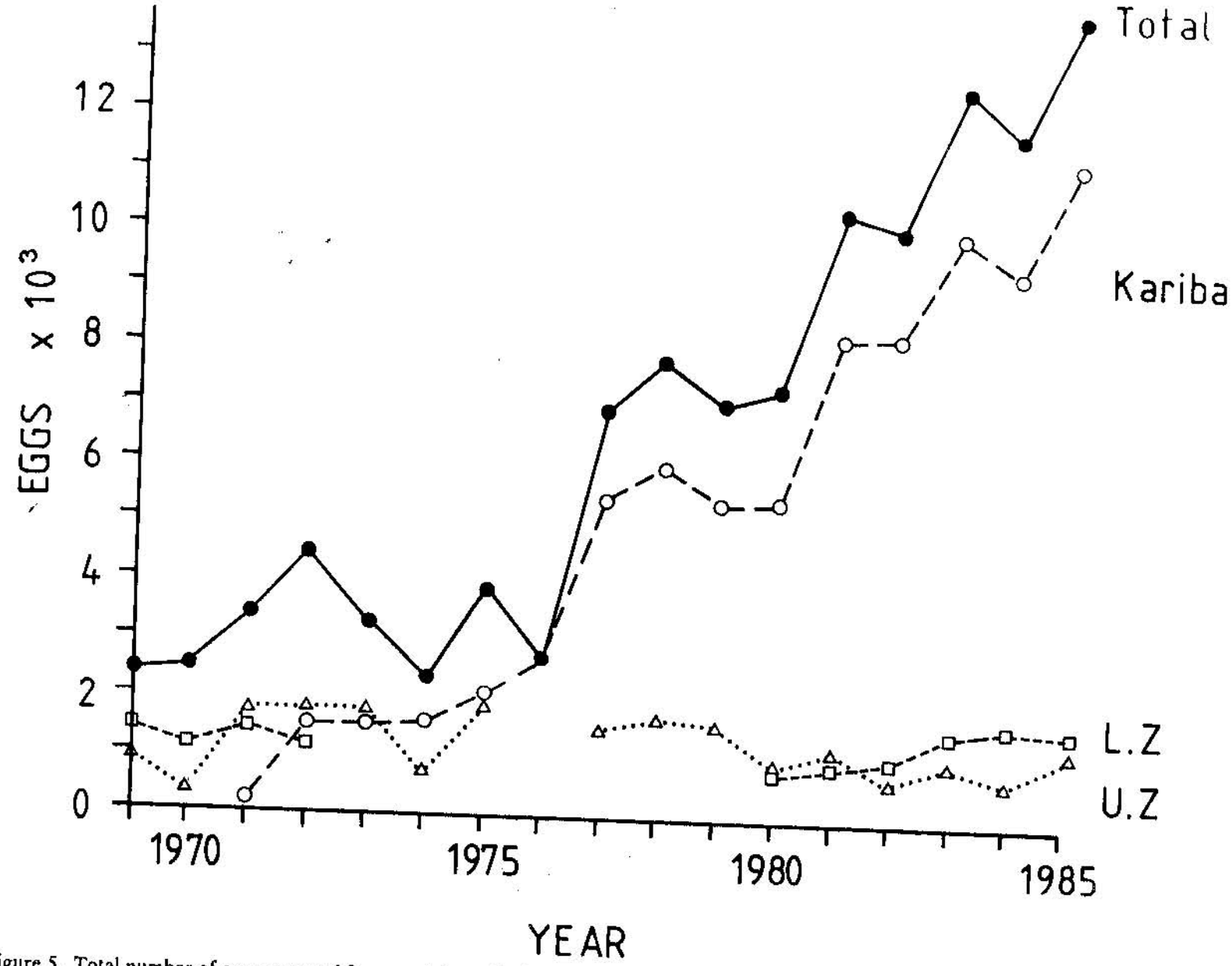

Figure 5. Total number of eggs removed from nests in each of the three main collecting localities in the Zambezi valley since the first issue of egg collecting permits. U.Z = Upper Zambezi River, L.Z = Lower Zambezi River, Kariba = Lake Kariba (see Fig. 1).

set by the Department too conservative. As detailed below, the information necessary for modeling, prediction and improved management is being sought as a matter of priority.

Monitoring and research - As part of the Department's monitoring efforts, stations have been required to submit information on the fate of every clutch collected since 1969. Unfortunately, although there is some important information of clutch size and the number of nests in broad localities, these records allow no measure of natural predation and collecting efficiency, nor do they give the exact locality of nests. In 1985, after analysis of all the available data, the system of returns was altered and stations are now helping gather this information.

It has already been noted that direct census and monitoring of population numbers has also been of limited value. As a result, census and survey techniques are being researched. In order to gain enough information to measure and monitor the size structure of the population, radiotelemetry is to be used to establish movement and dispersion patterns and capture-recapture experiments are planned to provide correction factors which can be applied to eliminate bias inherent in different forms of survey.

Recent research into the dynamics of a Nile crocodile population has identified the critical data required before exploited populations can be modeled and the demographic effects of different exploitation regimes predicted (Hutton 1984). Together with the University of Zimbabwe, the Department is now directing research towards obtaining information such as growth rates, size and age at maturity, sex ratio, proportion of females breeding each year, reproductive success and size-specific mortality from Lake Kariba crocodiles.

CONCLUSIONS

Crocodile management in Zimbabwe is based on the pragmatic philosophy that, particularly with species which conflict with man, utilization can lead to conservation. This has proved to be the case. Crocodile numbers have climbed since the end of uncontrolled hunting in the early 1960s and it is now estimated that there are more than 30,000 crocodiles in Lake Kariba alone. The economic benefits of utilization have proved particularly important where emotive conservation and development issues have been argued.

As a result of recent research into the dynamics of crocodile populations, it has been possible to make some predictions as to the level of exploitation which would be sustainable in a population of a given size and age structure. Unfortunately, despite considerable expenditure of resources, accurate measurement of these parameters for larger populations has proved elusive, thus requiring that management remain both conservative and adaptive. More research is being focused on census techniques, particularly with respect to factors which affect apparent age structures, such as size-specific dispersion.

Even with utilization, Zimbabwe's burgeoning population threatens to deplete the crocodile resource unless more obvious benefits are made available to rural communities which coexist with the animals. More emphasis is being placed on this aspect of management and in one scheme cooperative rearing stations are planned.

The industry has been largely dependent on inexpensive meat from game cropping. While the use of game meat is likely to remain economically justifiable, social pressure against its use is anticipated and alternative food sources are being investigated. To allow rearing stations to expand and to buffer them from unfavorable egg quota decisions, the keeping of limited captive

breeding stock is being encouraged and it is expected that food, rather than the availability of eggs, will limit the size of the industry.

ACKNOWLEDGMENTS

Our wild crocodiles wish to express their gratitude to all those in the Department, the CFAZ and elsewhere who have ensured their survival through the success of sustainable utilization.

LITERATURE CITED

Blake, D.K. 1974. The rearing of crocodiles for commercial and conservation purposes in Rhodesia. Rhod. Sci. News 8:315-324.

_____. 1982. Crocodile ranching in Zimbabwe. Zimb. Sci. News 6:208-209.

_____ and J.P. Loveridge. 1975. The role of commercial crocodile farms in crocodile conservation. Biol. Cons. 8:261-272.

Child, G.F.T. 1977. Problems and progress in Nature Conservation in Rhodesia. Koedoe 20 (supplement):116-137.

CITES. 1984. First Meeting of the Technical Committee, Brussels (Belgium), 25-30th June 1984, CITES Secretariat, Gland (Mimeographed).

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

Foggin, C.M. 1987. Disease and disease control on crocodile farms in Zimbabwe. Pp. 351-362 *in* G.J.W. Webb, S.C. Manolis, and P.J. Whitehead, eds. Wildlife Management: Crocodiles and Alligators. Surrey Beatty and Sons. Chipping Norton, Australia.

Garnett, S.T. 1983. Nutrition and farm husbandry of the green sea turtle (*Chelonia mydas*) and the estuarine crocodile (*Crocodylus porosus*), Ph.D thesis, James Cook University of North Queensland, Australia.

Groombridge, B. 1982. Amphibia-Reptilia Red Data Book, Part I, crocodilians and chelonians. IUCN. Gland, Switzerland.

Hutton, J.M. 1984. The population ecology of the Nile crocodile, *Crocodylus niloticus* Laurenti, 1768, at Ngezi, Zimbabwe. D.Phil thesis, University of Zimbabwe.

_____. 1986. Cashing in on crocs. Zimbabwe Wildlife, March 1986:27-29.

_____. 1987a. Growth and feeding ecology of the Nile crocodile (*Crocodylus niloticus*) at Ngezi, Zimbabwe. J. Anim. Ecol. 56:25-38.

_____. 1987b. Incubation temperatures, sex ratios and sex determination in a population of Nile crocodiles (*Crocodylus niloticus*). J. Zool. (Lond) 211:143-155.

_____ and S.L. Brennan. 1985. An analysis of records of the crocodile rearing industry in Zimbabwe, Branch of Terrestrial Ecology Internal Report, Department of National Parks and Wild Life Management, Zimbabwe.

Joanen, T. and L. McNease. 1974. Propagation of immature American alligators in controlled environmental chambers. Proc. Am. Assoc. Zoo, Parks Aquar. Reg. Conf.:262-268.

Magnusson, W.E. 1980. Hatching and creche formation by *Crocodylus porosus*. Copeia 1980:359-362.

_____. 1984. Economics, developing countries and the captive propagation of crocodiles. Wild. Soc. Bull. 12:194-197.

Pooley, A.C. 1969. Preliminary studies on the breeding of the Nile crocodile (*Crocodylus niloticus*) in Zululand. Lammergeyer 10:22-44.

Siziba, C. 1985. Design of pens for hatchling crocodiles, B.Sc. Honours thesis, University of Zimbabwe.

Van Jaarsveldt, K.R. 1987. Flaying, curing, and measuring crocodile skins. Pp. 387-392 *in* G.J.W. Webb, S.C. Manolis, and P.J. Whitehead, eds. Wildlife Management: Crocodiles and Alligators. Surrey Beatty and Sons. Chipping Norton, Australia.

Webb, G.J.W., R. Buckworth, and S.C. Manolis. 1983. *Crocodylus porosus* in a controlled-environmental chamber: a raising trial. Aust. Wildl. Res. 10:421-432.

EDITOR'S NOTE: Since this manuscript was received, substantial changes have been made to the management system in Zimbabwe. Anyone interested in obtaining further information should contact the senior author.