1. CAPTIVE BREEDING AND THE MANAGEMENT OF ADULT CROCODILES

1.1 Captive Breeding

Most crocodile species have been bred in captivity but on a commercial scale only a few species are involved. Breeding is normally seasonal and one clutch a year is the rule although double clutches sometimes occur in captive animals and are quite common in the mugger.

As in many other animals environmental factors such as rainfall, day length or temperature changes act as seasonal stimuli to breeding but little is yet known about this and an internal rhythm may also be involved. Crocodiles have been known to retain their original breeding season even after they have been moved to captivity in a different climate. Whatever factors are involved it is to be expected that the nesting season in each area will have been selected so as to give the best chance of success in the wild.

In the breeding season crocodiles of both sexes show increased levels of hormones from the pituitary gland. These hormones, circulating in the blood, stimulate the reproductive organs to produce their own hormones which are associated with production of sperms and eggs. In open air captivity these seasonal changes usually coincide fairly closely with those of local wild crocodiles, so that breeding occurs at about the same time. Details of breeding behavior vary with the species but there is always a period of courtship before mating, nesting and egg laying.

For several species the period between mating and egg laying is known to be about 3-6 weeks but longer periods have been reported. American alligators, during the act of egg laying, become extremely docile and the eggs may actually be caught by hand as the female lays them. (Cardeilhac & Larsen, 1981). A similar trance-like state during laying has also been reported in the Nile crocodile.

The basic requirements for captive breeding can be stated as follows:

- compatible animals in breeding condition

- adequate depth of water for courtship and mating

- suitable nest sites and nest material

The first requirement is simply stated but really presents all the problems. Breeding condition is not always achieved in captivity and when crocodiles are in breeding condition they may become highly territorial.

Males may guard and defend a territory against other males which can be killed if they are not free to leave the territory. Species differ in this regard but C. porosus can be especially troublesome as both sexes are territorial and serious fighting may take place between females or individuals of opposite sex as well as between males.

Nevertheless, breeding success has been achieved under widely different conditions. Isolated pairs have nested quietly in secluded pens and others have nested equally successfully in large enclosures where hundreds of crocodiles of both sexes were crowded together. The explanation seems to be that under extreme crowding the crocodiles are not able to maintain their normal territorial behaviour. There are advantages and disadvantages in such a communal system and it is probably not the most efficient way to breed crocodiles for maximum egg production.

Captive breeding programmes for commercially-important species are briefly reviewed. Below.

1.1.1 Thailand

The Samut Prakan farm in Thailand provides the best example of communal breeding and it has been well publicised in tourist brochures as well as in the scientific literature.

The breeding crocodiles are kept in large enclosures each with a single breeding pool of irregular shape and a smaller feeding pool. An area of land 'somewhat larger than the water area' surrounds the ponds in each enclosure.

At maximum density a breeding pond of 0.2 hectare holds about 250 crocodiles with a sex ratio of 1 male to 3 females. The pools are concreted and have a concrete border which helps to keep the surrounding soil out of the water. The main pools are never drained but clean water is pumped in and the discharge is carried away through an overflow pipe as necessary. The depth of water is maintained at approximately 1.5 metres.

Water in the small feeding pools is only 50 cm deep and these pools are cleaned daily after feeding. The purpose of the system is to avoid contaminating the main pond with uneaten food.

Around the edge of the enclosure are nesting stalls in the form of brick cubicles each of 4 x 4 m with an open top and a 60 x 60cm opening at floor level facing the pool. During April dried grass is heaped in each stall as nesting material. The breeding females then select a stall and although they may fight over the same one the female which eventually occupies a stall can easily defend it because of the small entrance.

Two species, C. porosus and C. siamensis are kept together in the breeding enclosures. Their breeding requirements and behaviour are similar and the two interbreed. The offspring are said to be strong and fast growing. Females usually lay their eggs about a week after selecting a stall. During this period they build a nest by mixing the dried grass with sand and shaping it into a mound. Egg laying has been seen to take place most often in the morning (0500-0900 hrs) and the process takes only a few minutes. Management policy at Samut Praken is to drive the female out of her stall when the eggs are laid, and then to block the entrance.

During the incubation period, temperature and humidity in the nest are monitored and maintained by the farm workers. A hatching success of 70-86% is reported. After hatching the young are collected and kept in groups of 8-15 in small hatchling tanks. They are moved to progressively bigger tanks as they grow.

The above details were obtained from Yangprapakorn et al (1971) and Suvanakorn and Youngprapakorn (1981). These authors also mention that during the mating season, which lasts from December until March, some males will fight and wound each other with one or two being killed each year.

Presumably, because of the overcrowding and large numbers involved, it is impossible for a few dominant males to prevent all the others from breeding so a good proportion of the crocodiles do manage to breed successfully. The communal breeding enclosures also present a Spectacular attraction for tourists and income from tourism must certainly amount to much more than income from the sale of crocodile products. The farm is therefore highly successful.

If success is to be measured only in terms of egg production then better results should be obtained by keeping smaller breeding groups under conditions where fighting and stress are at a minimum; most breeding programmes have to begin with small numbers in any case. And though the death or injury of a few animals a year can easily be tolerated at Samut Praken it would be most serious in a small enterprise.

1.1.2 U.S.A

In the wild up to 68% of female alligators nest each year (Chabreck, 1966). Age at first nesting is 9 years 10 months both for wild alligators and those reared in outdoor enclosures (McIlhenny, 1935; Joanen & McNease, 1975). Age at first nesting for animals reared in environmental chambers for their first three years was 5 years 10 months. Captive males become sexually mature at about 1.83 m total length but the social order favours breeding by bigger animals (Joanen & McNease, 1979).

To date most captive breeding records compare very poorly with values obtained from the wild. Moreover, at the Rockefeller Refuge in Louisiana, early breeding records showed that farmbred alligators had a lower reproductive efficiency than wild caught ones in captivity as shown in the table below.

Table 1. Alligator Breeding in Louisiana. Compiled from Joanen,T., & McNease,L. (1981)

	% of Females Nesting	Average Clutch Size	% Fertile Eggs
Very Young Captive-bred alligators	26.3	27.6	39.5
Wild Caught Alligators In Pens	48-50.0	39.0	74.4
Alligators In the Wild	68.0	39.0	87.5

The small clutch size is to be expected in wild or captive animals during their first two or three reproductive years but the lower proportion of females nesting and of fertile eggs is a widespread problem even in older animals and is less easy to explain.

At the Rockefeller Refuge wild caught alligators were used for breeding until enough farm bred animals had matured. In addition to the reproductive differences tabulated above it was found that the wild caught alligators needed much more space than captive bred ones. Stocking rates were critical and fighting was a major problem.

In early research by Joanen & McNease (1971) simple rectangular pens of 0.1 ha were used. They contained a single pool with a small island in the centre. The pool was surrounded by a land area a few metres wide to give a total water to land ration of 7:3. Despite the natural vegetation which grew to provide cover only one pair of wild caught alligators could be kept in each pen. If others were introduced the dominant male and female 'either killed them or forced them to flee'. For each breeding female, therefore, a male had to be kept and a pen had to be allocated to each breeding pair.

In later research (Joanen -t al 1981) pen size varied from 0.1 ha to 0.8 ha and a number of separate pools were excavated in each pen. A deep water courtship pool was the main water area and was always rectangular and at least 30 x 5 m. The water was 1.8 m deep and was maintained by pumping from a well. In addition, for every female stocked a 6 x 3 m isolation pool was provided. Feeding sites were established on land and tracks to them were kept clear of dense vegetation.

Even under these conditions multiple stocking of wild caught males proved to be uneconomic because the area needed for 2 wild caught males per pen was four times greater than that needed for 1 per pen. Under the best pen conditions a breeding group of 5 wild caught alligators could be maintained per 0.4 ha while animals that had been bred and reared together in captivity could be kept at much higher densities. On a commercial alligator farm in Louisiana 45 captive bred adults were kept per 0.4 ha.

In Florida a communal breeding colony has been described by Smith and Cardeilhac (1981). An enclosure of 0.48 ha contained a pool of 0.28 ha. The pen held 100 alligators (presumably captive bred) with a sex ration of approx. 1 male to 3 females (26:74). In 1980 twenty eight nests were found with a total of 1079 eggs.The hatchling rate was 57%.

One important factor in this breeding colony is the shape of the pool. Starting with a natural hollow the shore-line was reshaped with a tractor and back-hoe to form a series of inlets (Fig. 1). This had the effect of almost doubling the length of shoreline and providing a number of secluded bays and separate basking banks. The depth of water was not stated but it is unlikely to have been less than 1 metre and was maintained by pumping from a borehold.

The effects of stock density and pen design upon breeding success will only be revealed by long-term studies. Current research at the Rockefeller Refuge includes a programme to monitor stress hormone levels in a series of penned animals so that the levels at different stock densities can be compared with those in wild alligators.

1.1.3 Papua New Guinea

At the time of writing two large commercial farms are breeding C. porosus with efficient production of hatchlings as the main goal. In both cases the intention is to determine the most successful pen design and stocking density for small compatible groups. Both breeding programmes have only recently begun but some experience had already been gained at the Moitaka government farm near Port Moresby.

During the 1970s up to 80 breeding crocodiles were kept at Moitaka and although no systematic breeding research was carried out some observations may be useful. Both C. porosus and C. novaeguinea were bred but the species were kept separately as adults; one saltwater male killed a freshwater male which accidentally

entered its pen.

Both species build very similar mound nests and the process was observed in a captive C. porosus. She piled up material by scraping backwards with simultaneous movements of left front and right rear feet and then right front and left rear and so on. It appeared to be clumsy and much of the nest material was thrown onto her back but a mound resulted after several hours (Whitaker, 1980).

The majority of the breeding animals were kept one pair to a pen and even that sometimes presented problems of compatibility, especially in the case of C. porosus. One male killed two successive females before mating with a third. Experience indicated that a new male could be introduced more easily into the pen of an established female than vice versa. The chances may be better still if the new male is at least as big as the established female.

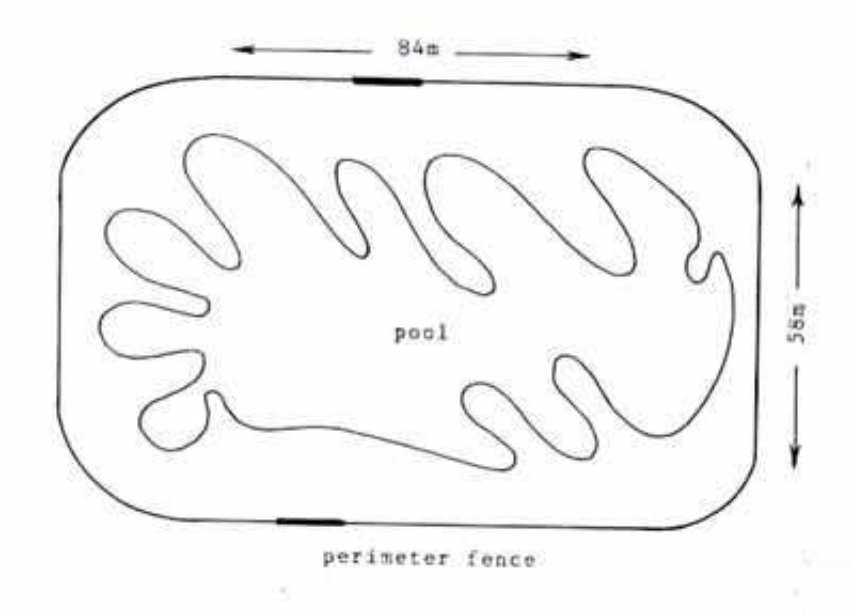
There was no attempt to determine the minimum area of land or water necessary for breeding but the smallest enclosure used measured 12 x 9 m with a single pool of 12 x 4 m. Water depth was not less than 1 m - which appeared to be the minimum necessary depth. The pen accommodated one pair of C. porosus, the male measuring 3.45 m and the female during two 2.55 m. They nested successfully ng two seasons that they were observed by the writer.

The greatest number of C. porosus kept together at Moitaka was seven (1 male, 6 females) in a pen of 78 x 36 m with a pool of 24 x 15 x 1+ m deep. There were also two subsidiary pools of 5 x 3 x 1 m deep - each of which was used exclusively by a female. Five clutches were laid in this pen during the 1979/80 season but only three clutches in the following season. The provision of small isolation pools certainly appeared to reduce the frequency of aggressive encounters.

All the breeding pens at Moitaka had earth pools, a cover of natural vegetation and chain link wire fences.

The New Guinea freshwater crocodile (C. novaeguineae) proved to be easier to keep communally than C. porosus. One enclosure of 66 x 56 m had a pool of 38 x 30 x 2 m deep. Twenty freshwater crocodiles (4 males, 16 females) were accommodated with no obvious behavioural problems. There were no subsidiary pools but there was a general tendency for females to select the same site to nest each year. In this pen the nests were built from earth and vegetation growing naturally. Despite the apparent social harmony the nesting record was very poor. Nine clutches were produced in 1979/80 and only three in 1980/81. The crocodiles were fed on whole fish which appeared to keep them in excellent health but which is probably an inadequate diet for breeding stock (see 1.2).

Fig 1
Alligator Breeding Pond
With -Modified Shoreline
(From Smith & Cardeilhac,1981)



1.1.4 India

There is as yet no commercial breeding of crocodiles in India but a commendable programme of breeding for conservation and restocking is well advanced. Three species are involved - the mugger (C. palustris), the saltwater crocodile (C. porosus) and the gharial (Gavialis gangeticus).

By the early 1970s it was apparent that all three types were in danger of extinction, having been hunted for skins and displaced from their habitats by human activity. In particular, the gharial must have been one of the world's rarest reptiles with less than 150 adults as the estimated population. Accordingly, all crocodiles were given the highest order of protection under the Indian Wildlife Protection Act (1972) and a conservation programme was begun by the Government of India with FAO/UNDP assistance. The programme has been reviewed by Whitaker & Whitaker (1985) who record that at least 38 sanctuaries, national parks or other protected areas in India now manage crocodiles and more than 2000 crocodiles of the three species have been released at 20 sites since the programme began. The bulk of this production was from ranching rather than captive breeding but all three species in India have been bred in captivity.

The largest centre for crocodile breeding (as distinct from rearing) in India is the Madras Crocodile Bank, a private trust established in 1975. Details of the bank's breeding record have been supplied by Whitaker (in litt). The centre is located on coastal sands and the breeding enclosures are made simply and cheaply by digging down below the water table until water lies to a depth of 1-3 m with a surface area of about 250 square metres. A brick or stone wall is then built to a height of 1.5 m to enclose the pool and similar-sized area of land.

In enclosures of this type mugger have bred very successfully and the bank is unique in having several females consistently laying two clutches of eggs each season. A minimum breeding age of 6 years 8 months has been recorded and clutch sizes have ranged from 10 to 46 with an average of 27. One or two males are stocked with 6-12 females and over 2,000 hatchlings have been produced.

The mugger is a comparatively easy species to manage for it appears that only males are strongly territorial and then only for a limited period during the breeding season (B.C. Choudhury in Bustard, 1980). Even so, the problem of territory cannot be ignored. Fig. 2 shows an enclosure with separate small pools used for eleven mugger (3 males, 8 females) at the Nehru Zoological Park, Hyderabad. One male with his associated females occupied each pool and adjacent land area as his breeding territory (Bustard, 1980).

For five consecutive seasons C. porosus has bred at the Madras Crocodile Bank where enclosures as described are used to house each breeding pair.

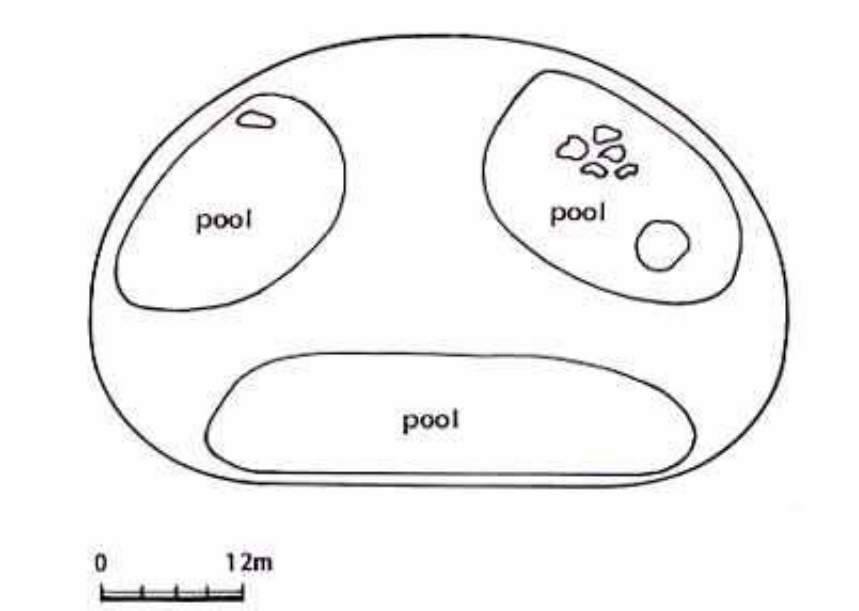
Gharial are stocked communally with 3 males to 10 females but breeding has not yet been achieved. A shortage of mature males has been a major problem. Gharial were bred at the Nandankanan Biological Park in Orissa after a mature male was flown from the Frankfurt Zoo on a loan arrangement.

In the short term the Indian crocodile conservation programme seeks to ensure the survival of the three indigenous species but the expressed intention is to formulate a management programme and it is to be expected that this will eventually include commercial utilization of the resource. In the meantime the Madras Crocodile Bank forms a nucleus of breeding animals and there are plans to include a number of exotic species. Several spectacled caimans (Caiman c. crocodilus) were acquired in the mid 1970s and have been breeding successfully since they were six years old.

1.1.5 Africa

Although crocodiles have been ranched in Africa for many years, captive breeding has not been significant in commercial production until quite recently. In Natal, South Africa, captive Nile crocodiles were first bred for restocking purposes in 1974 and they have been bred in increasing numbers since then. Once the feasibility of captive breeding had been proven a number of commercial farms were started in South Africa and all 'ranches, in Zimbabwe were encouraged to set aside potential breeding females or to purchase breeding stock.

Fig 2. Breeding Enclosure for Mugger with Separate Pools to Provide Territories for Three Males and their Associated Females. (After Bustard, 1980)



There were about 280 animals being kept for breeding by 1984 (Child, 1985). Several African countries now have an interest or involvement in commercial crocodile production.

Breeding behaviour of the Nile Crocodile, and other species in the wild, probably depends to some extent on variable factors such as crocodile density, sex ratios and availability of nest sites. In general, however, male C. niloticus will fight in the breeding season when they compete for the best breeding territories. After courtship the females may also compete for the best nest sites but they are colonial nesters and several females will nest in close proximity. The writer has seen as many as fifteen excavated nests all within a few metres of each other. The females guard the nests while the male defends the entire breeding ground occupied by his females which in South Africa may number from one to six in the wild (Pooley, 1980).

In Zimbabwe twenty-three clutches of eggs were once obtained from 23 females kept in captivity with one male (R. Gee pers. COMM.). This was an exceptional instance and a lower sex ratio is likely to be more successful.

1.2 Nutrition and Fertility

Even when crocodiles have been properly accommodated in compatible groups or pairs and all nesting requirements have been met the crocodile breeder may be disappointed with the number of eggs produced and further disappointed by the percentage which hatch. Infertile eggs, showing no development at all, will be easy to distinguish from deaths due to incubation faults.

It has been said that low reproductive efficiency is a world wide problem in crocodilian farms and can be extreme in the older alligator farm (Godwin & Cardeilhac, 1981). It has certainly been common experience to find that many apparently healthy, mature females do not lay eggs and when they do there is a high proportion of infertile ones.

There is some evidence that a diet of fish, while excellent for growth, is not adequate for breeding females. In Louisiana when the diet of young breeding alligators (captive bred) was changed from fish to nutria they showed marked improvement in reproductive efficiency. Both diets were supplemented with a vitamin premix (Appendix 1). The percentage of females nesting exceeded that recorded for wild alligators but egg fertility and hatching success was still inferior to that recorded for eggs collected from the wild. (Joanen and others, 1981; Joanen and McNease, 1985).

It is known that vitamin E, selenium and other trace elements are essential for egg production and hatchability in poultry. Lance and others, (1983) studied these elements in alligator blood. They found that plasma levels of calcium, magnesium, zinc, copper and iron were not significantly different in wild and farm-reared female alligators during the breeding period. Selenium levels varied according to diet but were adequate and not likely to have been a factor in reproductive failure. Nor could the problem be explained by vitamin E deficiency. Nutria-fed alligators had similar vitamin E levels to alligators in the wild.

Until more research finds are available it can only be recommended that diets be varied and enriched with multi-vitamin supplements. Different feeding regimes could be tried though Joanen and McNease (1971) have concluded that a rate of 7-8% of body weight per week is optimal for breeding stock.

1.3 Some Conclusions On Captive Breeding

Many questions have yet to be answered but obviously the particular needs of each species, as far as they are known, must be taken into account when setting Lip a captive breeding programme. It is quite possible, however, that in captivitv there will be some behavioural differences; wild and captive crocodiles are quite capable of responding differently to their particular circumstances. Routine behaviour in the wild might not even be possible in captivity. For example, the Nile crocodile may make seasonal journeys of several kilometres to and from its breeding ground (Hutton, 1982).

With our present state of knowledge, accepting that each case needs separate consideration, only a few general observations can be put forward.

Water depth should be at least 1 m to allow for courtship and mating. Plenty of nest material (decaying vegetation and moist earth) must be provided for mound nesters and a good depth (at least 60 cm) of loose earth or sand for hole nesters. Failure to provide these in time may result in eggs being scattered about the pen or even retained in the female's body so that she dies (Bustard, 1980).

Nest sites should be provided close enough to water for the female to sock herself without making a long or awkard journey. There should be both sun and shade at the nest site - especially if the eggs are to be left in place for all or part of the incubation period and the female is to be allowed to guard them. There must be no danger of nests being flooded.

The breeding enclosure should be disturbed as little as possible. There should be a screening of bushes or a solid fence and visitors should be kept away.

If breeding females are in short supply it seems unwise to confine several of them with one male until that male has proved that he can serve them. In order to establish breeding groups with more than one male the breeding pool can be shaped so that there are visually separated areas. This can be done very effectively by having the pool in the shape of a meandering channel. Shallows or constrictions between bends further help to break up the pool into separate territories while still allowing it to be managed as a single pool. On land sections of the channel can be screened by bushes.

With earth pools the scale of operations must be quite large because narrow strips of land between water will soon be destroyed by erosion and crocodile activity.

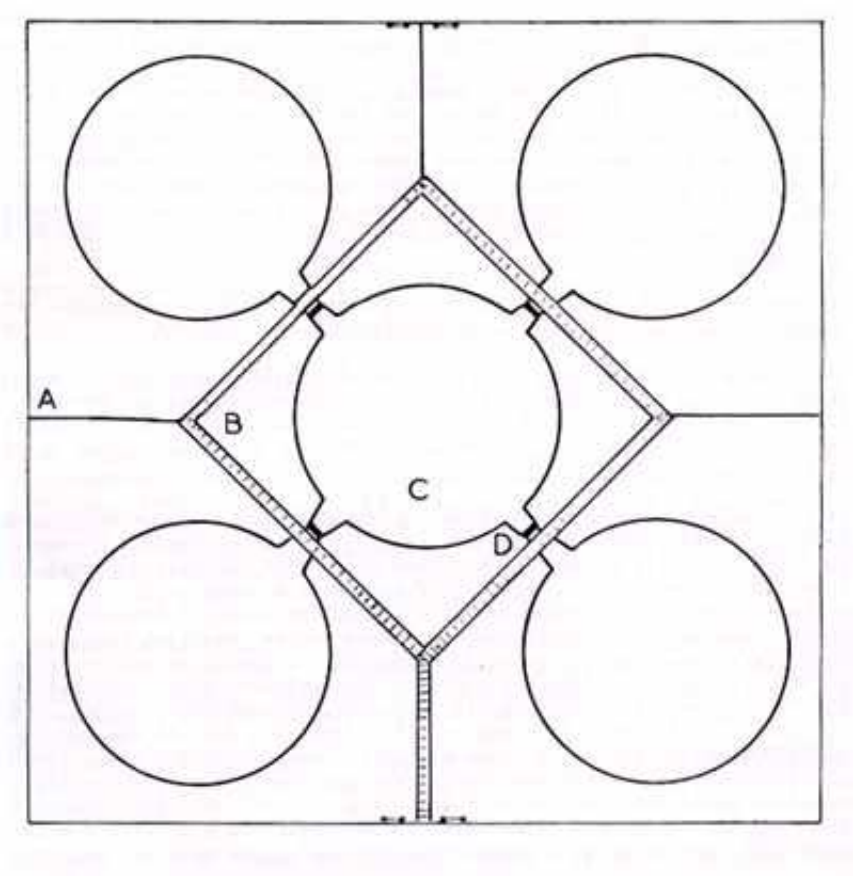
Where one male is kept together with several females there must be a main pool for mating but fighting between females can be reduced if they are provided with small, separate isolation pools. This could permit a smaller and less costly enclosure than one for multiple males but water levels have to be maintained by pumping to all pools separately.

Perhaps the most sophisticated breeding enclosure will be one which offers maximum flexibility and provision for experiment. It seems reasonable to suppose that if crocodiles are able to select their own mates then the most successful combinations of breeding animals will result. The managers' dilemma is that he has to decide whether to select the groups or pairs himself or else put numbers of males and females together and risk failure or losses in the resulting battles. if the resources are available it should be possible to design an enclosure which would, at least partly, overcome this problem. An enclosure with a central breeding pool could have a number of other pools, also large enough for breeding, arranged around it. These could be connected to the central pool by shallow, narrow channels. This might prove to be sufficient separation for several males but the facility would be greatly improved if the pools were separated by fences with drop-down gates over the channels as in Fig. 3. In such an enclosure subordinate males should have a far better chance of establishing a territory with a mate or mates than they would in a single breeding pool. One male for each pool could therefore be introduced with any reasonable number of females. An important advantage of such a design is that any section or sections can be closed off as and when indicated to form completely separate pens. No space need therefore be wasted.

If crocodiles intended for breeding are being reared in captivity it may be an advantage to put them together in the breeding enclosure before they show signs of sexual maturity. A social order might then be established gradually, so avoiding maximum aggression.

Until more is known about crocodile nutrition breeding animals should be given a variety of food and fed once a week or more frequently. If possible, whole animals such as rats should be added to the diet. Fur or feathers should be left on as roughage. Special attention should be given to calcium in the diet and a multivitamin supplement will be worth including as a precaution against deficiencies.

Fig 3
Breeding Enclosure Designed to Eliminate Wasted Space and Increase Management Options. Drop-down doors to be used as indicated by crocodile social order



A = chain link wire fence
B = walkway with handrail along fence top permits safe observation of all pools and operation of drop-down gates
C = earth pool with shallow connecting channels
D = drop-down -ate (hardwood grid construction, joints glued with epoxy resin)

- Select only strong, healthy animals for breeding.

1.4 Handling Large Crocodiles

When large crocodiles have to be caught and handled for translocation, measuring etc. there is an obvious danger to the handlers and a risk of injury to the animals. The risks are reduced by using immobilizing drugs.

1.4.1 Immobilization

The use of gallamine triethiodide 1/ as an immobilizing agent for crocodiles was pioneered in the early 1970s by Woodford (1972) who tested it on four Nile crocodiles. Since then it has been used quite extensively for Nile crocodiles (Loveridge & Blake, 1972, 1985; Loveridge, 1979) and other species and immobilization with Flaxedil is now generally accepted as a tested and useful technique. The notes that follow are based mainly on the work of Loveridge and Blake.

Gallamine triethiodide is a synthetic substance which relaxes the muscles. It can be diluted with sterile distilled water and is stable for many months, even when diluted, if kept in a cool dark place. After injection with the drug crocodiles soon become slow to react and appear to have difficulty in moving on land. Complete immobilization

usually occurs within half an hour. In this stage crocodiles make no voluntary movements at all and may be so relaxed that they can not even keep their jaws closed. When an immobilized crocodile is rolled on to its back it is unable to right itself on land but shows more coordination in water and can even manage to swim slowly. If pushed under water the nostril valves close (Woodford, 1972).

Changes in heartbeat and respiration have been reported following injection but when totally drugged the animal's heartbeat and respiration are not very different from normal.

It must be emphasized that gallamine triethiodide is NOT an anaesthetic. An immobilized crocodile is fully conscious and receiving input from its sense organs. In human terms, the crocodile can feel pain but cannot respond because it is paralysed.

Body weight is the obvious parameter by which to determine the dose of a drug but there is some evidence that bigger crocodiles need proportionally less gallamine. For this reason it is recommended (Loveridge & Blake, 1972, 1985) that a maximum of 2 mg/kg be given for the smallest crocodiles (about 2 kg) but only 0.5 mg/kg for the biggest animals (500 kg). On this basis a crocodile of 200 kg would receive 200 mg of the drug (1 mg/kg) and a 50 kg animal would receive about 85 mg (1.7 mg/kg). The safety margin for gallamine is fortunately quite high so that body weight does not have to be judged accurately. Very small crocodiles have tolerated doses as high as 4 mg/kg and effective immobilization has been obtained in crocodiles of 50 kg with doses of less than 1 mg/kg. In fact I mg/kg could be used generally as an easy rule of thumb (Loveridge & Blake, 1985).

1.4.2 Recovery and the Use of Antidotes.

Unaided recovery is slow and may take more than a day. For this reason it is common practice to use the specific antidote - neostigmine methylsulphate 2/.

Injection of neostigmine reverses quite rapidly the effects of the immobilizing drug, usually restoring the ability to move within 10-20 minutes.

1/ Flaxedil, May & Baker Ltd., Dagenham, England

2/ Prostigmin, Roche Products Ltd., Welwyn Garden City, Herts, England

This antidote must be used very carefully, however, because it also affects the transmission of nerve impulses to the muscles and even small doses may cause side effects such as urination, defaecation (sometimes with blood in the faeces) and possibly vomiting.

The dose need not exceed 0.06 mg/kg for the smallest crocodiles and can be reduced to 0.03 mg/kg in the heaviest animals. The dose can be further reduced if the crocodile has been immobilized for several hours.

To combat the side-effects of the antidote Loveridge and Blake (1985) tried injecting atropine sulphate before the neostigmine injection. A dose of 0.03 mg/kg was found to be successful but the authors point out that more research is needed because crocodiles do not always show adverse reactions to the neostigmine.

In all cases, with or without the antidote, recovery of crocodiles after immobilization will be assisted if the animals are kept warm (though not above 32°C body temperature) and allowed access to shallow water to help in the excretion of gallamine.

1.4.3 Administration of the Drugs, Handling and Aftercare

Syringes and needles should be sterile to prevent infection. All the injections mentioned above can be made in the muscle of the upper hindleg or foreleg but large crocodiles may have to be immobilized at a range of a few metres and in this case the side of the tail base offers the best target. Darting equipment consisting of a pistol which fires projectile syringes is available from Palmer Chemical and Equipment Co., USA (compressed $C0_2$ - fired and percussion injected) or Paxarms Ltd., New Zealand (percussion fired and compressed air injected). Both types have been used for crocodiles and provided the syringe strikes the skin at nearly right angles no problems should arise. There is an obvious danger to the operators if the equipment is used carelessly. In some circumstances a crocodile can simply be injected on the other side of a fence with a syringe on a pole.

It is important to handle immobilized crocodiles carefully. Rolling them over, for example, can dislocate the limbs if they are not laid against the body. Because they are so limp small crocodiles may suffer a damaged spine if they are not supported properly when handled. Large crocodiles should be carried on stretchers, bedded on straw

and covered against the sun and drying wind. The nostril must not become blocked and the animals should not be tied as this can interfere with blood circulation and even cause gangrene. To reduce stress the eyes and ears should be covered during handling and transporting.

1.4.4 Anaesthesia

Major surgery involving total anaesthesia should only be attempted by qualified persons with proper facilities.

For minor surgical work, such as treatment of wounds or amputation of toes, large crocodiles can conveniently be immobilised as above - then the area to be treated can be injected with a local anaesthetic. Procaine hydrochloride or lidocaine hydrochloride are recommended by Loveridge and Blake (1985). In removing a neck scute section, for example, these authors inject 250 mg of procaine hydrochloride under the scute, half from in front and half from behind. For swift recovery (from immobilization) neostigmine, with or without a prior injection of atropine, is used in the normal way.