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Cover. *Tomistoma Schlegelii*, one of a captive group held at Samutprakan crocodile farm, Thailand. This species remains one of the most urgent priorities for conservation action.

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ABSTRACT

An Overview of Stress in Farmed Crocodilians

Valentine A. Lance

Disease, poor growing performance, and reproductive failure in farmed crocodilians can generally be attributed to stress. Identifying the cause of stress is often difficult. Acute stress, such as transportation, results in an increase in catecholamines, an increase in blood glucose, an increase in corticosterone and a decrease in reproductive hormones. If the stress is relatively brief there are no long term effects. Chronic stress, on the other hand, can lead to death. Examples of chronic stress can include poor housing design, overcrowding, inappropriate temperature, and inappropriate nutrition. Whatever the cause of the stress, the result is chronically elevated plasma corticosterone levels, decreased growth, a decrease in the number of circulating white blood cells and an increased susceptibility to disease. Data on circulating hormones and white blood cells in juvenile alligators under various artificial stresses suggest a direct relationship between increased corticosterone secretion and a decrease in circulating lymphocytes. Vitamin E has been shown to protect against the pathological effects of stress in cattle. Decreased vitamin E in response to poor diet has been seen in alligators, but more research in this area is needed.

STRESS IN CROCODILIANS - THE IMPACT OF NUTRITION

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What is stress actually? Everyone feels stressed at some time or imagines that they do but what are the symptoms which indicate a stressful situation?

In humans, which includes crocodile farmers, these symptoms are relatively easy to self-diagnose:

- Increased blood pressure.
- Irritable behaviour.
- Headaches.
- Frustration.
- Lack of patience.

All these point to the fact that the pressures of life and the environment may eventually become too much to handle.

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In intensive crocodile farming enterprises the objective is to produce high quality skins of a specific size within the shortest possible period, but at the lowest cost. The crocodile, in intensive production systems, is continually subjected to environmental changes as well as to husbandry practices such as grading and transport which may evoke panic reaction as the reptile tries to escape. All these factors can impose considerable stress on the homeostatic mechanisms. This situation creates stress in the crocodiles which will result in poor performance. Grenard (1991) states that mortalities of up to 90% may be encountered among crocodiles in the first year. The art of good management will be to reduce stress while maintaining a profitable operation. A knowledge of stress levels, factors causing stress and procedures to reduce stress, and the detrimental effect thereoff is thus of prime importance.

The major question confronting the manager is how to assess behavioural or emotional stress in these animals. It will also provide the scientist with scientific evidence to improve production and the well-being of the animals in production systems. The following model which was developed by Moberg (1985) is a valuable tool in depicting stress, its response and consequences to the animal (Fig 1).

Freeman (1987) states that the zoological, let alone the biological, concept of stress continues to elude satisfactory definition. The common element in proposed definitions is that stress contains a negative element and that it should be avoided. It is further suggested by Selye (1951) that "stressors" describe the stimuli and that "stress" is to describe the responses.

Stressors

A wide range of stimuli have been described as stressors which can be grouped under the following headings:

- Climatological.
- Environmental.
- Physiological.
- Physical.
- Social.
- Psychological.
- Nutritional.

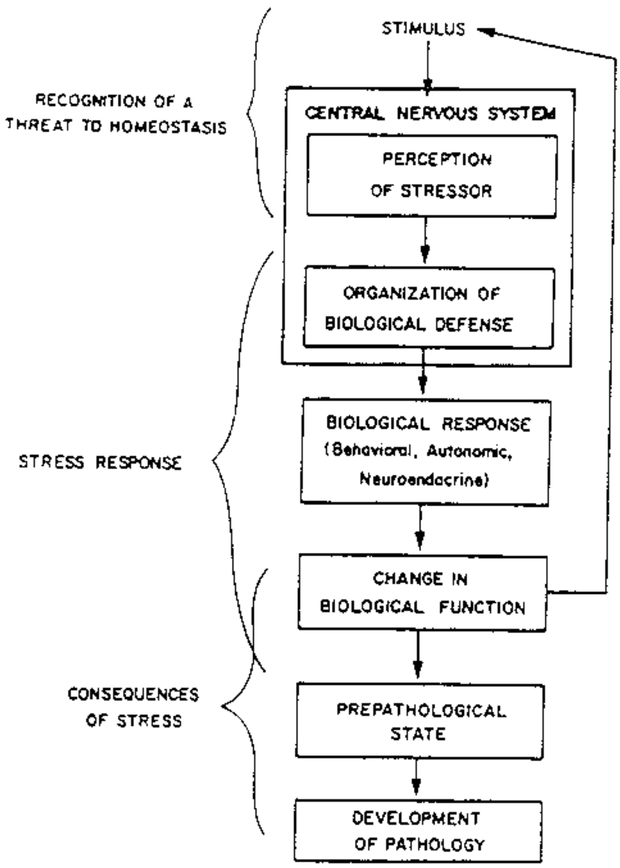


Figure 1 Model for the response of animals to a stressful event. (Moberg, 1987).

In intensive crocodile farming various situations arise which may contribute to stress and which can be classified under these groupings. An understanding of the relevance of the various situations is thus essential as it may assist the producer to manage in a way or to adapt certain practices in order to reduce the impact of the specific stressor.

In this presentation the contribution of the various stressors will be discussed with emphasis to be placed on the role of nutrition as a stressor or a mitigator of stress.

Climatological

Optimal growth of crocodiles is obtained in environmentally controlled houses where the temperature is kept at 31-35°C. The reason being that these reptiles maintain optimal digestion, absorption and protein synthesis and consequently growth at these temperatures.

Coulson et al. (1990) reported that neither domestic nor wild alligators ate voluntarily at temperatures below 25°C and their appetites were diminished below 29°C. Coulson et al. (1986) indicated that 31°C must be close to the optimum temperature for digestion. The temperature is important as it affects the rate of blood-flow through the intestine and the rest of the body. It is thus responsible for controlling the rate of digestion, absorption and assimilation and in maintaining a really perfect balance among the three processes. The accelerated rates of digestion, absorption and assimilation at 31°C are in accordance with the increase in metabolic rate when the temperature was raised above 28°C (Coulson et al., 1964). Whether a further increase in temperature would be beneficial is questionable as there is a narrow gap between the temperature at which metabolic rate is maximal and that which is injurious to the alligator.

Rapid temperature changes in growth houses caused by either adding warm or cold water after cleaning or transferring the crocodiles to houses with different temperatures are a common hazard on various farms. Optimal performance will not be achieved in these situations as the wide temperature fluctuations could be as stressful to crocodiles as was proven for fish (Wagner, 1987). Though optimal growth will not be supported by these practices, the degree of stress may be lower than anticipated as the crocodiles may become accustomed to the fluctuations and thus not perceive it as stress. This phenomena has been proven in fish (Wagner, 1987) and in poultry Davies et al. (1991). Conditioning shows promise in stress reduction as it changes the crocodile's perception of a stressful situation.

In situations where temperatures exceed 31°C by several degrees, "heat stress" may result. It was demonstrated in in vitro studies with chicken epithelium that total uptake of amino acids i.e. methionine into the intestinal epithelium was significantly reduced by heat stress (Dibner et al., 1992) (Fig 2).

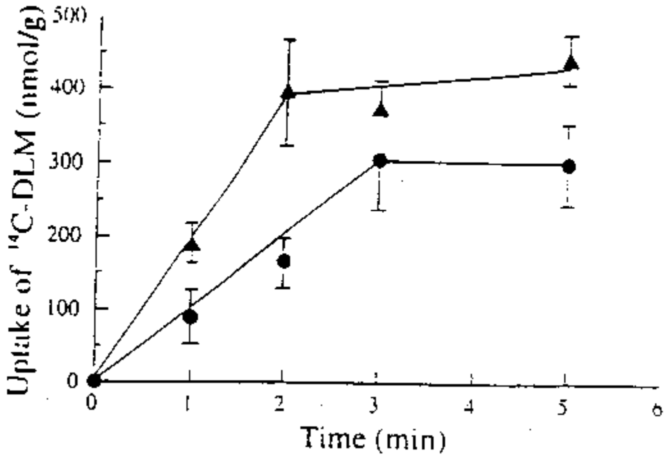


Figure 2 Energy- and sodium-independent (ESI) uptake of DL-[^{14}C-methyl]-methionine (^{14}C-DLM, 15 mM0 by everted intestine slices from thermoneutral (TN,) and heat-stressed (HS,) broilers. (Dibner et al., 1992).

The detrimental effect of heat stress can however be reduced by the inclusion of the Vit A, D, E and B groups (Ferket et al., 1992).

Cold stress is however more of a problem with crocodilians and occurs from 25°C or below. The studies of Lang (1987) on A. mississippiensis living in thermally altered habitats are instructive. When heated water was available throughout the winter months, animals moved between areas of warm (>25°C) and cool (<15°C) water but frequently moved out of warm into cool water. They did however tend to spend more time in the warm water.

Sudden changes in temperature does however influence the cell function. Welch (1993) indicated that immediately after a sudden increase in temperature all cells, from the simplest bacterium to the most highly differentiated neuron, increased production of a certain class of molecule that buffers them from harm. This phenomenon was originally called heat shock response but the same response is observed in cells subjected to environmental assaults including toxic metals and metabolic poisons (Fig 3).

SOME CONDITIONS THAT INDUCE THE EXPRESSION OF STRESS PROTEINS

Environmental stressors
Heat shock
Transition heavy metals
Inhibitors of energy metabolism
Amino acid analogues
Chemotherapeutic agents

States of disease
Viral infection
Fever
Inflammation
Ischemia
Hypertrophy
Oxidant injury
Malignancy

Normal cellular influences
Cycle of cell division
Growth factors
Development and differentiation

Figure 3 Some conditions that induce the expression of stress proteins. (Welch, 1993).

It occurs in traumatized cells growing in culture in tissues of feverish children and in the organs of heart-attack victims and cancer patients receiving chemotherapy. These molecules are referred to as stress proteins. These proteins participate in essential metabolic processes including the pathways by which all other cellular proteins are synthesized and assembled. Some stress proteins appear to orchestrate the activities of molecules that regulate cell growth and differentiation and may thus influence growth efficiency.

Several laboratories set out to purify and characterize the biochemical properties of stress proteins. The most highly inducible heat shock protein (hsp) 70 accumulated inside a nuclear structure, is the nucleolus. The nucleolus manufactures ribosomes, the organelles that synthesize proteins. The location of hsp 70 was intriguing: previous work had demonstrated that of heat shock cells stopped making ribosomes. Indeed their nucleolus became awash in denatured ribosomal particles. The hsp 70 might somehow recognise denatured intracellular proteins and restore them to their correctly folded biologically active shape (Fig 4).

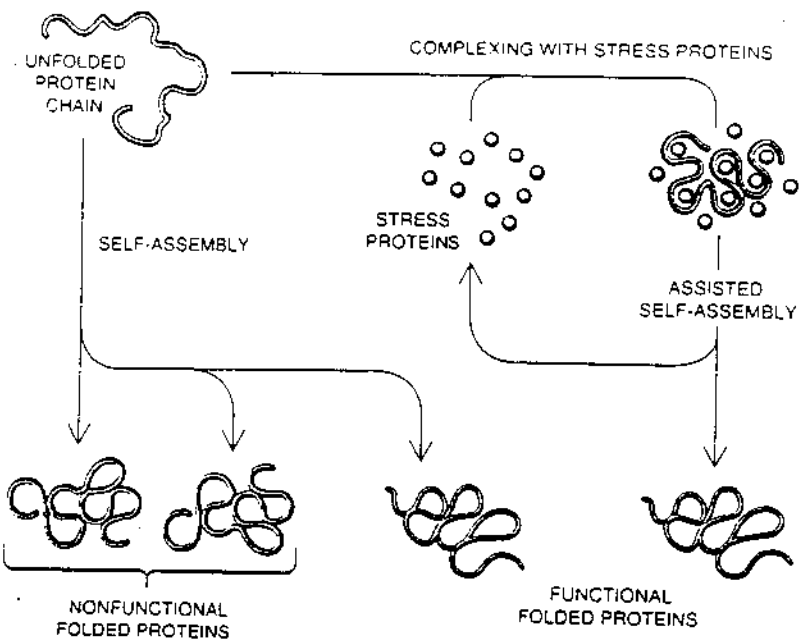


Figure 4 Protein folding. Stress proteins help cellular proteins fold themselves rapidly and with high fidelity. (Welch, 1993).

The hsp 70 family of related proteins share certain properties, including an avid affinity for adenosine triphosphate (ATP). With the exception of one, all of these related proteins were present in cells growing under normal conditions, yet in cells experiencing metabolic stress they were synthesized at much higher levels. More-over, all of them mediated the maturation of other cellular proteins much as immunoglobulin binding protein (Bi P) did. Bi P bound to newly synthesized proteins as they were being folded or assembled into their mature form. If the proteins failed to fold or assemble properly they remained bound to Bi P and were eventually degraded.

In healthy or unstressed cells the interaction of the heat shock protein 70 family member with immature proteins is transient and ATP-dependent. Under conditions of metabolic stress, where newly synthesized proteins experienced problems maturing normally, the proteins remained slightly bound to a heat shock protein 70 escort (Welch, 1993). Stress proteins seem to help ensure that cellular proteins fold themselves rapidly and with high fidelity. These proteins also play a role in allergy and inflamation (Polla et al., 1993). In the folding process the amino acids must be supplied in the appropriate amount and ratio. This is a situation which requires correct nutrition at all times. This can only be associated with properly balanced diets.

Cognisance must however be taken of the fact that incubation temperature had a definite influence on the subsequent thermal behaviour and selected temperature of young crocodiles. Hatchlings from eggs incubated at higher temperatures consistently selected higher temperatures in comparison with those from eggs incubated at lower temperatures (Lang, 1987). Allowing crocodilians to thermoregulate by providing a suitable yet variable thermal environment is probably the best raising strategy with the least stress. An aspect which ties in very closely with variable thermal environment is the seasonal variations in the immune system as was demonstrated by Zapata et al. (1992) to occur in lower vertebrates (Fig 5).

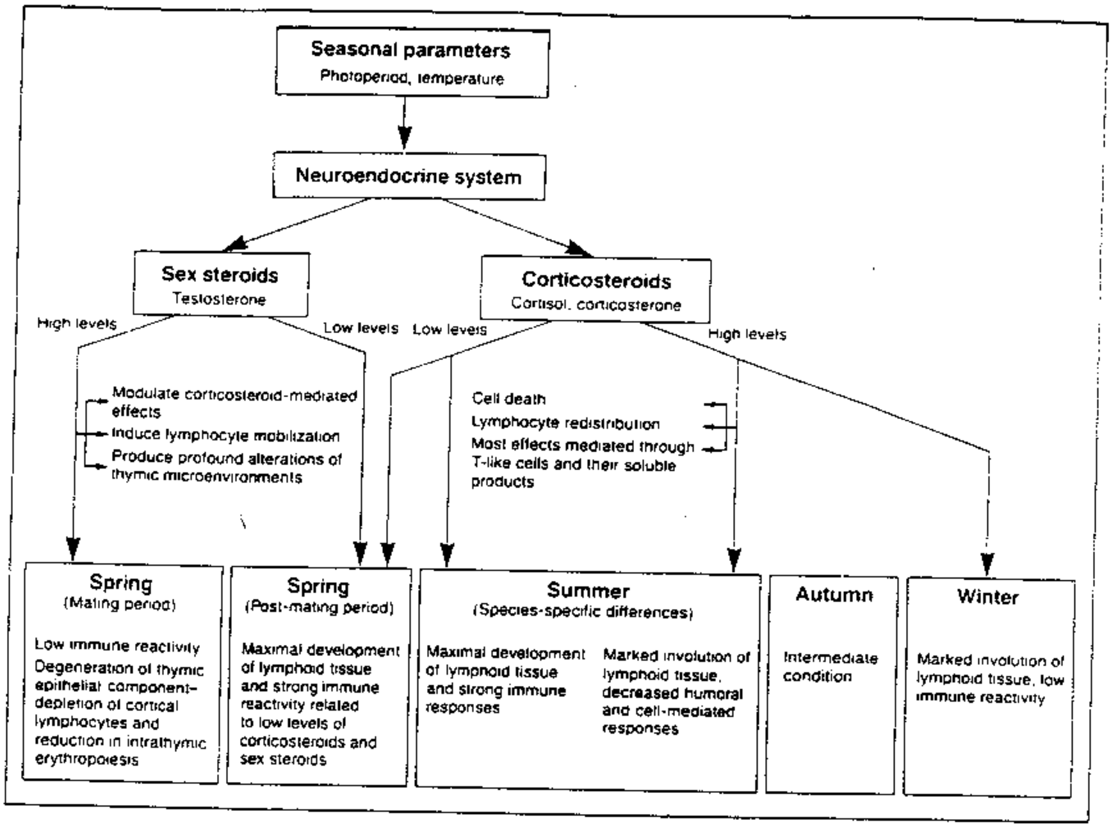


Figure 5 Seasonal changes affecting the structure and function of the ectotherm immune system are modulated throughout endogenous neuroendocrine rhythms involving corticosteroids and sex steroids. (Zapata et al., 1992).

Environmental

Another strategy which has been explored in the removal of awareness of a stressor is by using darkness. It is interesting to note that darkness was beneficial in reducing stress in fish being subjected to a stressor but not in resting fish.

Physical

Increased stocking densities in commercial crocodile farms lead to stressed animals, reduced reproductive success and hatchling liveability. Elsey et al. (1990) indicated that the reproductive failure in crowded alligator pens may be due to high levels of plasma corticosterone and poor ovulation and nesting rates. Though growth rates were higher in captive alligators than in wild alligators (Coulson et al., 1973), eggs produced by farm-raised alligators have lower fertility and lower hatching rates and initially smaller clutch sizes than eggs produced by wild alligators and artificially incubated under identical conditions. This will reduce profitability and may lead to the demise of the farmer. Unacceptably high mortalities, for instance, led to the abandonment of a farm in New Guinea (Bolton & Laufa, 1982). Elsey et al. (1990) reported that a lower corticosterone level in the blood of alligators in lower stocked pens reflected in a greater reproductive success in these pens. It thus seems that there is a connection between population density and nesting in that excessive agnostic behaviour could restrict mating opportunities. Campbell et al. (1992) found that stress resulted in a dramatic increase in the plasma cotisol concentration of trout, both hens and cocks (Fig 6). This resulted in a reduced egg weight and volume and reduced sperm counts (Fig 7).

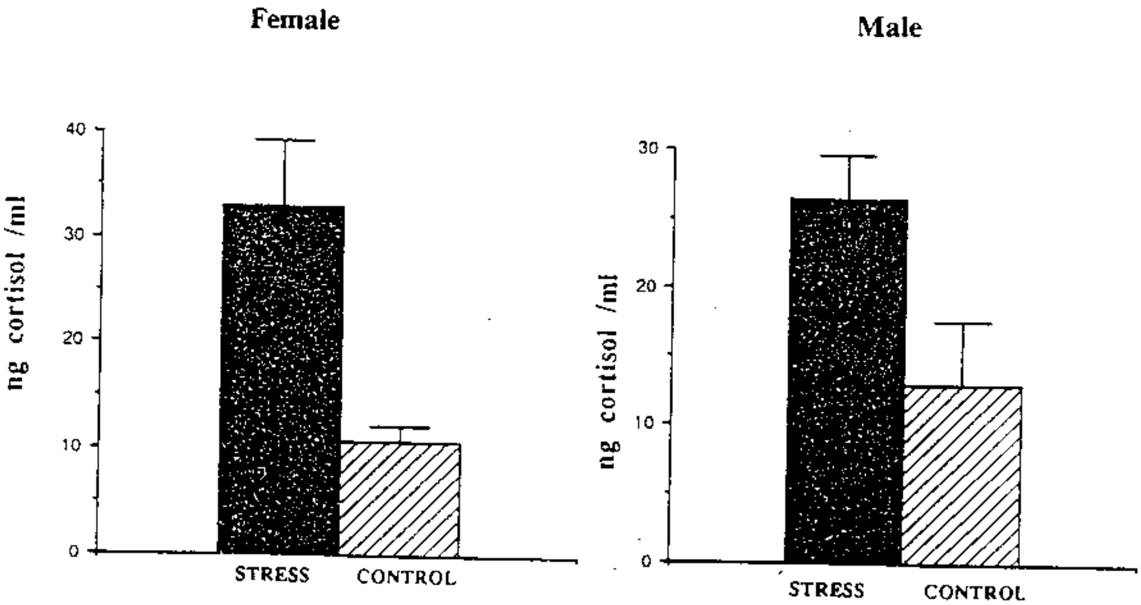


Figure 6 Plasma cortisol concentrations in rainbow trout. (Campbell et al., 1992).

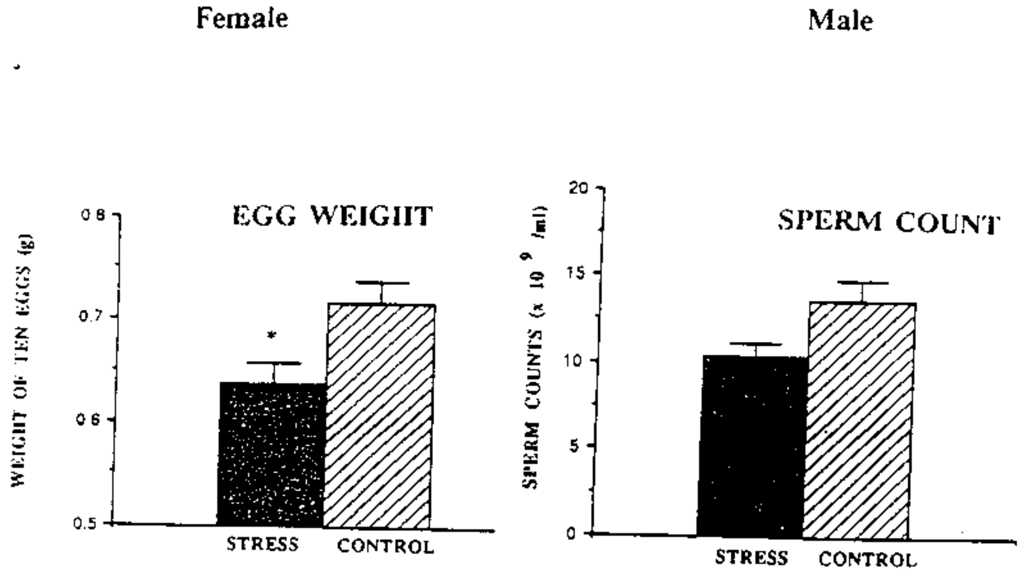


Figure 7 Effect of repeated acute stress on egg weight and egg volume of female rainbow trout. (Campbell et al., 1992).

Similar results with respect to plasma corticosterone levels were found with the lizard (Cnemidophorus sexlineatus) by Grassman et al. (1992). Physical stress does have a metabolic cost as substantiated by Barton et al (1987) who indicated that minor physical disturbances elicited a more than two-fold increase in metabolic rate in juvenile steelhead trout. Even the minor physical disturbances reduced the energy available. Stressed fish would thus have less energy for activities such as sea-water adaptation, disease resistance or swimming stamina. Oxygen consumption is a direct method of evaluating the effects of stress (Fig 8).

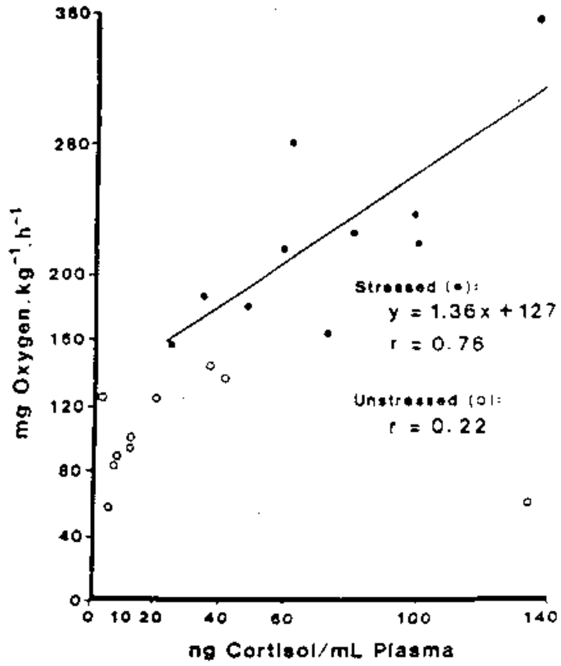


Figure 8 Linear regression of individual oxygen consumption rates on corresponding plasma cortisol concentrations of juvenile steelhead. (Barton <u>et al</u>., 1987).

Barton <u>et al</u>. (1987) stated that physical disturbances of greater severity or duration occurring during normal fish rearing operations would impose a greater energetic burden than the mild effect of the trial treatments. Research should be conducted to determine the effect of stress severity on metabolic reactions in crocodilians as well as the time required for recovery in order to determine the degree of stress the reptiles can experience before their health or survival is compromised.

The most obvious stressors are those that do cause fright, discomfort or pain. Practices such as grading, sexing,- weighing, tagging, injecting and physical handling, typically cause corticosterone concentrations to skyrocket. Wagner (1987) indicated that depending on the time of disturbance recovery usually occurs within 13-24 hours. Recovery from 30 second handling stress occurred within 6 hours in juvenile Chinook salmon (Barton et al., 1987) in crocodilians this period may be even longer.

Winkler (1987) indicated that stressful conditions in fish during travel which led to increased mortality and to overall lack of fitness, could be reduced by relatively simple adaptations to the transport chambers. A similar situation may be possible in crocodile farming enterprises where the size of the growth pen and the density within the pens may determine the stress level. McGlone et al. (1993) demonstrated that shipped pigs lost 5.1% of their body weight compared to resident pigs which gained 0.02% in body weight. Body weight change during shipping and plasma cortisol levels in blood were negatively correlated indicating that pigs that had greater adrenal response to shipping also lost more weight. It was further found that socially intermediate and submissive pigs were probably more likely to succumb to viral infections after shipping than are socially dominant pigs because their immune systems are suppressed. All the above indicate that physical stress, be it transport, immobilization, crowding or handling, may be extremely detrimental to the well-being of the animals.

Social

Grading and the subsequent regrouping of the animals within houses or pens destroys the social structure. A new hierarchy of dominant and submissive individuals is formed in which subdominant individuals are chronically stressed and became more susceptible to diseases than the dominant crocodiles.

Psychological

Elsey et al. (1990) reported findings which indicated that even the presence of an observer in the room caused fear-induced bradycardia in Caiman crocodilus, thus indicating that the reptiles may be stressed though they are not physically handled.

Physiological stress

The concept of physiological stress was first developed by Selye (1936, 1973) who gathered his observations into the General Adaptation Syndrome. These findings indicated lymphatic involution, gastrointestinal ulceration and adrenal enlargement. The fight or flight reaction is characterized by huge releases of adrenal medullary hormones and catecholamines from the sympathetic nervous system. These compounds cause rapid release of glucose, primarily by glycogenolysis, from body reserves. This produces available energy to elude a stressor. The reptile then enters the stage of resistance which is characterized by release of adrenocortical hormones. This causes the formation of glucose from reserves such as protein by the process of glyconeogenesis. The important aspect of this stage of resistance is that it will continue until recovery from the stressor occurs or the reptile enters the stage of fatigue and dies. The endocrine aspects of physiological stress is shown in Fig 9.

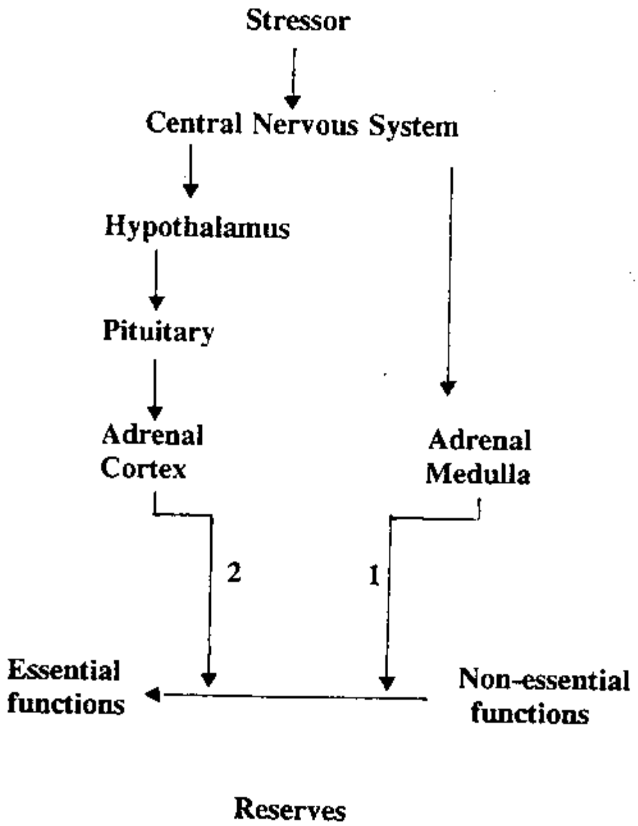


Figure 9 Schematic of endocrine aspects of physiological stress. (Brake, 1988).

Non-essential functions includes immune function, growth and reproduction. Essential functions include blood flow and respiration. Stressors cause the conversion of nutrients and reserves from economical important traits to functions necessary for survival. When the adrenal cortex becomes depleted the survival function can no longer be supported (Fig 10). If the adrenal cortex is depleted before the stressor is removed, then death will occur (Brake, 1988).

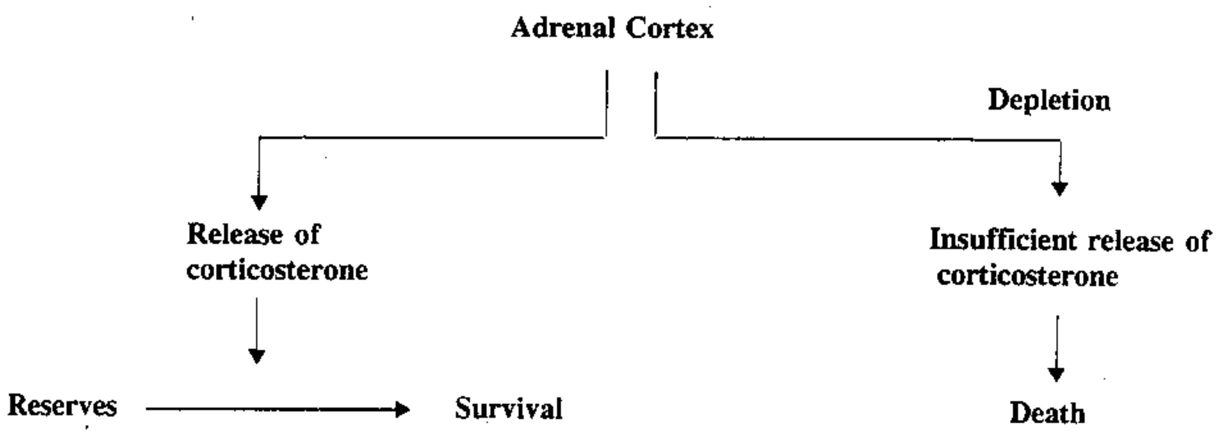


Figure 10 Importance of continued production of corticosterone during physiological stress. (Brake, 1988).

The severity of the stressor is determined by the previous experience of the reptile. A stressor is measured against the current "set-point". When the environmental conditions change the mechanisms must change to maintain homeostasis. Physiological stress allows the adaptions to occur. The concept applies to typical stressors such as crowding, temperature, transport, growth, reproduction, disease and toxicities. Growth and reproduction both call on the body to constantly change and are by definition stressors.

The crocodile produced in intensive production systems is simultaneously exposed to a number of stressors simultaneously. These include growth, disease, environment, reproduction, management and nutrition. The successful producer manages these stressors by

- knowing the status of the animals
- anticipating stressors
- modifying the environment
- modifying nutrition

The effect of these stressors on the crocodile may however be modified by nutrition. Attention will consequently be focused on the nutritional aspects which may exaggerate or mitigate the influence of stress (Fig 11).

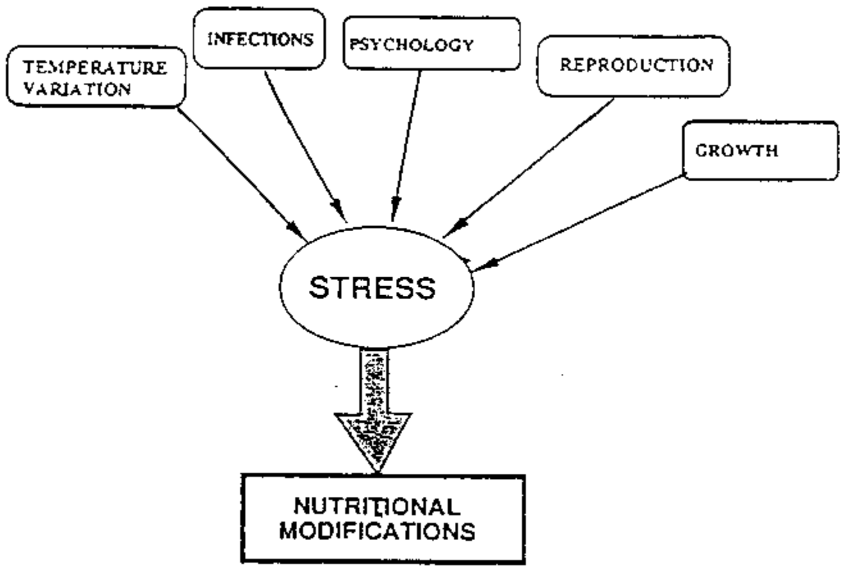


Figure 11 Sources of stress in dogs. (Van Deventer, 1994).

The animal and thus the crocodile can only deal with stress if energy and the necessary nutrients such as amino acids, vitamins and minerals are supplied in amounts and in a way and form which by itself does not place stress on the animal.

Energy

The biochemical changes which occur in the animal when subjected to stress are depicted in Fig 12.

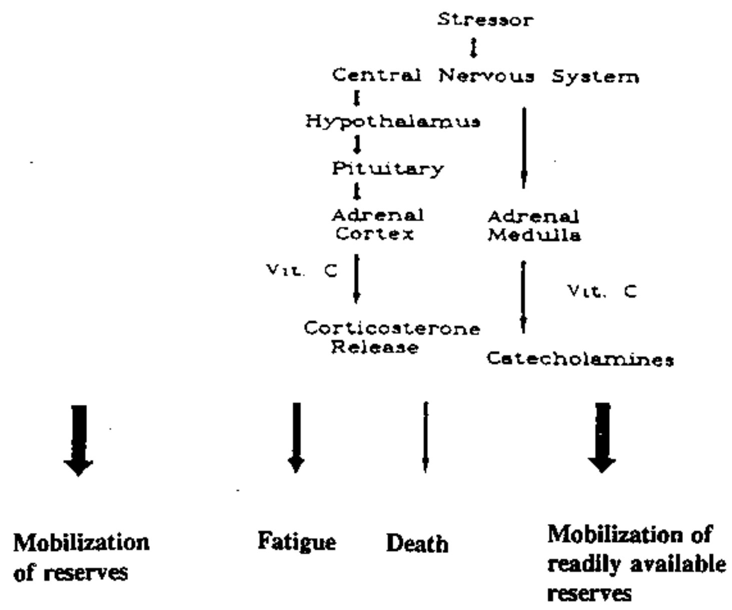


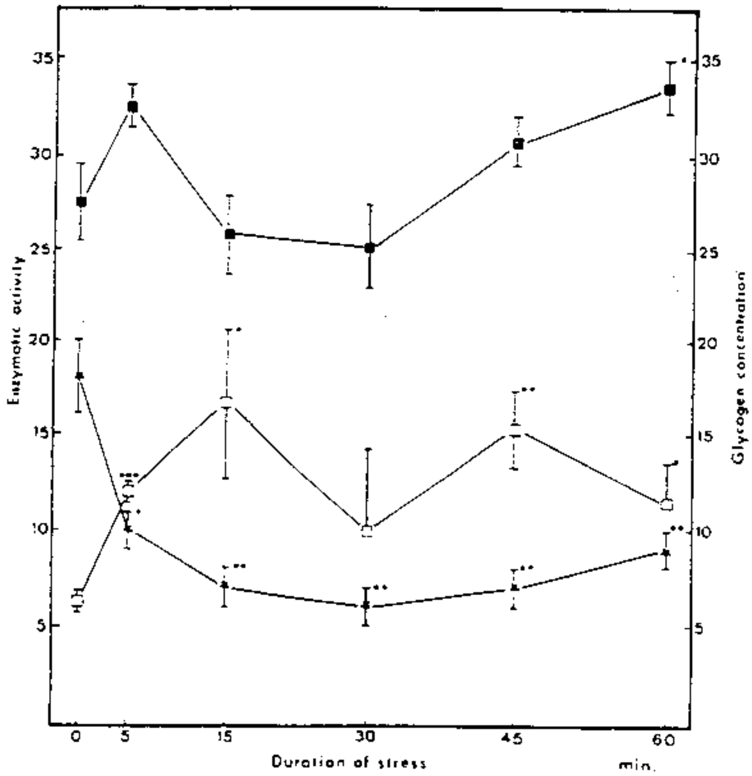
Figure 12 General Adaptation Syndrome. (Fenster, 1989).

As is evident from Fig 12 one of the main factors in an animal's ability to cope with stress is its ability to maintain energy reserves. In trout (Onchorychus mykiss) it was found that when starved, the fish maintained a high glycogen level in the tissue, especially in the liver. Similar observations have been made in other cold-blooded species, such as goldfish (Stimpson, 1965) and frogs (Hanke & Neuman, 1972). By contrast, liver glycogen in a warm-blooded omnivore is exhausted within 24-48 hours.

Nakano & Tomlimson (1967) reported that in rainbow trout handling stress produced hyperglycemia, a decline in muscle glycogen and an increase in the amount of active glycogen phosphorylase in skeletal muscle but they did not measure the hepatic phosphorylase. Morata et al. (1982) tried to estimate the relationship between hepatic glycogen degradation and glycogen phosphorylase actively in rainbow trout under conditions of stress, especially during the early stages of disturbance in order to elucidate the significance of glycogen storage in the liver of poikilothermic animals.

The study by Morata et al. (1982) indicated that degradation of glycogen takes place during the first stages of an emergency and seems to be directly related to the increase of glycogen phosphorylase activity. Although the activity of the enzyme remains high, glycogen not only stops being degraded after 30 minutes of stress, but even starts being resynthesized. The glyconeogenic substrate would be the lactate produced in the white muscle which is at considerably higher concentrations after the first onset of stress (Fig 13 a & b).

(a) Stress on liver and muscle glycogen phosphorylase in rainbow trout

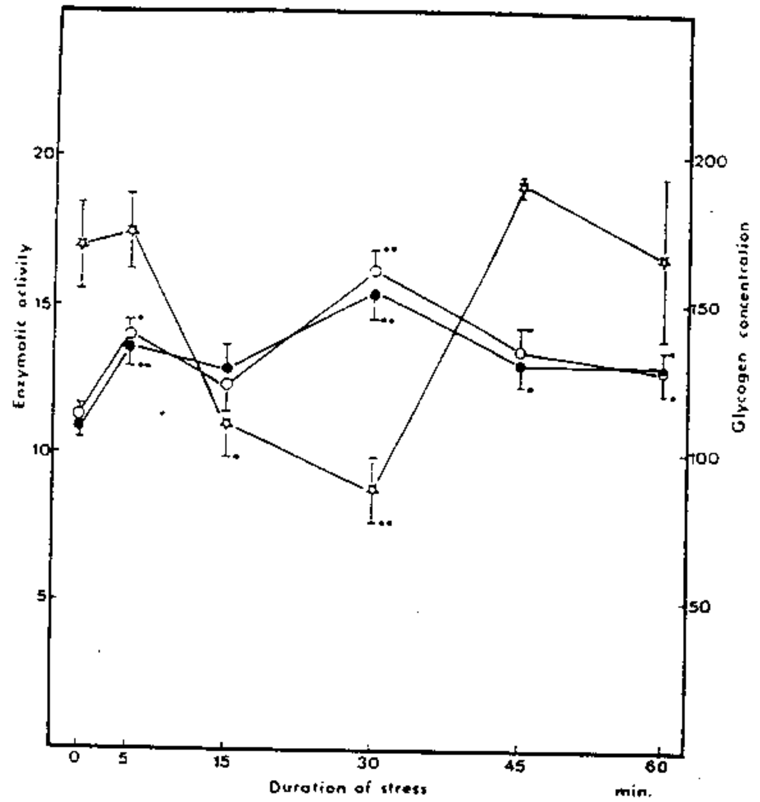


■ Phosphoylase activity with 5'-AMP

□ Phosphorylase activity in absence 5'-AMP

★ Glycogen

(b)



☼ Glycogen

○ Phosphorylase activity with 5'-AMP

● Phosphorylase activity in absence 5'-AMP

Figure 13 a & b Stress on liver and muscle glycogen phosphorylase in rainbow trout. (Morata et al., 1982).

During long-term stress, energy must be supplied in the diet as proved by Thomas et al. (1986) with juvenile Coho salmon. These workers indicated that starved groups of presmolt Coho salmon had significantly lower plasma cortisol concentrations than did groups receiving a 3% ration, particularly after 2 weeks of exposure. Plasma cortisol concentrations were at least 30% lower in the starved groups than in groups receiving a 3% ration (Fig 14).

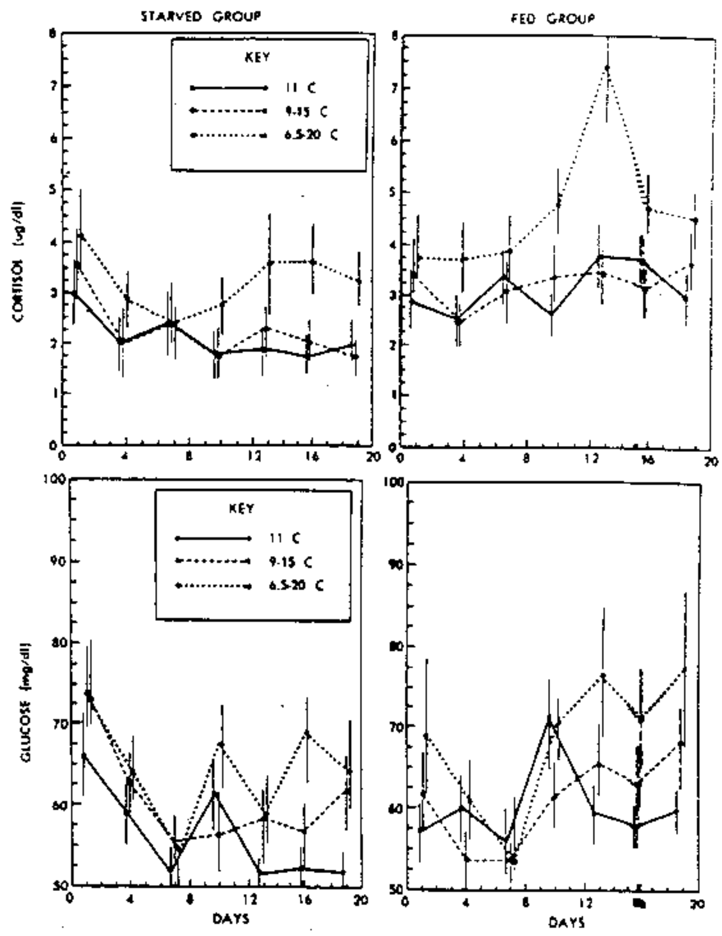


Figure 14 Mean plasma cortisol and glucose concentrations of starved and fed coho salmon. (Thomas et al., 1986).

The same situation did however not occur in rainbow trout. Fluctuating temperatures for a 19 day period did not cause significant differences in liver weight or liver glycogen in either the starved or fed groups of presmolts (Fig 15). Over the long-term, energy reserves will become depleted in starved fish and plasma concentrations of glucose must inevitably decrease. It is thus evident that during the stress reaction the body uses its reserves of carbohydrate in the form of liver and muscle glycogen to meet immediate glucose needs of the brain and other tissues.

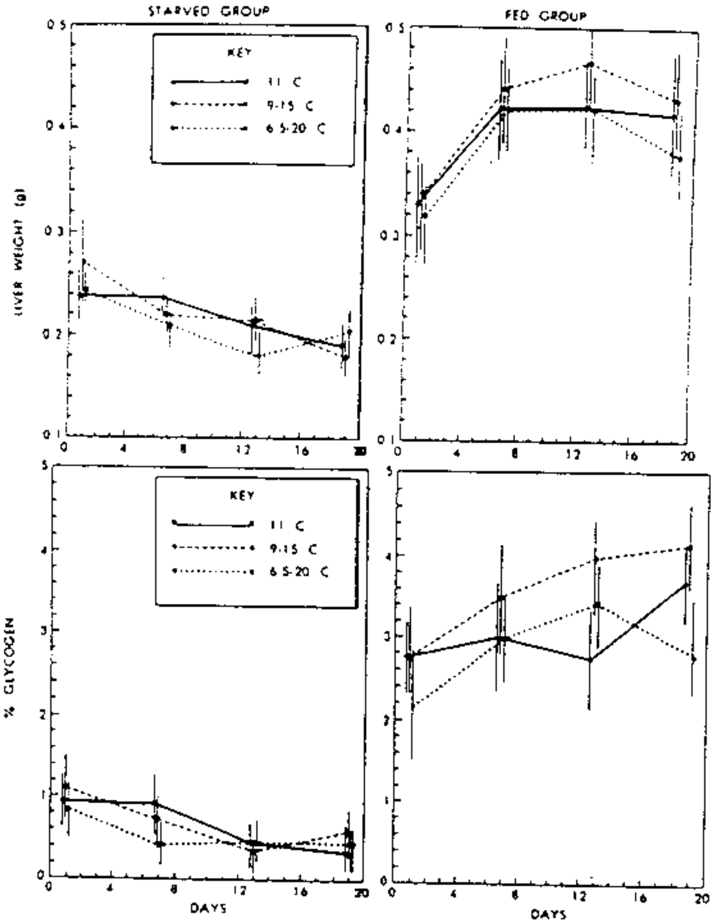


Figure 15 Mean liver weights and mean percent glycogen in livers of starved and fed coho salmon presmolts. (Thomas et al., 1986).

Carbohydrates as energy source

In studies with cod (Gadus morhua) Hemre et al. (1991) indicated that where the response of cod to stress was quantified, it was found that when the cod was fed a diet with carbohydrate, the plasma glucose level was about a third higher than in fish fed a carbohydrate-free diet. In the group fed carbohydrate the blood-glucose level rose to more than double the resting value and remained high during the recovery phase. This indicated a stress-related change in carbohydrate metabolism depending on the composition of the diet supplied. The difference in stress response between the carbohydrate and carbohydrate-free dietary groups showed that the physiological reactions were affected by the diet prior to stress, thus giving reason to believe that a change in diet in advance of handling and transport could reduce some of the stress-related losses (Hemre et al., 1991).

Both Staton (1988) and Labuschagne (1993) have demonstrated that crocodiles can utilize carbohydrates efficiently. The best growth was achieved with a carbohydrate level presented as cooked starch of 22-24% (Fig 16).

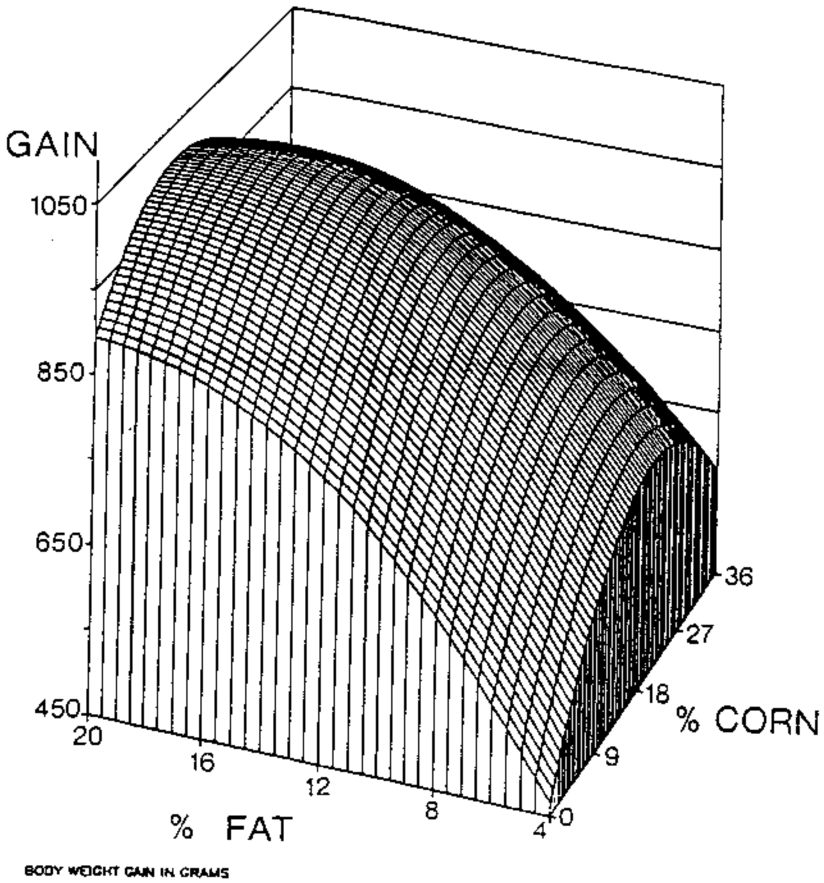


Figure 16 Gain as a function of dietary fat and corn weeks 1 - 15. (Staton, 1988).

It may thus be of value to supply diets to crocodiles with a minimum amount of carbohydrates in order to ensure a continuous supply of glucose. An example of such a diet is given in Table 1.

Table 1 Crocodile hatchling and grower diets

(a) Hatchling

Raw material	Percent
1 Yellow Maize (cooked)	32.97
2 Fish meal 60%	59.68
4 Carcass meal	6.86
9 Premix	0.50

Nutrient	Level in feed
ME Poultry	13.19 MJ/kg
Crude protein	42.0%
Lysine	3.0%
Methionine	1.1%
Isoleucine	1.7%
Tryptophan	4.4%
Threonine	1.8%
Valine	2.1%
Arginine	2.6%
Fat	8.1%
Crude Fibre	1.5%
Calcium	2.1%
Total Phosphorus	1.6%
Avl Phosphorus	1.6%
Sodium	6.0%

(b) Grower

Raw material	Percent
1 Carcass meal	39.92
2 Fish meal	16.80
3 Premix	0.50
4 Yellow maize	20.00
5 Beef raw	20.45
7 Sunflower oil	0.48
9 Lysine HCL	1.40
10 DL Methionine	0.45

Nutrient	Level in feed
ME Poultry	14.70 MJ/kg
Crude protein	38.0%
Lysine	3.0%
Methionine	1.0%
Isoleucine	1.2%
Tryptophan	2.7%
Threonine	1.3%
Valine	1.6%
Arginine	2.2%
Fat	10.0%
Crude Fibre	1.1%
Calcium	3.1%
Total Phosphorus	2.0%
Avl Phosphorus	2.0%
Sodium	2.0%

Lipids as energy source

Staton (1988) and Labuschagne (1993) demonstrated that the crocodilian however had a limited ability to utilize fats. Growth was negatively influenced when the diet contained more than 10% fat in the diet. When fed higher fat levels the crocodile was thus under nutritional stress. An aspect which has not been thoroughly researched is the influence of fatty acid composition on lipid utilization. In studies at the University of Pretoria, we found that optimal growth was supported by a diet containing linoleic:linolenic acid ratio of 3.1:1. Roosendaal (1992) demonstrated that the degree of fatty acid saturation may significantly affect the utilization of the lipids by chickens during early growth. The reason being that lipase secretion was only initiated during the development of the chick's intestine. This should also be considered when formulating diets for hatchling crocodilians as a similar situation may exist in crocodilians. Garnett (1985) indicated that immature C. porosus require C20:5 and C22:6 as essential fatty acids thus giving support to the hypothesis that hatchlings would require highly unsaturated fatty acids for optimal utilization. Apart from its nutritional impact the level of lipids in the diet may influence the animal's resistance to stressors such as diseases. In man lipids are particularly important in providing tissue concentrations of poly-unsaturated fats including linoleic acid which cannot be synthesized in the body and which is required by lymphocytes for optimal function. It is clear from whole-animal body studies that obesity and consumption of diets high in fat, particularly unsaturated fat, depress immunocompetence and enhance the risk for serious infectious diseases (Maki et al., 1992).

A minimal level of lipids in the diet is thus essential but high levels should be avoided as it also decreases access of proteolytic enzymes to protein, thus resulting in observed reduction in protein digestibility (Garnett, 1988) and is therefore a stressor in the nutritional process.

Protein and protein:energy ratio

When the carbohydrate reserves of the body have been depleted to meet immediate glucose needs of the brain and other tissues, proteins will be utilized. Protein from the diet as well as from muscle and other organs is used to produce glucose through gluconeogenesis.

Providing glucose will not stop the breakdown of tissue protein if the stress is severe. Good protein status prior to the stress condition offers protection from excessive muscle and organ catabolism. Provision of a recovery diet containing protein of high biological value at higher than requirement levels, but not at levels which will burden the kidneys, can retard losses of tissue protein. A high ratio of protein to energy is necessary to prevent excessive amounts of tissue protein from being used for energy and to prevent

- diminution in immunecompetence
- hypoalbuminaemia
- decreased wound healing
- decreased synthesis of enzymes and plasma proteins
- infection
- pressure sores associated with poor protein status

It is however not only the supply of protein which is crucial but also the correct energy level which must be maintained. Protein-energy malnutrition should be avoided as it leads to a severe negative impact on immune-competence (Chandra, 1992).

In humans moderate stress requires 1.0 - 1.5 g of protein per kg body weight while severe stress requires 1.5 - 2.0 g of protein per kg of body weight. During severe stress the body may be unable to convert essential amino acids to non-essential amino acids so that a dietary complement of all amino acids is essential. Blood levels of the branched chain amino acids (BCAA) leucine, isoleucine and valine, are low during stress. Feeds containing high levels of BCAA's could theoretically provide a readily available energy source for muscle as well as amino acid groups for the synthesis of non-essential amino acids thereby conserving tissue protein (Macrae et al., 1993).

Driedzec & Hochachka (1976) found an activation of phosphofructokinase and pyruvate kinase simultaneously with an increase in NH^{+4}-content in the muscle of common carp (Cyprinus carpio) during activity, thus indicating the use of free amino acids as well as glycogen as energy sources in white muscle. The increase in muscle lactate together with stable glycogen values after 2 hours of handling, may point to a use of free amino acids as a "first" energy reserve and a use of glycogen as a "second" energy reserve in white muscle.

Protein quality

The amino acids required for protein synthesis must be supplied to the crocodile in a readily-available form and in the correct proportions. Herbert et al. (1975) demonstrated that the digestion of an imbalanced protein such as gelatin can lead to the development of toxic levels of some amino acids and consequently a possible serious rise in the total osmotic pressure in the body and thus act as a stressor. The choice of dietary components which will ensure a high level of amino acid availability is thus crucial in diet formulation. In Table 2 an indication is given of the protein digestibility of various protein sources.

Table 2 Crude protein digestability of protein sources in salmon diets

Protein source	Percent
Flame dried herring meal	93.8
Steam dried herring meal	73.8
Menhaden meal	88.5
Corn gluten	95.0
Canola meal	74.1
Soybean meal	71.3
Blood meal	39.8
Brewers dried yeast	87.9
Feather meal	62.3

The general picture of protein digestion and assimilation in crocodilia appears to be one of considerable efficiency. The rate-limiting factor in protein digestion, absorption and assimilation seems to be digestion (Coulson et al., 1970). The supply of highly digestible dietary components is thus essential. The temperature at which the animals are housed does however effect digestion and absorption significantly as is evident from Fig 17. At a lower temperature the protein and thus the amino acids will be utilized less efficiently. The actual requirement by the animal may be reduced as was also found by Klasing et al. (1988) in chickens due to immologic stress. The role of the hsp 70, and the requirement of amino acids must be considered in this regard (Fig 17).

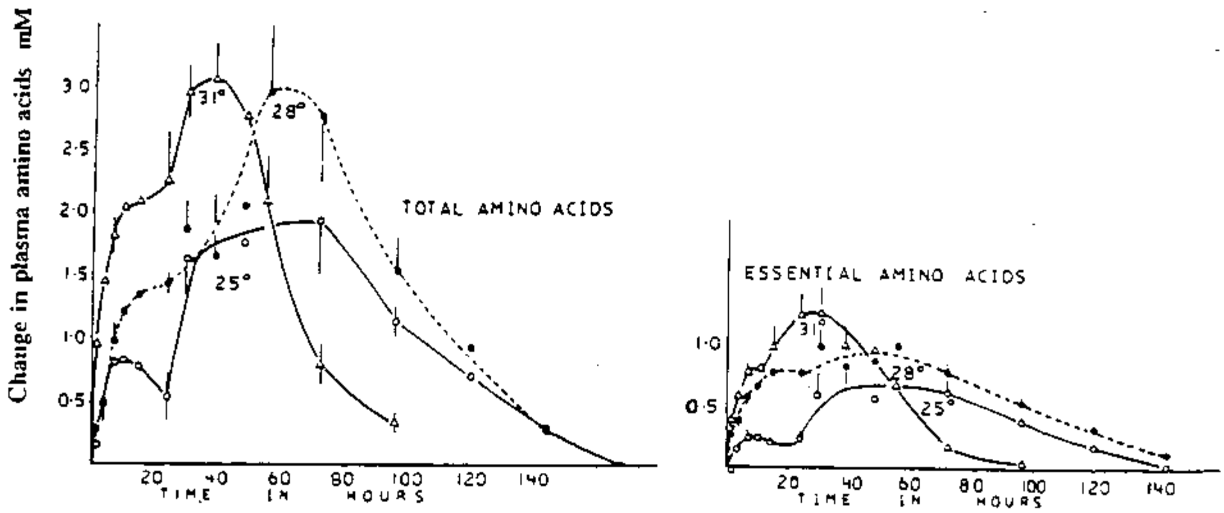


Figure 17 Changes in plasma amino acids after feeding lean meat (50 g/kg) to alligators kept at 25, 28 or 31°C (Coulson et al., 1986).

Vitamins

During acute stress, minerals and vitamins are well-utilized up to a point but previous nutritional status and the duration, frequency and intensity of the stress as well as stress-related nutrient losses will influence the requirements of specific nutrients. Because the adrenal glands have the highest concentrations of Vit C of any organ in the body and because this vitamin is needed for the synthesis of catecholamines, increased levels of this vitamin in the diet may be beneficial. In reptiles Vit C is synthesized in the kidney, but the level may be insufficient under stress (Fig 18).

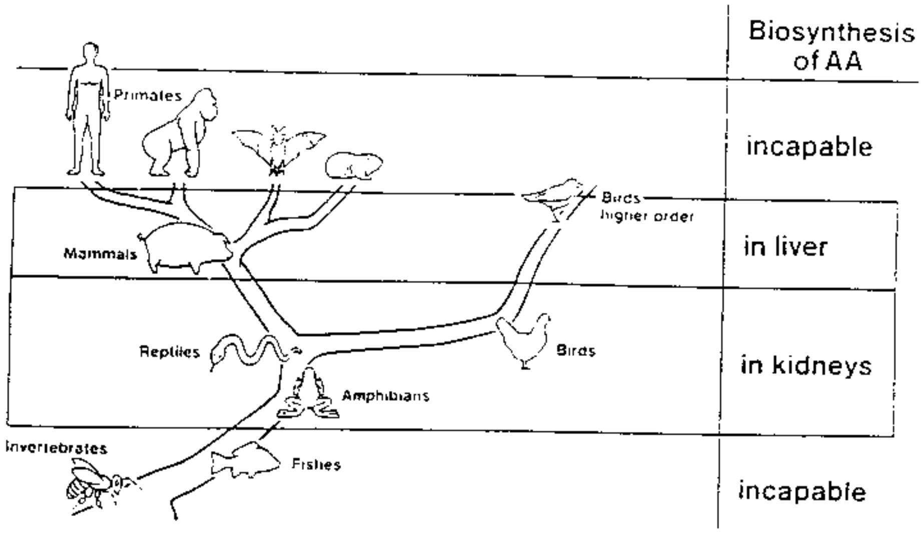


Figure 18 Capability of vitamin C synthesis associated with the evolutionary process. (Fenster et al., 1989).

Vitamin additions in the diet may thus be essential for immune-enhancement (Bendih, 1992). The value of additional Vit C during stress has been eloquently demonstrated in the poultry industry in reducing bacterial and viral diseases (Gross, 1992). In pigs it was demonstrated by Hoppe et al. (1989) that the so-called porcine stress syndrome reflected an antioxidant abnormality which may be ameliorated by increasing the antioxidant content of the diet. In this respect Vit A, B and Vit C played an important role in reducing the influence of "reactive oxygen metabolites" (ROM) which are oxygen-centred free radicals and their metabolites. ROM are produced endogenously by normal metabolic processes but amounts may be increased markedly by exogenous factors including solar radiation, fungal toxins and pesticides. Deficiencies of natural protective substances or excess exposure to stimulators of ROM production may result in oxidative stress which occurs when pro-oxidants exceed the capacity of antioxidants. Vit E terminates peroxidative chains by reacting directly with a variety of organic peroxy radicals. Vit E is oxidized when ROM are quenched but can be regenerated by Vit C. In addition to regenerating Vit E, Vitamin C can act directly as a water-soluble antioxidant (Miller et al., 1993).

In severe stress the requirements of vitamins A, B_1 B_2, B_6, C, D, E, K, nicotinic acid, folate and pantothenic acid as well as for minerals, iron, zinc, copper, selenium and magnesium are probably increased although the actual requirements are unknown. The inclusion of a vitamin supplement as given in Table 3 is thus very valuable in the feeding of crocodilians in an intensive system.

Table 3 Recommended vitamin supplements for Crocodylus niloticus (amount.kg^1 diet)

Vitamin	Broodstock	Hatchling	Grower
A	20 000 IU	12 000 IU	8 000 IU
D_3	3 000 IU	2 000 IU	1.5 00 IU
E	150 mg	120 mg	100 mg
K	20 mg	15 mg	12 mg
B_1	20 mg	15 mg	10 mg
B_2	30 mg	20 mg	15 mg
Calpan	60 mg	50 mg	40 mg
Niacin	120 mg	100 mg	80 mg
B_6	20 mg	15 mg	12 mg
Folic	4 mg	3 mg	2 mg
B_{12}	0.05 mg	0.03 mg	0.02 mg
Biotin	1 mg	1 mg	1 mg
C	1000 mg	1000 mg	1000 mg

The introduction of processed feeds, be it pelleting or extrusion, as well as the emersion of the feed in water, may influence the level of vitamin availability (Tables 4, 5 & 6).

Table 4 Retention of vitamins in immersed feed (%)

Vitamin	Extruded 2 min immersion	Pelleted feed 120 min immersion
A	100	100
E	68	100
B_1	90	6
Panthothenic acid	96	9
Folic	90	82
Boitin	98	32
C (Rovimix Stay C)	92	39

Table 5 Stability of vitamins in pelleted shrimp feeds

Vitamins	Retention % 3 months
A	63
E	82
B_1	64
Panthothenic	68
Folic	77
Biotin	78
C (Rovimix Stay C)	84
	99

Table 6 Stability of vitamins in extruded feeds

Vitamins	Retention % 3 months
A	75
E	100
B_1	95
Folic	67
C (Rovimix Stay C)	100

Minerales

Other nutrients that are lost in the urine with stress e.g. zinc, copper, magnesium and calcium, do not present problems if adequately supplied in the diet. Potassium which is lost along with protein catabolism of muscle and organ tissue may be an exception but can be supplied in the diet. Zinc, copper, selenium and magnesium are probably increased although actual requirements are unknown. Sherman (1992) reported that inadequate nutrition of zinc, copper and iron alter immunocompetence in humans and other experimental animals. For each of these minerals a deficient status leads to increased susceptibility to infectious illnesses. For zinc, copper and iron the importance of adequate nutrition in maintaining immunocompetence cannot be understated, a statement supported by the work of Nockels et al. (1993) done with calves.

Calcium plays a role in certain stress situations (Ait-boulahsen et al., 1993) and Benedetti et al. (1993) indicated that dietary calcium supplementation had an antihypertensive effect in rats that is unassociated with changes in plasma renin activity, intravascular volume depletion or change in sodium or phosphorus balance. The antihypertensive effect of calcium supplementation appears to be due to a generalized peripheral vasodilation with preserved cardiac output and a decreased response to norepinephrine.

Stress may however influence the utilization of calcium and that may result in abnormal egg shell calcification. This may effect hatchability of the eggs and thus the performance of the unit (Mills et al., 1987).

Stress itself induces sodium retention and water accumulation. Any dietary factors that further contribute to fluid retention, in particular excessive intake of sodium, may therefore increase the stress effect (Macrae et al., 1993).

Stress and feed intake

When stress builds up feed intake may be suppressed as appetite is reduced. This may enhance the problem of a vitamin deficiency or a lack of electrolytes which are required to counteract the effect of the stressor.

By implementing the correct nutritional programme and using properly balanced diets, the influence of non-nutritional stressors could be mitigated and nutritionally related stressor eliminated. This situation would be to the benefit of the crocodile and increase the profitability of the enterprise.

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FUNGAL DISEASE IN EGGS AND HATCHLINGS OF FARMED *CROCODYLUS POROSUS*.

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Abstract

Fungal disease in juveniles and eggs of captive *Crocodylus porosus* at a commercial crocodile farm was in epidemic proportions. The fungal pathogens involved were widely cultured from the natural farm environment. Nesting material was implicated as a major source of egg contamination. Changes to procedures in the incubation techniques to prevent infection of eggs are described. A significant increase in hatchability has been achieved.

Aim

To investigate fungal disease in the eggs of farmed *Crocodylus porosus*, reduce the incidence of embryo mortality due to fungal infection, and thereby increase the numbers of healthy live hatchlings.

Introduction

This applied research carries an economic significance to what is still a fledgling Australian primary industry. Major losses of juveniles due to disease cause financial problems for crocodile farmers (J. Lever, pers. comm). High losses of fertile viable eggs during incubation, combined with hatchling and yearly mortality could be financially ruinous.

Koorana Crocodile Farm, a commercial enterprise near Rockhampton on the Tropic of Capricorn, was established in 1980. It consists of 113 hectares of melaleuca and eucalyptus open woodland, mangroves, mud flats and salt pans, and is bordered by tidal creeks on three sides, becoming an island with causeway access at 4 metre tides. As such it was considered to be ideal potential crocodile territory. Salt water is used for adult and sub-adult lakes, this being pumped from the creeks at high tide.

Koorana is the most southerly crocodile farm in Australia and is on the southern extremity of the estuarine crocodiles' natural east coast range. Because winters can be quite cold (range 5°C to 25°C), a late wet season resulting in late nesting and hatching would lead to very high mortality in the wild due to cold stress. Hatchlings and juveniles must therefore, by necessity, be kept indoors in a heated environment.

The farm was officially opened in 1981 with nine crocodiles. Captive breeding on the farm commenced by 1985 with some early mortality of hatchlings in 1986. From then until 1990, hatchling and yearling losses continued to be a problem with the major cause of mortality and morbidity found to be systemic mycoses, predominantly caused by *Fusarium solani*, an ubiquitous fungus normally only pathogenic to plants. Losses of hatchlings to the end of their first year had been in excess of fifty percent (J. Lever, pers. comm.).

The present project commenced early in 1990. Initial progress on mycoses in juvenile *Crocodylus porosus* has been reported previously (Hibberd and Harrower 1991, Hibberd and Harrower 1993). It is also the subject of a poster presentation at this conference (Hibberd 1994).

Fungal diseases in reptiles are becoming more frequently reported. The most common being due to *Beauveria, Paecilomyces, Aspergillus, Cephalosporium* and *Fusarium* species. Fungal diseases have been reported in turtles, tortoises, snakes, lizards, chameleons and less frequently in crocodiles and alligators. *Fusarium solani* specifically has been found in several species of lobsters and prawns, caimans and crocodiles, sea-lions, seals, sharks, fish and green sea turtles. Interestingly, these cases have all been from animals in captive or farmed conditions. A recent paper has detailed infection by *Fusarium solani* of fertile snake eggs in captivity, resulting in embryo mortality and an abnormally small hatchling (Kunert *et al* 1993). Direct references to crocodilia includes the following fungi: *Beauveria bassiana, Aspergillus sp, Penicillium sp, Paecilomyces sp, Cephalosporium sp, Fusarium sp.*, and two references to *Fusarium solani*. The first came from a German zoo (Kuttin *et al*, 1978), and more recently (Muir & Cunningham, 1990) from farmed crocodiles in the Northern Territory, Australia. The majority of cases are of reports of deaths. Treatments where attempted have frequently been ineffective. A literature survey is the subject of a separate report for later publication.

Sensitivity tests carried out by Lord (1990) have shown *F. solani* to be particularly resistant to the common anti-fungal agents. Also, difficulties exist when trying to treat large numbers of infected animals which stress easily. The stress of being handled may cause further deterioration thus negating any beneficial effect of treatment.

In April and May of 1991, an important turning point was reached. Fungi were cultured from incubating eggs. Although *F. solani* was still the predominant fungus, two others were frequently isolated. One was an *Aspergillus sp.* and the other was *Paecilomyces lilacinus*. Of 26 nests incubated in 1991, fungus was cultured from 8 nests in the latter part of the season. Samples were taken from the shells, shell membranes, infertile eggs, early embryonic discs, the extra-embryonic membranes immediately after hatchling emergence from the egg, and from dead embryos. Massive mycelial growth was also found in the air spaces of some unhatched full term eggs. Samples of nesting material taken from one nest subsequently grew *F. solani* in abundance.

Work in the 1991/1992 and 1992/1993 breeding seasons (egg-laying November to March, hatching February to late May) involved investigating ways to remove fungal spores from freshly laid eggs without damaging the developing embryo, and ascertaining the method of entry through the shell. Previously the aim had been to determine how spores entered the live hatchlings and yearlings. Another question raised was whether eggs and hatchlings in the wild were affected by fungal disease. No opportunity has arisen to sample 'wild' nests and eggs in the local region. Scrapings.from the oviducts of captive laying females has not been carried out, but this has not been overlooked as a possible source of fungal contamination. The oviducts from a breeding female killed by another crocodile while defending her nest became available for mycological culture but results were inconclusive due to tissue contamination during the skinning and dissection process.

The current breeding season (1993/1994) has involved further refinement of the egg decontamination treatment building on previous seasons' results.

Methods and materials

1991 and previous breeding seasons.

Eggs were collected from the nests and incubated without any treatment, ie., no washing, or dipping or other decontamination process. The first incubator was a simple, small, chicken egg incubator. Over the years, this was replaced by a small laboratory incubator, then by a purpose built large shelved incubator, both with open racking. Temperature control for this last incubator was by a thermostatically controlled fan heater, monitored with a digital thermometer. High humidity levels were maintained by a large tray of water in the base of the incubator. The incubating eggs could be visually inspected through the acrylic doors, and infertile eggs or fertile eggs which had ceased development removed when necessary.

During 1991 laboratory based tests, following standard mycological procedures, were carried out to determine a suitable antifungal agent with which to treat the eggs. A readily available, relatively inexpensive veterinary and agricultural product, Arocide™, was selected for use, based on the laboratory results. (Arocide™, Alfa Australia, a proprietary mixture of alkybenzyldimethyl ammonium chlorides, a concentrated deodorant, and pentane-1,5Dial). Another product tested was Virkon™, (Antec International Ltd.) which has been used in Zimbabwe to combat fungal infections, including *Fusarium sp.* affecting hide quality in juvenile crocodiles, (Antec International Ltd. 1991). Malachite Green, commonly used in the aquaculture industry to combat fungal infections in fish, was also tested. Various other methods (eg. formaldehyde vapour) were rejected due to the danger to humans and developing embryos.

1991/1992 breeding season.

Eggs were collected from the nests, the top surface marked for later orientation purposes, then the oviducal mucus layer on the surface of the egg and any adherent nesting material were washed off by hand using running, ambient temperature tap water. This temperature ranged from 20°C to 27°C The washed eggs were then dipped in a bucket of Arocide™ diluted in ambient temperature tap water at a ratio of 1:150 for 5 minutes. This involved placing the eggs in a plastic bucket with holes drilled in the walls and base, and submersing this inside a larger bucket already filled with the antifungal agent. After the correct time, the bucket of eggs was lifted out and allowed to drain. The cleaned and decontaminated eggs were then positioned in trays of dry vermiculite on racks in a walk-in purpose built incubation room. A thermostatically controlled electric fan heater was used to control temperature, and two large troughs of tap water helped maintain humidity levels. Temperature and humidity were monitored using a chart recording Thermohygrograph, and a Grant Data Logger with four temperature probes.

Nesting material from all nests was collected in the 1991/1992 breeding season and sampled mycologically, following standard procedures. The eggs were also randomly sampled before washing, after washing, after dipping, and during incubation.

1992/1993 breeding season.

The procedures and materials used were as for the previous year, except that the incubating eggs were positioned in trays of wet vermiculite, moistened until droplets of water could be squeezed out. This was trialed after discussions with Zimbabwean and South African crocodile farmers and researchers (Blake 1991), during the 11th Working Meeting of the Crocodile Specialist Group in August 1992. Later in the season, the vermiculite was dried out until it was damp but not as moist. Eggs were sampled mycologically after washing and after dipping. Eggs were candled after one weeks incubation and infertile eggs removed. Eggs with embryos which subsequently died were removed at regular intervals for examination and mycological culture. A humidity probe became available for use with the Grant Data-Logger and was added to the other environmental monitoring equipment used previously.

1993/1994 breeding season.

The process was further modified in that eggs were no longer 'cold' water washed by hand, but were irrigated by warm tap water using hose attachments. Water was heated by a temperature adjustable gas heater positioned at the water storage tank outlet, to allow water temperature at the nozzle outlet to be approximately 3°C higher than that of the recorded nest temperature at egg collection. The clean eggs were then dipped for 5 minutes in the Arocide™ solution (1:150) at the same temperature, then incubated as previously in damp vermiculite. Candling, and removal of non-viable eggs followed the procedures of the previous year.

Mycology.

Samples from eggs were routinely taken by scraping with the wooden ends of sterile swab sticks. Swabbing with the cotton tips of these swab sticks resulted in cultures overrun with bacterial growth, whereas scrapings yielded predominantly fungal growth. Culture tubes with slopes of half-strength Potato Dextrose Agar (HPDA) were used for primary cultures. These were incubated at 30°C and sub-cultured onto sterile HPDA plates to obtain pure culture, and then identified using MEA, CYA and G25N media as per the method of Pitt and Hocking (1985). Slides were made at each sub-culture stage using Acid Fuchsin in Lactic Acid as the principal stain. Purified mycelial cultures from post-mortem or post-hatching tissue samples were obtained following the method of Harrower (1989).

Results

Hatchling survival data to the 31 December each year from 1989 to 1993 can be referred to in Fig 1.

Year	**Hatchling Survival**		
	30 June	**31 Dec**	**31 Dec excluding unrelated deaths**
1989	**	53.1%	**
1990	**	40.8%	**
1991	**	44.1%	**
1992	**	66.6%	77.4%
1993	88.8%	73.6%	78.9%

Fig. 1: Hatchling survival at 31 December. (figures not available)**

Year	Total Laid	Damaged Not set	Infertile	Fertile Viable	Embryo Deaths	Live Hatch
1984	40	**	**	**	**	13
1985	110	**	**	**	**	40
1986	600	**	**	**	**	110
1987	660	**	**	**	**	300
1988	1002	**	**	**	**	362
1989	1206	**	**	**	**	386
1990	1152	**	**	**	**	343
1991	1015	**	**	**	**	365
1992	1374	34	267	1073	702	371
1993	2015	68	407	1540	971	569
1994 to Nest 23	1098	34	141	923	259	664
1994 total, (32 nests)	1521	60	222	1239	???	???

Fig 2: Production chart using actual eggs numbers. (figures not available)**

	As % of total eggs laid					As % of Fertile
Year	Damaged Not set	Infertile	Fertile Viable	Embryo Deaths	Live Hatch	Live Hatch
1984	**	**	**	**	32.5%	**
1985	**	**	**	**	36.4%	**
1986	**	**	**	**	18.3%	**
1987	**	**	**	**	45.4%	**
1988	**	**	**	**	36.1%	**
1989	**	**	**	**	32.0%	**
1990	**	**	**	**	29.8%	**
1991	**	**	**	**	36.0%	**
1992	2.5%	19.4%	78.1%	51.1%	27.0%	**34.6%**
1993	3.4%	20.2%	76.4%	48.2%	28.2%	**36.9%**
1994 to Nest 23	3.1%	12.8%	84.1%	23.6%	60.5%	**71.9%**
1994 total, (32 nests)	3.9%	14.6%	81.5%	???	???	**???**

Fig 3: Production Chart, expressed as percentages (figures not available)**

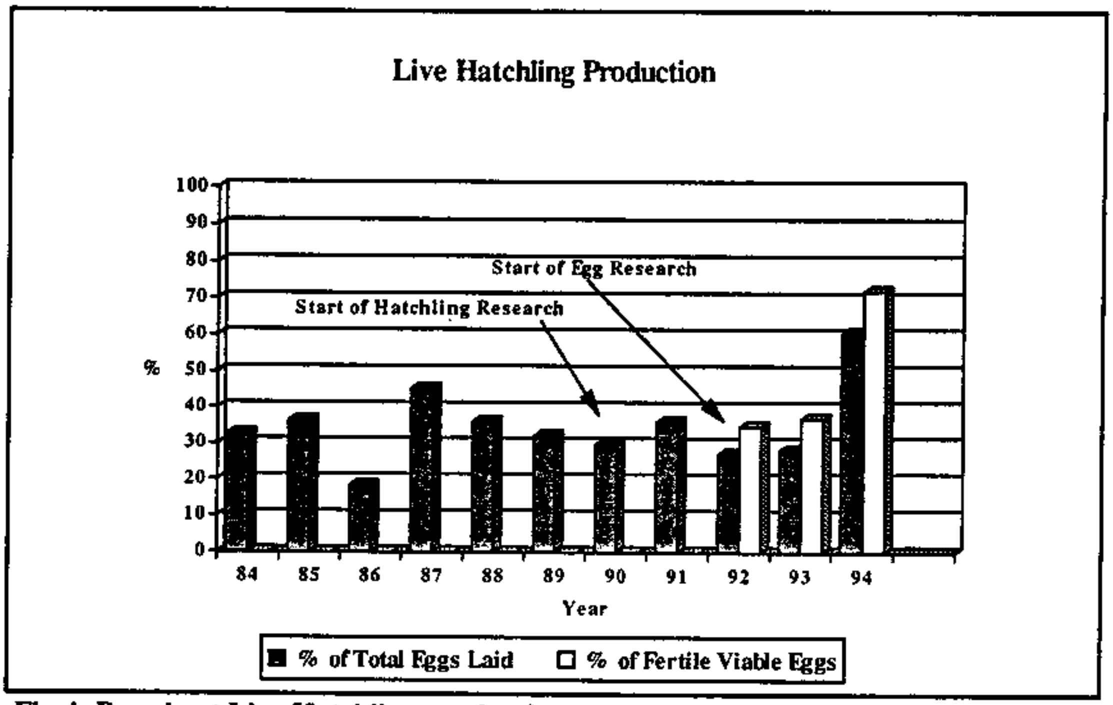

Fig 4: Bar chart Live Hatchling production.

Egg production and live hatchling figures are listed by actual numbers in Fig 2. The data, expressed as percentages of the total eggs laid, and also as a percentage of fertile viable eggs, are listed in figure 3. These are simplified in graphical form in Fig 4. From the graph it can be seen that whichever method of comparison is used (ie. as a percentage of total eggs laid, or as a percentage of fertile viable eggs) the results to date for the 1993/1994 breeding season have approximately doubled the results for each of the preceding five years.

Discussion

From the results tabled, it can be seen that hatchling survival as at the 31 December of each year has been gradually improved from 1990 to the end of 1993. The figures have been calculated as a percentage of those which originally hatched live, not as a percentage of fertile eggs, nor a percentage of total eggs laid. Unrelated deaths in 1992 were considered to be the result of a heating failure and subsequent cold stress. Post mortem results gave no pathological reason for death. Unrelated deaths in 1993 were animals which had been used in a trial and were then euthanased.

In summary, hatchling survival at the end of the first year has been approximately doubled. Contributing factors which have combined to produce this increase are a reduction in hatchling density in the pens, additional covered retreats in each pen, better control over the pen temperature, (heated air and water), extra feeding stations per pen, and a better cleaning regime, all of which reduce external stresses on the hatchlings. Less fight wounds are apparent and therefore there is a reduced chance of fungal infection through wounds. A more reliable supply of fresh meat has been organised to avoid dietary changes, and vitamin and mineral supplements are included on a regular basis.

Regarding egg anti-fungal treatments commenced for the 1991/1992 breeding season, results were initially disappointing. However, it is considered that the method of cleaning the eggs by 'cold washing' had actually contributed to embryo mortality by setting up a temperature gradient, which helped draw fungal conidia from the cooler water into the warmer egg. The extra handling involved in hand washing the eggs of debris also contributed to embryo mortality due to mechanical stresses set up around the embryonic disc. A heating malfunction due to a power surge after a cyclone was responsible for some mortality. The method of using dry vermiculite for the incubation medium contributed to desiccation of some eggs and subsequent mortality, even with high humidity levels in the incubation room. The use of moist vermiculite removed the possibility of desiccation the following year, but this created the opposite extreme, with some eggs swelling to the point of cracking. Transferring the eggs to fresh trays of damp vermiculite which had been partially dried in sunlight eliminated further swelling. Humidity levels were maintained at a consistent 98 to 99%.

The most recent method of using warm water to wash the eggs, combined with a reduction in egg handling by irrigating rather than hand washing, and the use of warm antifungal treatment, have produced very encouraging results for the hatching to date (23 nests out of 32 have hatched). After allowing for two totally infertile nests (nests 24 and 25), and assuming a similar hatchability for the later nests as for the first 23, the overall live hatchling production for the most recent breeding season is expected to be approximately 55% to 57% of the total eggs laid, or 69% to 70% of viable fertile eggs.

In addition, growth figures for hatchlings as at 31 Dec 1993 were very pleasing. Data gathered does not lend itself to yearly comparisons, however maximum length and weight for the 1993 surviving hatchlings was 980mm and 3.542kg, minimum 360mm and 66 grams (sick bay), with an average of 745mm and 1.449kg. (Number of animals = 419) The ages for the group ranged from 11 months to 7 and a half months. The largest hatchling was from a nest which hatched on the 9th March 1993 so was just under 10 months old at the census date. If these growth rates can be continued, skinning could be carried out by the end of the crocodile's second year.

Conclusions

During the course of this research egg hatchability has been approximately doubled. Those crocodiles which hatch are larger and healthier, and the survival rate to the end of the first year has also been approximately doubled. The net effect for the commercial farm has been a quadrupled output, which has beneficial financial implications for the future. Previously the enterprise was highly dependent on the tourist market, however with this fourfold increase in the numbers of yearling crocodiles, and the accelerated growth attained, the commercial aspect of skin production has been assured.

The aim of the project has been reached with results exceeding expectations. I would encourage crocodile farmers with an unidentified high embryo mortality to investigate the possibility of fungal infection.

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My thanks are extended to my Supervisor Dr D K Morris for his guidance, and to Rowan Bond for computing assistance.

BLOOD COLLECTION AND SAMPLES PROCESS IN *Caiman latirostris* (PROGRESS REPORT)

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INTRODUCTION

Caiman latirostris is one of the two species of argentinian caimans it is widely distributed in northern Santa Fe, Argentina. There is no information about blood collection technics and blood glucose and cholesterol for the specie. There is some information about seasonal variations of hematocrit values (Garcia et. al., 1993) in *C. latirostris*. Information is given by Carmena about hematocrit values in *Crocodylus rhombifer*.

This work is aimed to check a technic for blood collection for *Caiman latirostris* and to obtain blood values of glucose, cholesterol (with its associated lipoproteins) and hematocrit, in captive animals.

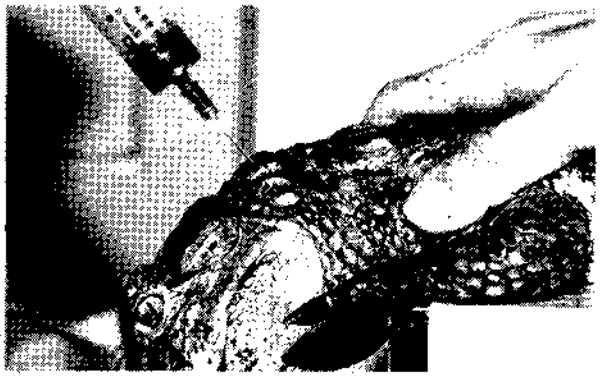
METHODOLOGY

The animals used in this study come from the Experimental Breeding Station (Estacion Zoologica Experimental) at Santa Fe city. The work was carried out with 160 individuals of Caiman latirostris aged between 2 to 4 years old, weighing 200 to 5100 gr and measuring 40 to 103 cm in length. Since hatch they were kept into heated pools, average density used was 15 animals per square metre. They were fed three times a week with a balanced composed of minced chicken, bran cereal and a vitaminic mineral mixture. The animals were selected randomly from the pools at the moment of obtaining the blood. The election of the blood collection technic was based on the paper published by Olson, Hessler and Faith: "Technics for blood collection and intravascular infusion of reptiles" (1975). Three technics of blood collection are proposed by Olson: from the internal jugular vein by cardiac puncture and from the caudal vein. The cardiac puncture, beside being a risky technic; it could produce, acording to our understanding, complications like chronic endocarditis. Some of the problems of the blood collection from the caudal vein, are that it is very difficult to localize and the blood volume is very low and it is not enough for the studies.

The technic we adopted, with some variants, as regards to the one described by Olson, consist in collecting blood from the internal jugular vein, between the first and the second cervical vertebrae. Thid vein is found within the vertebral column of the cervical spine (Figure 1). Disposable syringes of 5 or 10 ml and needles 21G x 1" (0.8 x 25 mm) are used for blood collection.

Animals may be restrained by keeping the mouth manually closed or using adhesive band, which is resistent and easy to take out, and inmobilizing the body and tail by hands. Dorsal flexion of the neck may help to enlarge the opening between the vertebrae. The vein is located by inserting the needle just cephalad and medial between the dorsal scutes behind the head, if the needle encounters a vertebrae it is walked forward or backward until it is felt to enter the intervertebral space. Caere should be taken not to penetrate the spinal cord which lies ventral to the vascular space.

Figure 1



The blood volume taken varied between 1 and 4 ml depending on the analysis wanted, and the animal's size. The studies realized were the following: blood glucose, total cholesterol, cholesterol associated to high and low lipoproteins and hematocrit in males and females. Commercial reactives for human biochemistry application were used.

-Total Cholesterol: an enzimatic method (Cholesterol Oxidasa/Peroxidasa) with Trinder colorimetry was used to determine cholesterol in serum or plasma.
Reactives:

1- Standard: Cholesterol solution 2gr/l

2- Enzym: Suspension containing fungal lipasa (300 U/ml) cholesterol oxidasa(3 U/ml) and peroxidasa (20 U/ml)

3- 4AF Reactive: 4-aminophenazona solution (25 mmol/l)

4- Phenol Reactive: Phenol solution (55mmol/l)

-HDL Cholesterol (High density lipoprotein): Precipitant reactive to separate high density lipoproteins in serum.
Reactives:

1- Dextran reactive: Dextran sulfate solution (PM 500,000) 0.032 mmol/l.

2- Magnesium Reactive : $Cl_2Mg.H_2O$ solution 1.5 mmol/l.

-LDL Cholesterol (Low density lipoprotein): precipitant reactive to separate the low density lipoprotein in serum.
Precdipitant reactive: Polivinil sulfate solution 10 gr/l diluted in polietilenglycol (PM 600) at 25%, pH 6.7

-Blood Glucose: Enzimatic method (Trinder) to determine blood glucose and other biologic liquids.

Reactives:

1- Standard: Glucose solution 1 gr/l.

2- GOD/POD: Glucose oxidasa (1000 U/ml) and peroxidasa (120 U/ml) solution.

3- 4AF Reactive: 4-aminophenazona solution 25 mmol/l in Tris Buffer 0.92 mol/l.

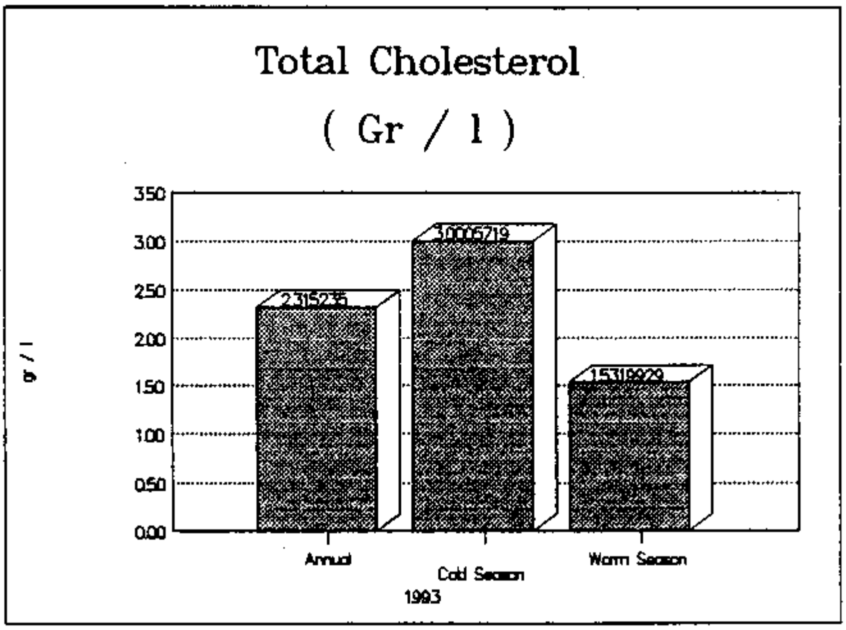
4- Phenol reactive: Phenol solution 55 mmol/l.

The technic used in each study are the ones indicated for each product. Some variants were done as regards to the used technics for human analysis; a bath of 37 °C during 30 minutes; immediately after the blood collection; and it is recommended to dilute the resulting coloured solution before reading in the spectrophotometer.

RESULTS

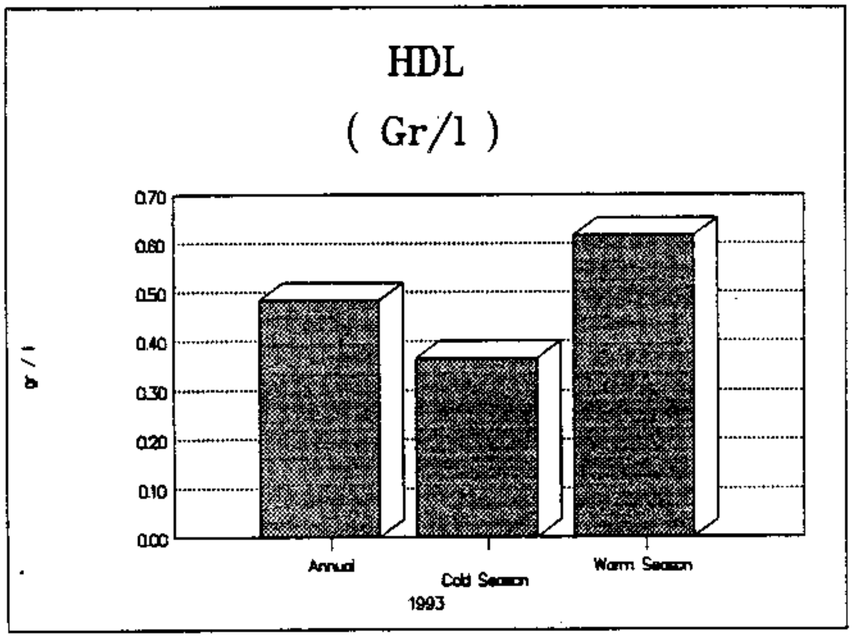
The medium total cholesterol value recorded was 2.315 gr/l, SD = 1.0655, (n = 60). A difference between cold season values (3.000 gr/l, SD = 0.8752) and warm season values (1.531 gr/l, SD = 0.6842) was observed (Figure 2).

Figure 2



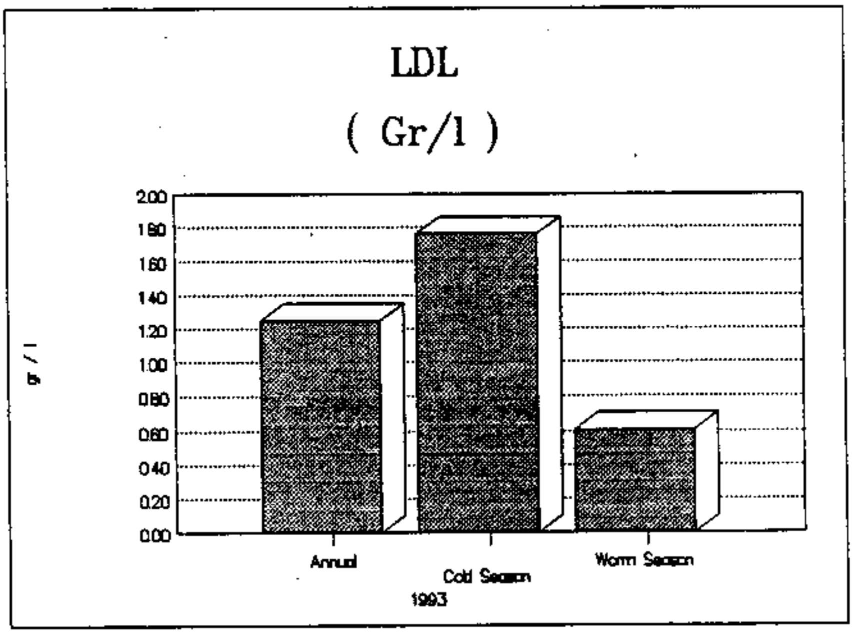
The medium HDL cholesterol value recorded was 0.4823 gr/l, SD = 0.3874 (n = 60). A difference between cold season values (0.3648 gr/l, SD = 0.2741) and warm season values (0.6166 gr/l, SD = 0.4522) was observed (Figure 3).

Figure 3



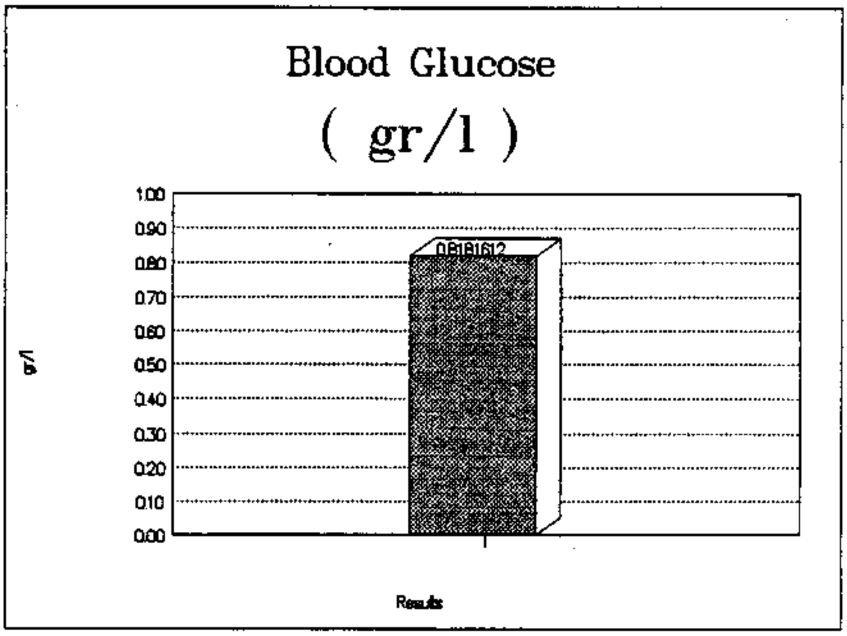
The medium LDL cholesterol value recorded was 1.2456 gr/l, SD = 0.8325 (n = 60). A difference between cold season values (1.7649 gr/l, SD= 0.7316) and warm season values (0.6016 gr/l, SD = 0.3557) was observed (Figure 4).

Figure 4



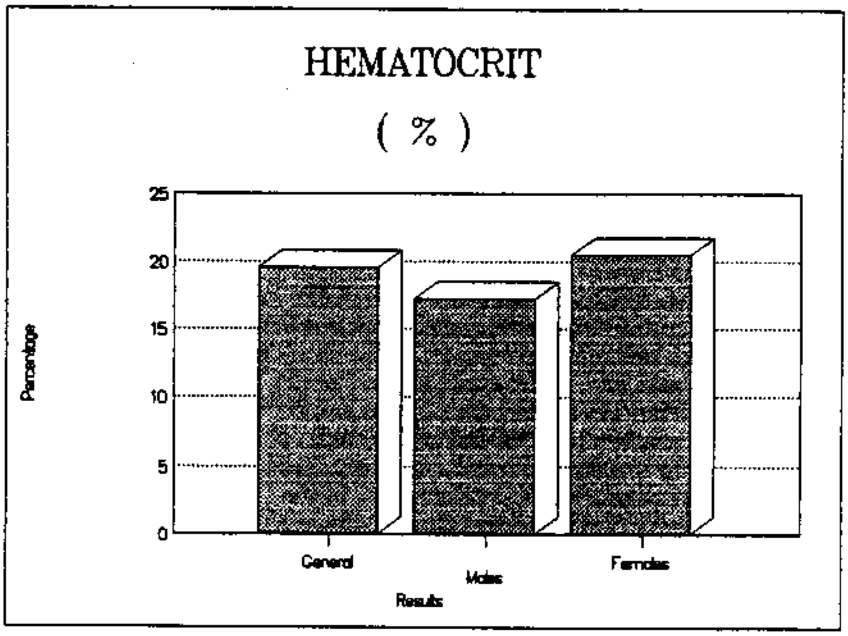
The medium blood glucose value recorded was 0.8182 gr/l, SD = 0.2249 (n = 48). (Figure 5)

Figure 5



The medium hematocrit value recorded (without taking into account the sex) was 19.52 %, SD = 4.2414 (n = 58). The medium hematocrit value recorded for females was 20.5% (SD = 4.7302) and for males was 17.19% (SD = 3.6465).(Figure 6)

Figure 6



CONCLUSIONS

The technic used in order to take blood samples from internal jugular vein in ***C. latirostris***, showed that it was safe and effective.
Hematocrit values vary significantly in respect to those given by García et. al. (1993), but they are similar to those given by Carmena et. al. (1979) for ***Crocodylus rhombifer***.

Considering the number of samples for the total cholesterol, HDL and LDL values, we have now the approximate normal values for the specie.

Diferences between cold and warm season for cholesterol and its associated lipoproteins were found.

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Organ morphometry and stomach pH in farmed Nile crocodiles

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In animals with very large variations in size it often is difficult to judge the relative size of a particular organ. For this reason Huchzermeyer and Van Der Vyver (1991) used the spleen/heart ratio (SHR) in turkeys infected with a malaria parasite to quantify the hypertrophy of the spleen and Huchzermeyer and De Ruyck (1986) the relative right ventricular mass (RRV) in broiler chickens to express the degree of hypertrophy of the right ventricle of the heart.

The objective of this study was to determine the relationship between body length and heart mass, RRV and SHR as well as fat body/heart ratio (FHR), kidney/heart ratio (KHR) and the stomach pH in farmed Nile crocodiles.

These parameters were established on some or all of 453 crocodiles submitted for routine post-mortem examination from January, 1991 to December, 1993. For this purpose the body length was recorded unless part of the tail was missing, the auricles were removed from the heart, and the ventricles, spleen, fat body and right kidney weighed on an electronic scale. In specimens of suitable size the right ventricle was separated from the left ventricle and septum as described by Huchzermeyer and De Ruyck (1986), the right ventricle was weighed (right ventricular mass = RV) and then both ventricles together with the septum (total ventricular mass = TV).The ratios were then established as follows: RRV = RV : TV; SHR = spleen mass : TV; FHR = fat body mass : TV and KHR = right kidney mass : TV. The stomach pH was determined with the help of indicator strips.

For the regression of heart mass on body length nonlinear least squares statistics were used with the formula $Y = ab^x$ and for the comparison of SHR values the nonparametric Kruskal-Wallis analysis was used.

The predicted values and 95% confidence limits of the regression of heart mass on body length are shown in Fig.1. The distribution of the RRV values (n = 36; mean = 2,86; range: 0,22 - 0,36) is shown in Fig.2. The SHR values of crocodiles presumed not to have suffered from infections (n = 77) ranged from 0,19 to 0,72 and their distribution is presented in Fig.3. These values were significantly different from those of cases of conjunctivitis (0,11 - 2,12; n = 40), septicaemia (0,24 - 2,57; n = 84), salmonellosis (0,22 - 2,68; n = 70), gastritis (0,41 - 2,49; n = 54) and enteritis (0,34 - 2,71; n = 35). The percentage distribution of the FHR values (n = 433; range: 0 - 19,42) is given in Fig.4 and of the KHR values (n = 296; range: 0,59 - 7,31) in Fig.5. The distribution of the stomach pH values (n = 191; range: 1 - 8) is given in Fig.6.

As most of the mortality occurs in hatchlings, there was a preponderance of data on small individuals. therefore the upper end of the heart mass on body length regression curve is based on relatively few values and more data are needed from large crocodiles.

The distribution of RRV values follows a normal pattern, but reaches higher figures which in fowls would be taken as indicative of right ventricular hypertrphy (Huchzermeyer and De Ruyck, 1986). It is not known yet whether pulmonary hypertension does or can occur in crocodiles.

As in mammals and birds the spleen of crocodiles reacts to immune stimuli by increasing its output of lymphocytes with a consequent increase in size (hypertrophy). In such rapid bursts of growth the tissue breaks through the relatively strong capsule by "budding" which gives such a spleen an irregular, multilobulated appearance (Fig.7). Establishing the SHR can be useful in determing whether the animal has been exposed to an immune stimulus.

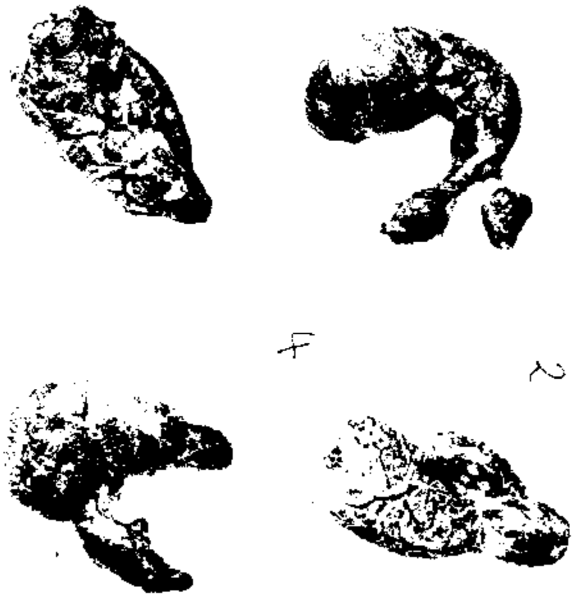

Fig. 7 Hypertrophic spleens of Nile crocodiles with multinodular, "budding" appearance.

The abdominal fat body is a fat storage organ containing fat cells with large, active nuclei, capable of mobilizing the fat stores rapidly when needed. This organ is also well vascularised and often is involved in general disease processes together with other internal organs. Here, I should like to propose the Latin name "steatotheca" to be able to call an inflammation of the fat body "steatothecitis". In the present material a large proportion of the specimens were runts or had been chronically ill, causing an equally large proportion of the FHR values to be below 1,0. The FHR is a useful parameter for judging the state of nutrition of an individual crocodile or even of a population.

Most of the KHR values gave a normal distribution from 0,59 to 2,0. The higher values were associated either with inflammatory processes, notably pyelonephritis, or as compensatory hypertrophy when the other kidney was missing.

High stomach pH values (4 - 8) were found to be associated with chronic disease and exhaustion of the fat body, while low, normal values (1 - 3) were found in animals which had died suddenly or after an acute illness. During storage of the specimen under refrigeration for up to 1 week the pH did not increase. It is now believed that, when death is due to the exhaustion of the energy reserves, the terminally ill animal is no longer able to dissociate NaCl to produce the necessary HCl and this leads to the rise of the pH.

Dr H. Van Ark is thanked for his assistance with the statistical analyses.

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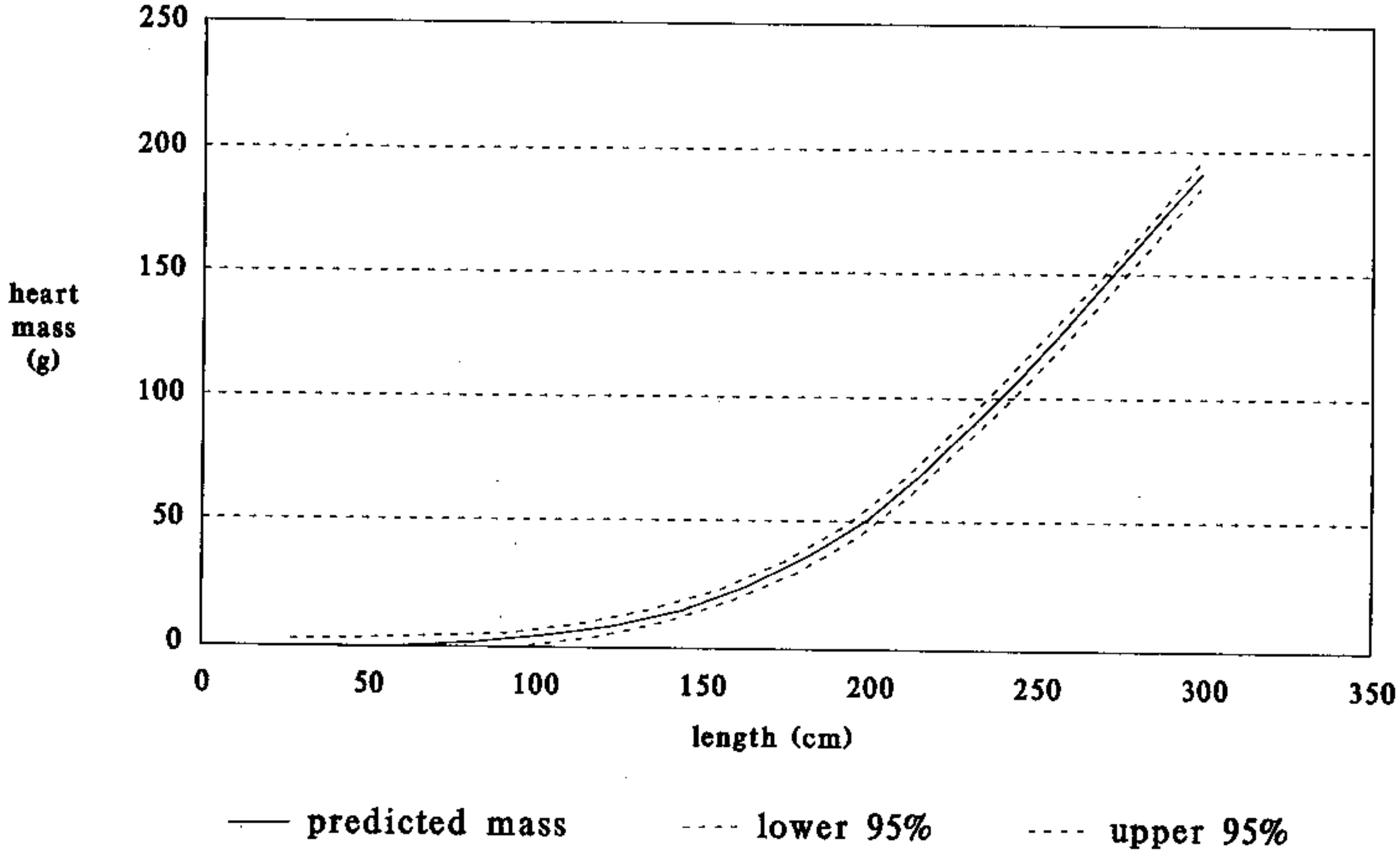

Fig. 1 Regression of heart mass on body length of Nile crocodiles, with 95% confidence limits.

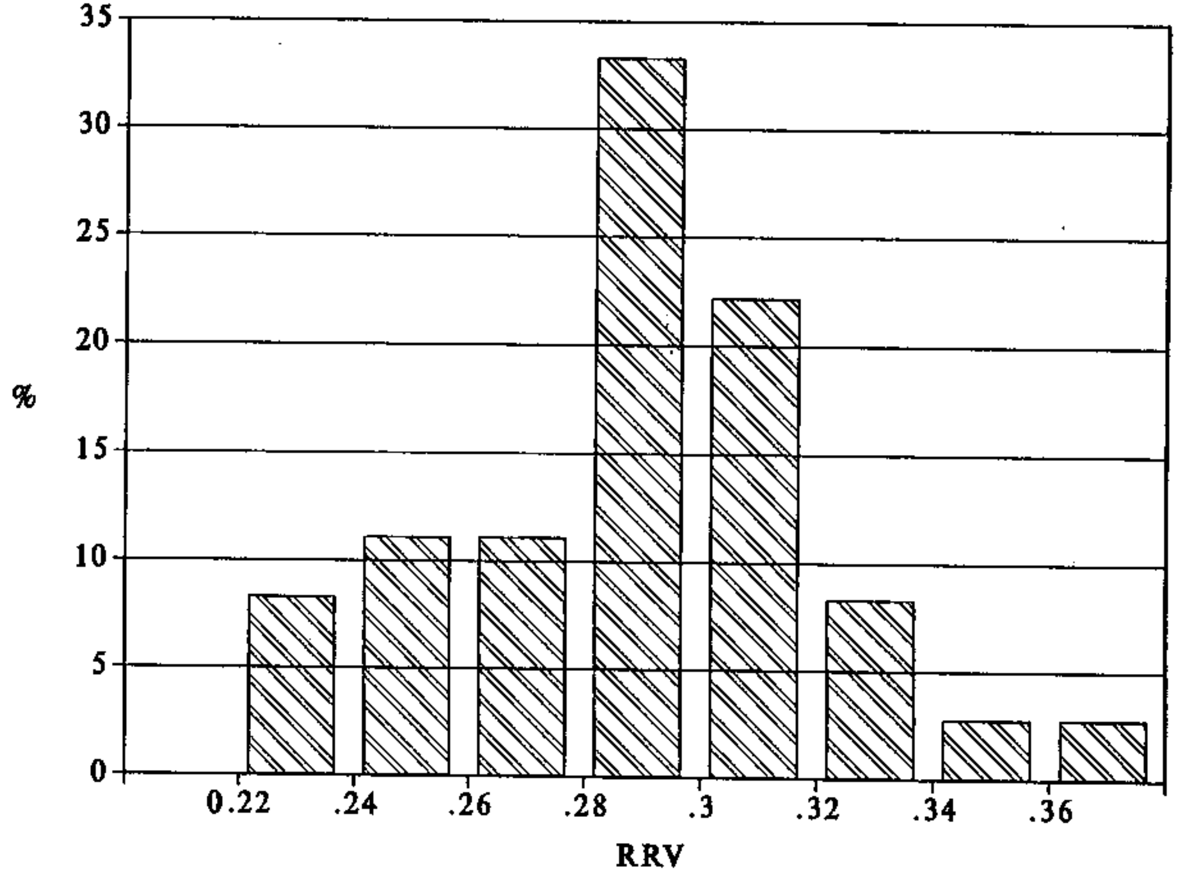

Fig. 2 Percentage distribution of relative right ventricular mass in Nile crocodiles.

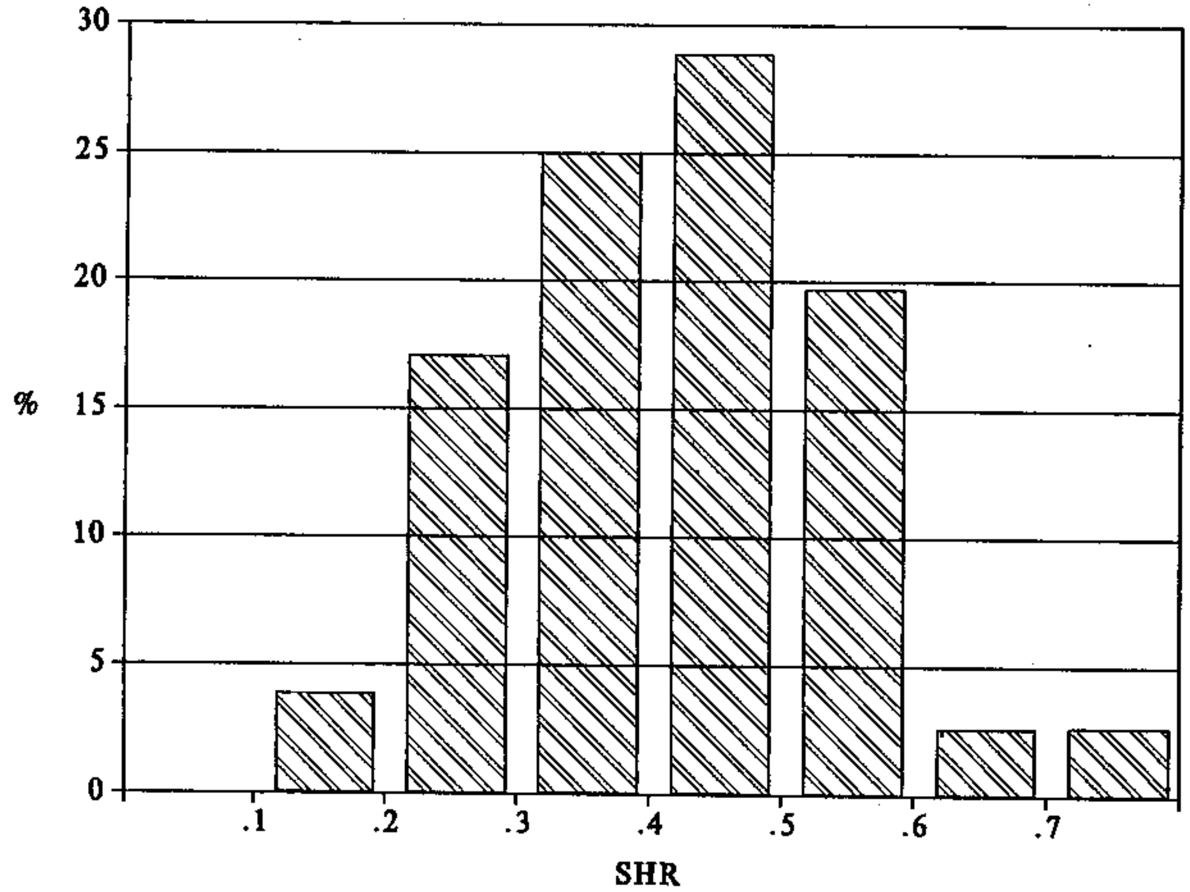

Fig. 3 Percentage distribution of spleen/heart ratio values of Nile crocodiles.

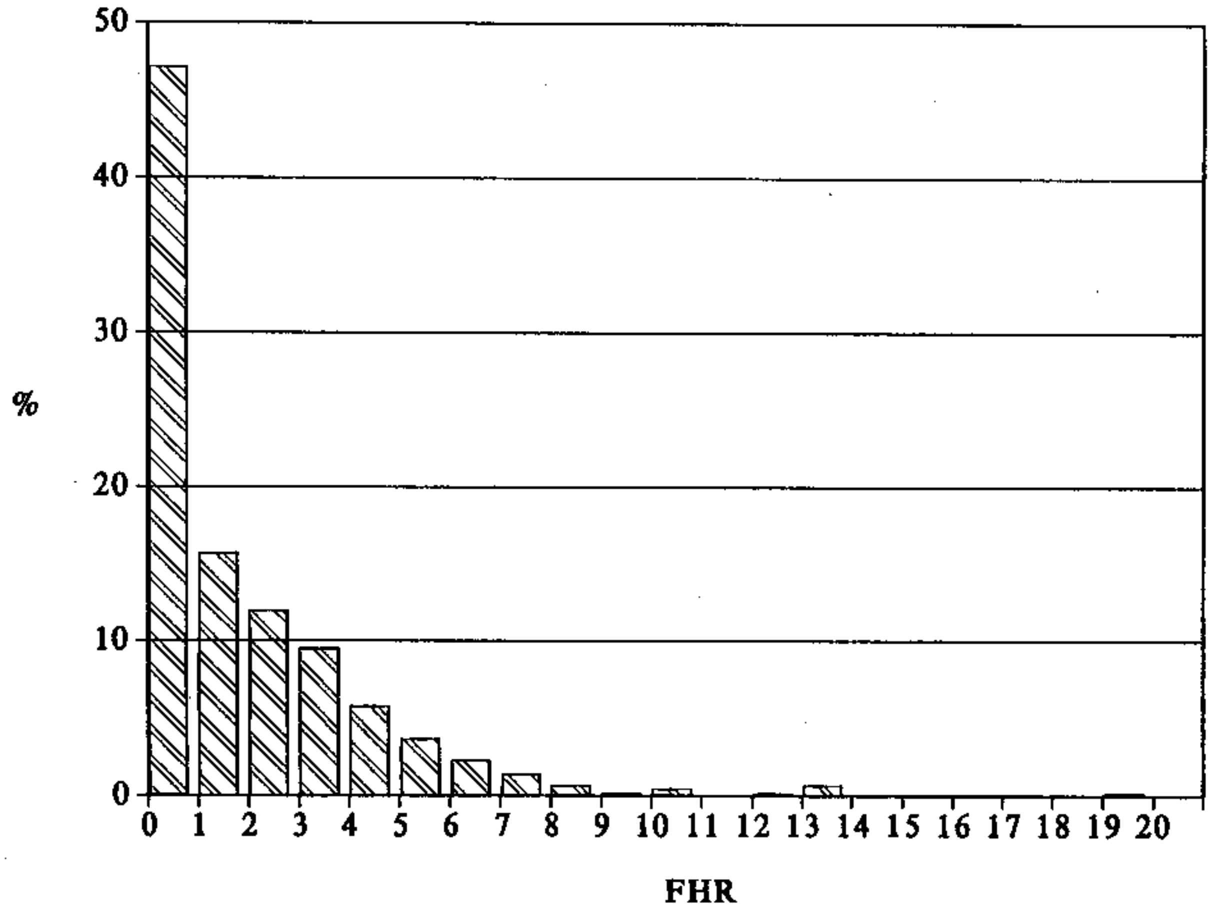

Fig. 4 Percentage distribution of fat body/heart ratio values of Nile crocodiles.

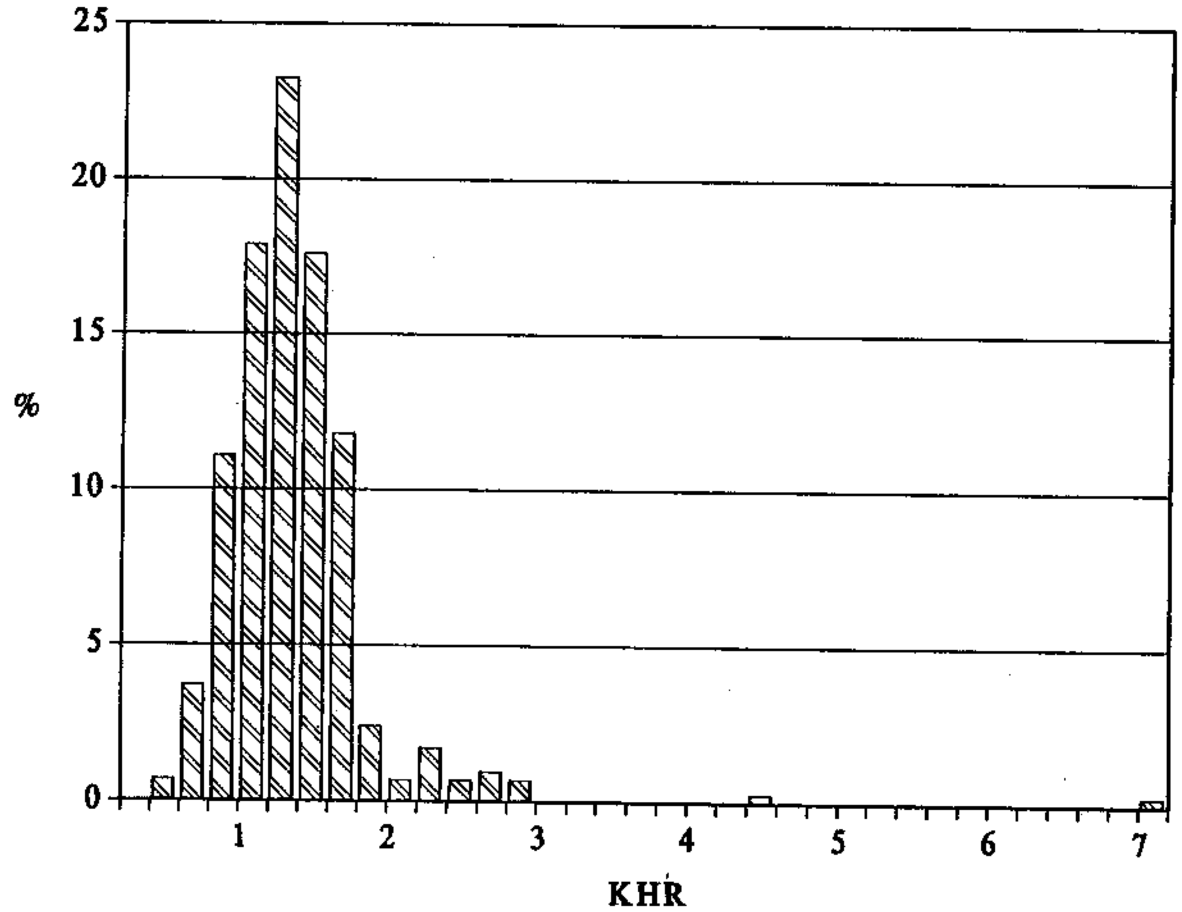

Fig. 5 Percentage distribution of kidney/heart ratio values of Nile crocodiles.

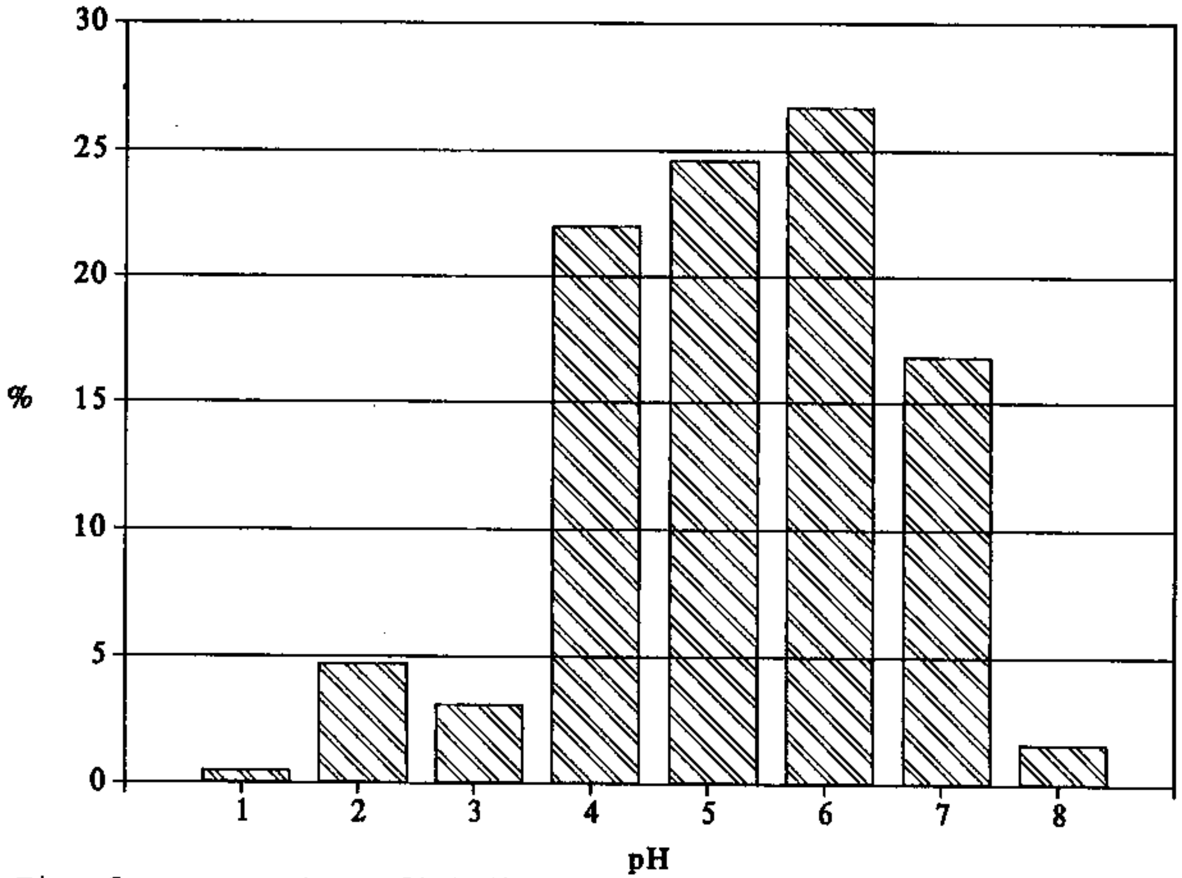

Fig. 6 Percentage distribution of stomach pH values of Nile crocodiles.

The influence of water temperature and clutch of origin on stress in farmed *Crocodylus porosus* hatchlings

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Water temperature has important effects on growth, disease susceptibility and mortality in farmed crocodiles. This study was undertaken to determine whether higher (36°C) and lower (28°C) than optimum (32°C) water temperatures resulted in stress and immunosuppression in farmed *Crocodylus porosus* hatchlings, and whether these parameters varied between clutches.

A total of 140 *C. porosus* hatchlings from five clutches were divided between five water temperature treatments such that there was an equal number of crocodiles from each clutch in each treatment.

Stress was measured by plasma corticosterone levels, and immune function by plasma immunoglobulin (Ig) levels and total and differential white blood cell counts. Crocodiles were weighed, measured and blood sampled on four occasions, before and after temperature changes were effected. Corticosterone levels were determined by an extractive radioimmunoassay procedure. An enzyme linked immunosorbent assay was developed to measure plasma Ig levels.

This study was the first attempt to quantitate corticosterone and Ig levels in *C. porosus*. Corticosterone levels ranged from 0.25–16 ng/ml, with a mean of 7.09 ng/ml. Crocodile Ig was determined to be IgG, with a molecular weight of 218 kDa and heavy and light chains of 57 and 27 kDa, respectively.

Corticosterone levels were elevated in crocodiles maintained at high temperature, and there was also a significant increase in corticosterone levels in one of the high temperature groups after the temperature was first elevated. Ig levels were not significantly affected by water temperature. Total white cell counts at the end of the study were elevated in the high temperature treatments. Heterophil percentages were higher and lymphocyte percentages concurrently lower in the high and low temperature groups. A return to pre-treatment lymphocyte percentage occurred in the low temperature group when returned to 32°C. Body weight was not affected by water temperature per se.

Clutch of origin had marked effects on growth. This was apparent at the first sampling time when conditions were optimal for all animals. There were also clutch differences in corticosterone and Ig levels.

Proportional change in body weight was negatively correlated to both corticosterone and Ig levels. However, there was no interaction between corticosterone and Ig levels.

These findings suggest that the high temperature used in this study was stressful, whereas the low one was not. Change in water temperature in both the high and low temperature treatments resulted in immunosuppression (as reflected by decreased lymphocyte counts) through a means other than the hypothalamic pituitary adrenal cortical axis. Clutch effects were extremely important, particularly in terms of growth, and suggest a role for selection of crocodiles according to growth and corticosterone levels for optimal performance under farmed conditions.

We wish to acknowledge the collaboration and assistance of staff of Grahame Webb Pty Ltd, the Conservation Commission of the Northern Territory, and the Berrimah Regional Laboratory of the Northern Territory Department of Primary Industry and Fisheries.

LAKE APOPKA'S ALLIGATORS: THE END OF THE RULING REPTILES?

H.F. PERCIVAL, K.G. RICE, G.R. MASSON, A.R. WOODWARD, C.L. ABERCROMBIE, AND M.L. JENNINGS

ABSTRACT

Compared to other Florida wetlands and pre-1981 counts, Lake Apopka (central Florida, USA) has very low densities of alligators (*Alligator mississippiensis*). This is due in large part to reduced egg viability rates though it may also involve low adult or juvenile survival. We investigated potential effects of microhabitat, nesting material, clutch temperature, and region of lake on clutch viability; we also compared such effects across six other Florida wetlands. These physical characteristics did not explain the reduction in egg viability. We hypothesize that chlorinated hydrocarbon pesticides have destroyed the Lake Apopka alligator's reproductive potential. We further speculate that the situation on Lake Apopka is only the most extreme manifestation of a problem that could be more wide spread throughout central Florida.

ALLIGATOR NIGHT-LIGHT SURVEYS OF IMPOUNDMENT HABITATS IN COASTAL SOUTH CAROLINA-A PRELIMINARY VALIDATION

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Abstract: Population surveys of American alligators (*Alligator mississippiensis*) commonly use night-light techniques, however, the proportion of the true population seen with this method is not known for impoundment habitats. If the percentage of alligators seen during night-light surveys is understood, the procedure may provide a means for estimating population size. Forty-four (44) alligators (≥183 cm) were captured and marked for mark-resight population estimation techniques in May 1993 at South Island, South Carolina. Bailey's population estimate of alligators ≥183 cm for impoundment habitats on South Island was 242 ± 30 (SE) (n = 3). Mean percentage of alligators ≥183 cm seen during night-light surveys in May was 9.09 ± 3.52 (SE)% (n =3). Initial analysis suggests that night-light surveys can be used to estimate alligator populations for impoundment habitats; however, further investigation is needed to determine if percentages change among impoundment habitat types.

A prerequisite necessary for successful wildlife management is knowledge of relative densities or trends of wildlife populations. Information on population size allows wildlife managers to detect change and evaluate population status; however, methods to accurately estimate population size are typically evasive or difficult and expensive.

Population size of American alligators has been estimated by aerial nest counts (Chabreck 1966), night-light surveys (Murphy 1977, Taylor and Neal 1984, Woods et al. 1985, Brandt 1989), basking counts (Thompson and Gidden 1972), and mark-resight (Brandt 1989, Woodward and Linda 1993) and mark-recapture techniques (Murphy 1977). Except for night-light surveys, the above techniques are presently not conducive in South Carolina due to funding and manpower restrictions and nonhomogeneous alligator habitats.

There are roughly 204,142 ha of coastal wetlands in South Carolina, of which approximately 14% (70,541 ha) are impounded (Tiner 1976). Historically, impoundments were used for the production of tidewater rice (Doar 1936), whereas, presently they serve as waterfowl hunting areas (Strange 1987). The majority of the alligator population in South Carolina is associated with intact wetland impoundments (Wilkinson and Rhodes 1992). Night-light surveys currently are used to monitor alligator populations associated with impoundment habitats in South Carolina, however, very little is known about the relationship between these surveys and population size.

A proposed quota-based alligator harvest on private lands in South Carolina provided impetus to determine the relationship between night-light surveys and population size of alligators associated with impoundment habitats. Our concept of using mark-resight techniques to validate night-light surveys on impoundments was inspired by the work of A. R. Woodward who used mark-resight techniques to verify night-light surveys on lake habitats in Florida. The objective of our study was to validate night-light surveys as a population estimation technique for impoundment habitats in South Carolina.

We thank S. Davies, A. DuPree, B. Harmon, C. Rhodes, M. Spinks, C. Wilkinson, and M. Wilkinson for their invaluable help in the field. Pilot C. MacIntosh provided expert aerial skills. Appreciation is extended to D. David, D. Otis, and A. Woodward regarding design, implementation, and review of this study. Logistical support and funding was made possible through B. Joyner. Funding was provided by the Yawkey Foundation and the South Carolina Wildlife and Marine Resources Department.

STUDY AREA

The study was conducted on the South and Cat Islands portions of the Tom Yawkey Wildlife Center, a 5,666 ha area on the north central coast of South Carolina (Fig. 1). These islands are located between the Winyah Bay and Santee Estuaries at latitude 33° 13" North and longitude 79° 15" West. South Island, a barrier island, is on the Atlantic Ocean while adjacent Cat Island is separated from the mainland by the Atlantic Intracoastal Waterway. Mosquito Creek separates the 2 islands as it passes between Santee and Winyah Bays.

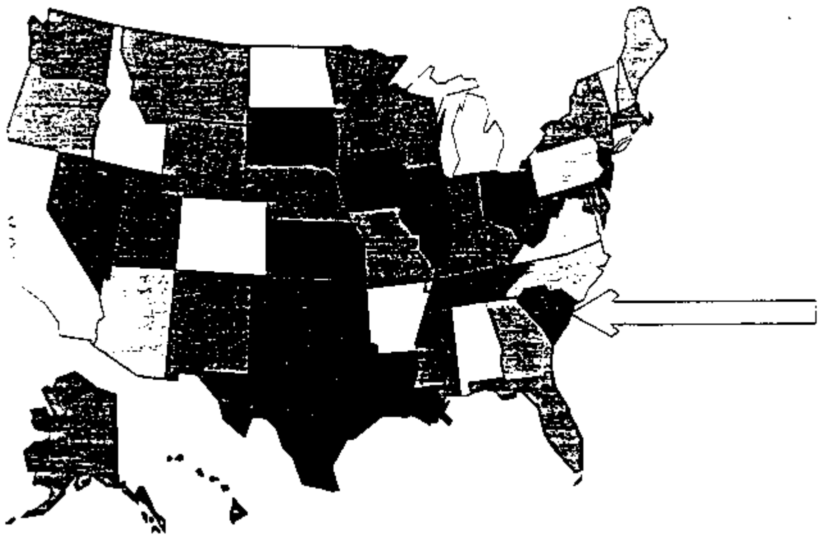

Figure 1. Location of the Yawkey Wildlife Center study area.

The study area was composed of 1,012 ha of managed waterfowl impoundments ranging in size from 5-170 ha. Additionally, there were six small, freshwater ponds totalling <12 ha. Most impoundments had roads along perimeter dikes or adjacent uplands that provided suitable access for night-light surveys. Vegetative cover within impoundments was typically a mixture of open water, submerged aquatics (e.g. *Ruppia maritima*), and emergent grasses (e.g. *Spartina cynosuroides*). Trees and shrubs were sparse, except on edges of dikes. Surrounding wetland areas were tidal salt and brackish marshes that were subject to extreme salinity variation (00 ppt-35 ppt) due to periodic freshwater discharges into the Santee River from the Santee-Cooper Lakes. The alligator population on this area had not been subjected to hunting in over 50 years.

METHODS

During the period 4 May to 13 May 1993, alligators ≥183 cm were captured using baited trip-snares, pole snares, and snatch hooks. All capture and handling of alligators was done during daylight hours so as not to induce aversion to lights that would bias night-light surveys. Capture effort was primarily concentrated in canals of impounded wetlands. Dorsal total length (TL), snout, ventral snout to the rear of vent, vent, ventral tail, and hind foot length and neck, torso, and tail girth were measured to the nearest 0.1 cm. Sex also was recorded (Chabreck 1966).

Captured alligators were color-marked with two, 4 x 16 cm strips of various combinations of green, orange, pink, white, and yellow spray paint applied to the dorsal neck region to differentiate alligators by 61 cm size classes. Tests conducted in Florida determined that painted alligators were detectable for a minimum of 25 days and that marks were large enough to be identified from the air but small enough so that the observer detected the alligator prior to observing the mark (Woodward, unpubl. data). All animals were released immediatley after handling at capture site.

Three helicopter surveys were conducted from 0930-1200 with 4 observers (including the pilot) at an approximate speed of 16 km/hr at an altitude of 35 m from 15 May to 17 May 1993. Observers, except for the pilot, rotated positions between surveys, and at least 1 new observer was added after each flight. One observer on each side of the helicopter recorded data for that side of the aircraft. Aerial surveys covered all impoundment and pond habitats on the Yawkey Wildlife Center. Only alligators seen inside impoundments were counted, however, color-marked alligators seen outside of impoundments were noted.

A night-light survey, initiated 1 hour after sunset, was conducted on 3 different nights within 1 day of the last aerial survey. Surveys were taken, from the back of a truck driven on impoundment dikes, by 2 observers shining lights over the same habitats surveyed by helicopter. All alligators seen were recorded, and when possible, sized according to snout length and entered in 30 cm size classes. Unknown-sized alligators were apportioned into size classes based on observed size structure of known-sized alligators (Jennings et al. 1988).

Population estimates of alligators ≥183 cm on the Yawkey Wildlife Center were determined for each aerial survey by Bailey's binomial model (Bailey 1952, Seber 1982:61):

$$\hat{N}_x = \frac{n_1(n_2+1)}{(m_2+1)}$$

with an estimated sampling variance given by

$$v\hat{a}r(\hat{N}_x) = \frac{n_1^2(n_2+1)(n_2-m_2)}{(m_2+1)^2(m_2+2)}$$

where $\hat{N}_x$ = population size for each survey (x = 1,...,3), n_1 = number of color-marked alligators in the population, n_2 = total number of alligators sighted, and m_2 = number of color-marked alligators sighted. We pooled m_2 and n_2 to determine average population size ($\hat{N}$) and variance ($v\hat{a}r(\hat{N})$) over the 3 helicopter surveys. Night-light surveys of alligators ≥183 cm were compared to population estimates to determine the proportion of alligators seen during night-light surveys:

$$P = \frac{\bar{S}}{\hat{N}}$$

with an estimated sampling variance given by:

$$var(P) = \frac{\bar{S}^2}{\hat{N}^2}\left(\frac{var(\bar{S})}{S^2} + \frac{var(\hat{N})}{\hat{N}^2}\right)$$

where P = proportion of alligators seen during night-light surveys and $\bar{S}$ = mean number of alligators ≥183 cm counted during 3 night-light surveys.

RESULTS

Forty-four (44) alligators ≥183 cm were color-marked and released (Fig. 2). Population estimates and the number of alligators ≥183 cm observed during night-light surveys are listed in Table 1. Mean estimated population size of alligators ≥183 cm on impounded wetlands of the Yawkey Wildlife Center was 242 ± 30 (SE). The mean proportion of alligators ≥183 cm observed during night-light surveys of impounded wetlands was 9.09 ± 3.52 (SE)%.

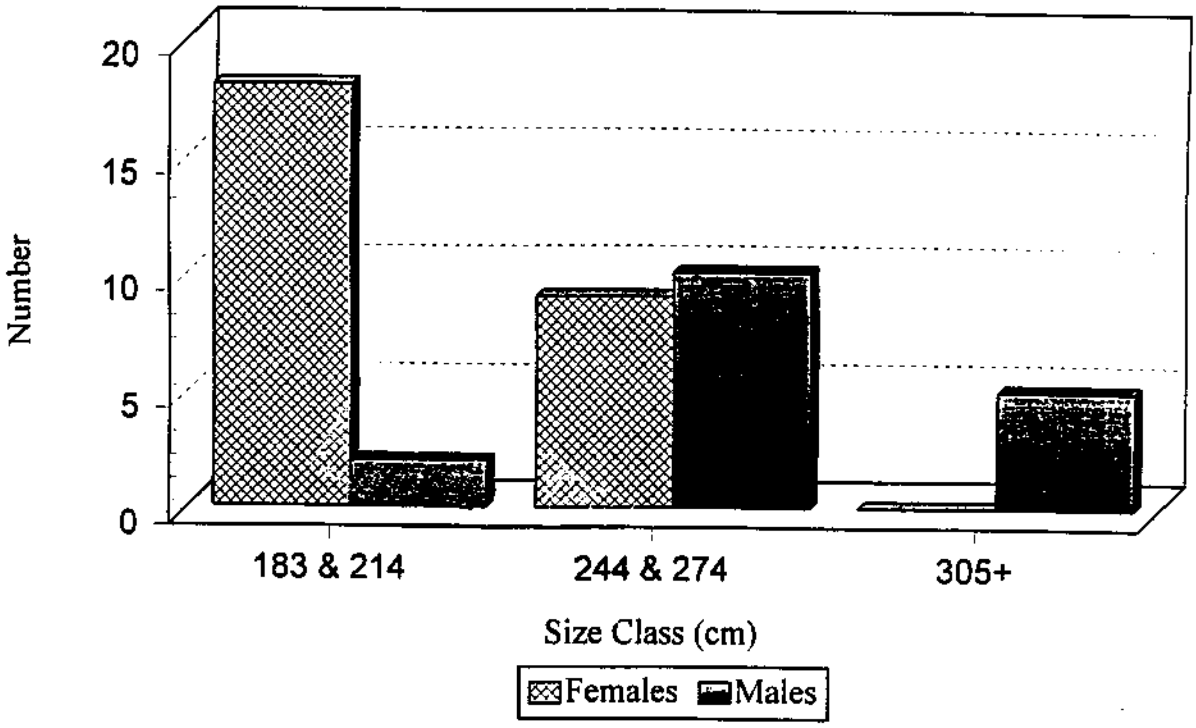

Figure. 2 Size distribution and sex of marked alligators used for mark-resight study on the Yawkey Wildlife Center.

Table 1. Results of helicopter basking surveys and night spotlight counts of ≥ 183 cm alligators on Yawkey Wildlife Center in May 1993. Mark-resight population estimates for Bailey's estimator are presented with estimated percentage of alligators seen during night spotlight counts.

Aerial Survey Date	# observ.	# marked	# resighted	$\hat{N} \pm \hat{SE}$	Spotlight survey date	# observ.	% of population seen (range)
15 May	100	42	16	250 ± 54	15 May	29	
16 May	103	42	19	218 ± 43	17 May	23	
17 May	90	42	15	239 ± 53	18 May	13	
$\bar{x}$				242 ± 30		22	9.09 (2.05 - 16.13)

DISCUSSION

Night-light surveys conducted from a vehicle traveling on perimeter dikes are the current technique used to monitor alligator population trends on impoundment habitats in South Carolina. However, a proposed quota-based, private lands alligator harvest program prompted the need to be able to estimate alligator population size efficiently and effectively. Because night-light surveys were being used on impoundment habitats in South Carolina, our objective was to determine what proportion of the estimated population was observed by current night-light survey techniques. It was not in the scope of this study to examine biases associated with night-light surveys, rather, we wanted to ensure that the mark-resight population estimate was valid so that we may calibrate our night-light surveys (with their associated biases) on a sound approximation of population size.

The validity of Bailey's estimator is based on the following assumptions: (1) the population is closed to additions (births or immigrants) and deletions (deaths or emigrants), (2) all animals are equally likely to be captured in each sample, and (3) marks are not lost and are not overlooked by the observer.

To mimic a closed population, we limited our study to a 14-day period on impoundment habitats of the Yawkey Wildlife Center. In a discussion of the weakened closed population assumption, Pollock et al. (1990) stated the nature of deletions and/or additions of animals determines for which sample the population estimate is valid. Because we have no information on movements and we feel that some movement of alligators in and out of impoundments was possible during the study period, we concluded that our population estimate was valid at the time of the first sample (marking period).

Woodward and Linda (1993) hypothesized that capture and aerial sighting probabilities may vary among different size classes of alligators and, possibly, among individual alligators within size classes. Because we recaptured alligators with an independent technique and saw no avoidance of the helicopter by either marked or unmarked alligators, we surmised that there was no trap response. Furthermore, we determined that capture probabilities were homogeneous because the proportion of marked alligators resighted among size classes did not vary when pooled over aerial surveys (Rhodes and Wilkinson, data from this study). As a result, we believe that we did not violate assumption (2).

We concluded that we met assumption (3) as well. Even though our marking technique (paint) was temporary, tag loss in our study was nonexistent because we completed our study in a short time period (14 days) and we saw no evidence of mark loss from alligators recaptured as late as the last day of marking. Studies conducted in Florida (Woodward, unpubl. data) determined that alligators marked in this fashion were visible up to 25 days after marking. Additionally, marks were small enough to ensure that the alligators were seen first, and the marks were sufficiently large to safeguard against being overlooked.

Bartmann et al. (1987) believed that more confidence could be placed in results when repeated surveys are combined into 1 population estimate (as was the case in our study); however, Rice and Harder (1977) warned that aerial samples should be independent with respect to day, time, and observers. A lack of compliance with independence will cause negative bias in variance estimates, but will not bias $\hat{N}$ if capture probabilities are equal for all animals (Rice and Harder 1977). During our study, surveys were flown on different days with observers rotating positions and at least 1 new observer was added on each survey. Due to timing of alligator basking activity we could not conduct surveys at different times of the day, however, we did begin surveys at various locations.

The proportion of the estimated population ≥183 cm detected with night-light surveys was 9.09%. We observed substantially less than Murphy (1977) and Brandt (1989) sighted (30-35%) during their work on Par Pond, Savannah River Plant, South Carolina. We believe that the open water habitat, the use of a slow-moving boat, and the inclusion of alligators <183 cm increased the sighting probability of alligators they sampled. Our results are comparable to the results of Woodward and Linda (1993) for Florida alligators occurring in vegetated lake habitats that resemble impounded wetlands in South Carolina. Although they included alligators ≥122 cm in their study, we feel that had we included that segment of the population in our investigation results would have been similar.

Our preliminary examination of night-light surveys as a population estimation technique for impoundment habitats proved encouraging. Our greatest concern is that the percentage of alligators observed may vary by location due to differences in impoundment habitat types. Pending financial approval, an analysis of that hypothesis is slated for the spring of 1994.

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A Walk-Through Snare Design For The Live Capture Of Alligators.

Traditionally, alligators have been live captured using a spotlight and pole snare (Chabreck 1963), baited trip snare (Murphy et al.), tredel trail trap (Mazzotti and Bradt 1988), harpoon (Woodward and David 1993), and weighted treble hook (Rhodes and Wilkinson 1994).

A simplified version of the Mazzotti tredel trail trap was developed for the live-capture of alligators during alligator mark-resight studies conducted in South Carolina (1993-94), and later implemented to capture nesting female alligators at Lake Apopka and Lake Woodruff, Florida.

Materials

A walk-through trap consists of two approximately 3cm (1.25 inch) x 3cm x 80cm (32 inchs) wooden stakes with a 1.25cm (.50 inch) wide x 1.6cm (5/8 inch) deep V-shaped groove routed longitudinally along the center of one side of each stake. A 2.0 cm (.75 inch) notch across one end (top) of the stake joins the V-groove. A .32cm (1/8 inch) hole was drilled through the V-groove from the side of the stake .32cm from the edge at the center of the stake. Two additional holes were drilled 10cm (4 inches) on either side of the center hole. Sufficient space behind each hole was allowed in the groove to accommodate a #2 snare cable. The bottom of the stakes were pointed to ease installation into ground (Figure 1).

Trap Placement

Traps were placed on recently used trails. Two stakes were driven approximately 10cm (4 inches) deep on either side of an active trail. Top (ends with cut through notch) of the stakes touched at approximately 60 degrees above the trail, V-grooves facing each other. A #2-182cm (72 inch) snare was looped to a diameter sufficient for the head of an intended alligator to pass through, but not its legs. The loop was positioned in both V-grooves and secured in place with a fragile green twig or grass stem passed through holes in each stake. The snare lock was positioned near the apex of the 60 degree angle. The end of the snare was secured sufficiently to insure the snare would draw tight when gently pulled. A rope secured to the end of the snare was tied to hold the alligator (Figure 1).

The snare was adjusted for different size alligators by adjusting the diameter of the snare loop and its distance from the ground. For example, a larger diameter loop positioned about 10 cm above the ground for larger alligators and smaller diameter positioned near the ground for smaller alligators.

Results and Discussion

Interpretation of field sign of alligator activity was important to the success of the walk-through capture method. Capture was most successful when alligator movements were predictable. Traps were placed at basking haulouts, levee crossovers, trails leading between guard holes and open water, and at nests.

In May 1994, forty-seven alligators ≥ 1.22m were captured in South Carolina during a seven day period for mark-resight studies. Three capture methods were employed: baited trip snare, weighted treble hook, and walk-through snare. Twelve (25.5%) alligators 1.91 to 3.73m were captured in walk-thru snares. Daily trapping success for this method was 19%. In late June and early July 1994, fifteen female alligators were captured at nest sites on Lakes Apopka and Woodruff, Florida during eight nights of trapping. The number of traps per night was not recorded, however sets/night varied from 5 to 18 and trap success was estimated at about 10%.

Trap specifications are approximate and may be varied considerably. Earlier designs were constructed from reeds tied together with thread across an active trail which supported the snare loop. Our design evolved because potential trap locations lacked suitable vegetation for on site trap construction.

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Walk-Through Snare Design
For The Live Capture Of Alligators

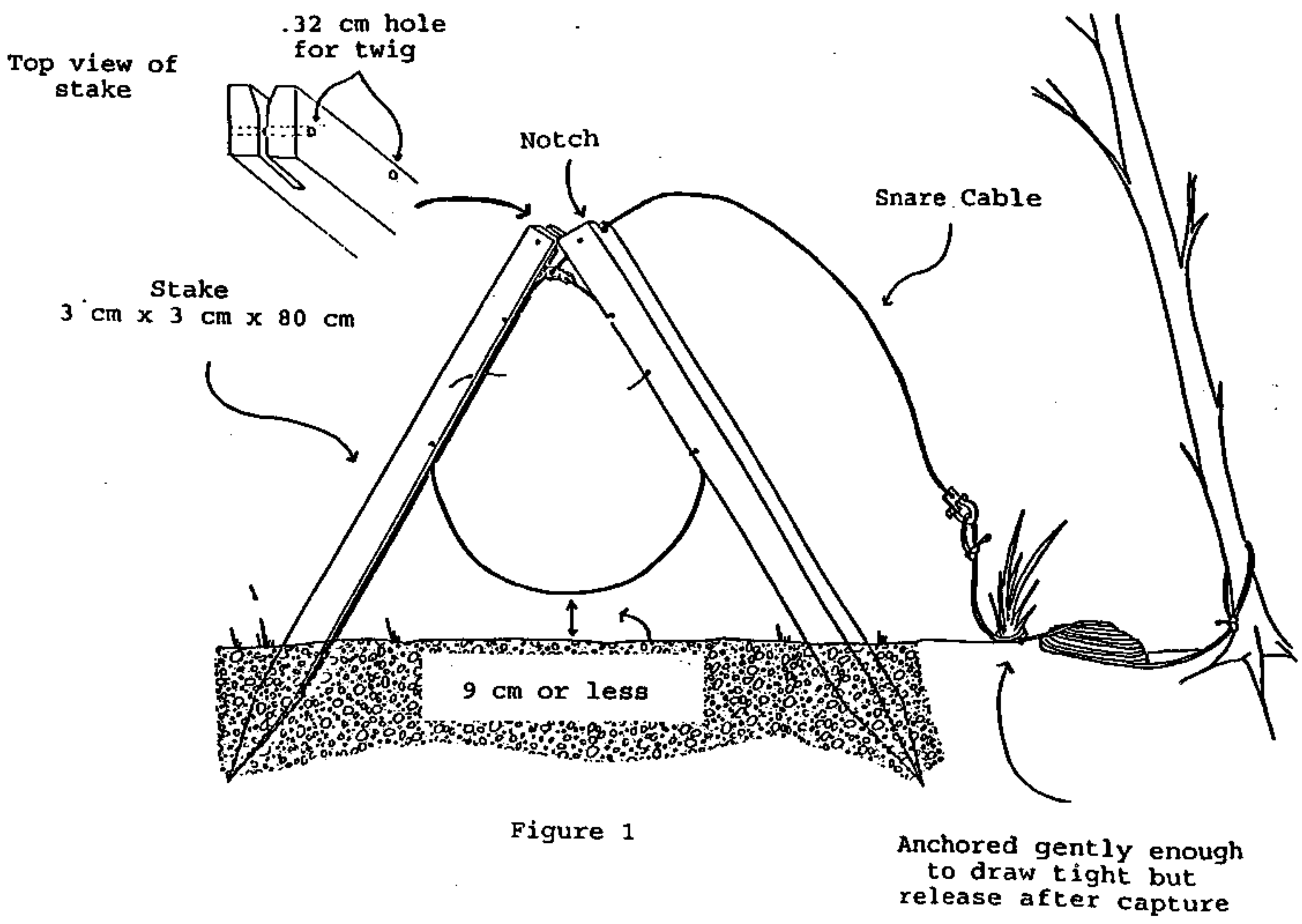

Figure 1

STATUS OF *CROCODYLUS POROSUS* AND *CROCODYLUS NOVAEGUINEAE* POPULATION IN PAPUA NEW GUINEA, 1981 - 1994

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Papua New Guinea

A paper prepared for the 12th working meeting of the Crocodile Specialist group of IUCN/SSC convened at Pattaya - Thailand.

2nd - 6th May, 1994

STATUS OF *CROCODYLUS POROSUS* AND *C. NOVAEGUINEAE* POPULATIONS IN PAPUA NEW GUINEA: 1981 - 1994

1.0 INTRODUCTION

Papua New Guinea has been dubbed the land of the "Expect the Un-Expected". It is a large island with a total land area of 462,840 Km2 and a population of 3.7 million people (National Statistical Office, 1990) with high mountains, virgin forests and virtually impenetrable swamps.

It is also fortunate to have a National Constitution, with one of its five stated national goals committed to conservation of the environment. This Goal states that the maximum benefits derived from commercial exploitation should be directed towards the resource owners and that wild harvests be gradually scaled down by the development of ranches and to ensure that the goal of sustainable yield harvests is on a long term basis (Hollands, 1984).

The significance of the species has been the commercial trade of their skins which has been going on for the last six decades. The foreign earnings to PNG as a developing country is of significance, and the resource requires attention in conservation and management strategies from both the government and the industry.

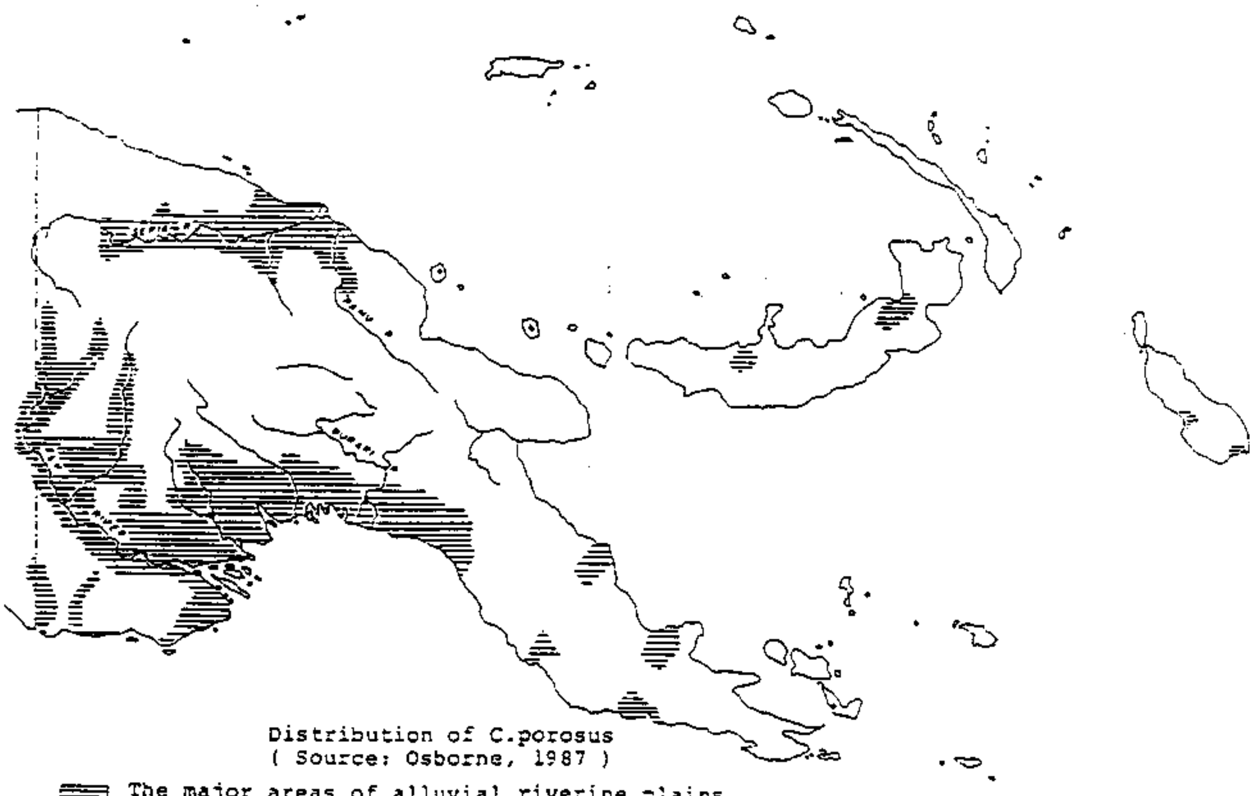
Papua New Guinea (PNG) has two species of crocodiles, Crocodylus porosus (the saltwater or estuarine crocodile) and the Crocodylus novaeguineae, (the New Guinea fresh water crocodile). The approximate distribution of these two species is shown in Figure 1. Both the PNG species are listed on Appendix II of CITES.

This paper presents an update of aerial survey results and data relating to the IUCN, Crocodile Specialist Group Meeting from data presented in the earlier working meetings of the CSG and that it is not intended to fully describe the already extensive Crocodile Management Programme in the country but as an update to the reports on the crocodile population status submitted to the group at each working meeting.

FIGURE 1: DISTRIBUTION OF C. NOVAEGUINEAE AND C. POROSUS IN PAPUA NEW GUINEA

: Distribution of C.novaeguineae
(Source: Osborne, 1987)

The major areas of alluvial riverine plains and tidal swamps containing crocodiles in Papua New Guinea



Distribution of C.porosus
(Source: Osborne, 1987)

The major areas of alluvial riverine plains and tidal swamps containing crocodiles in Papua New Guinea.

2.0 EXPLOITATION AND TRADE

It is a government policy to allow for the maximum use of the Crocodile resource by the village people (resource owners), consistent with the crocodile populations being able to sustain the harvests on a continued basis.
The bulk of the harvests has always been and in straight numerical terms continues to be the direct hunting of crocodiles from the wild for their skins, and PNG still maintains a stable level of exports (i.e. skins), for the periods 1992 and 1993 (Table 1 and Figure 2, 2a and 2b).

Although, the local law gives a landowner the right to kill any crocodile on his land (traditional exploitation has always been for food) their commercial hunting is limited to within certain size limits by licensing laws under the Crocodile Trade (Protection) Act, Chapter 213 which became effective in 1975 restricting limits on tradeable skins. These sizes includes an upper limit of 51cm to give some degree of protection to the breeding stock, and the lower limit of 18 cm to prevent the needless killing of large number of animals too small to give a commercial value skin. The 18cm limits restricted for exports became effective in 1981 (Table 2 and Figure 3).

One of the governments involvement in the industry is to encourage the development of the crocodile farms (Hollands, 1985, 1986). Although a small amount of rearing takes place in village farms the majority of village farmers depend on the movement of live crocodiles to the larger well organised ranches which have readily abundant access feed. The successful development of ranching to date is shown in Table 3.

3.0 POPULATION TRENDS

Both species of crocodiles are widely distributed (Figure 1) throughout PNG Mainland, with C. porosus also present on the larger offshore islands of New Britain, New Ireland, Manus and the North Solomons.

This range includes extensive areas of dense swamps, which together with the distance and poor communication systems makes surveys both difficult and very expensive.

Table 1: Export of Crocodile Skins from PNG, 1977 - 1993

Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
A: Crocodylus n. novaeguineae																	
Wild Skins 18 - 51 cm	14900	17200	22600	19000	13200	23300	13800	13200	16400	22100	20100	12000	14400	28517	21405	14803	15914
Wild Skins < 18 cm	11700	13800	12600	8300	1100												
Ranched Skins 18 - 51 cm			700	500	700	1500	1300	8100	3400	2300	3400	5200	7100	357	544	1060	5498
Captive Breed 18 - 51 cm														1000	2000	1500	
Sub-total:	**26600**	**31000**	**35900**	**27800**	**15000**	**24800**	**15100**	**21300**	**19800**	**24400**	**23500**	**17200**	**21500**	**29874**	**23949**	**17363**	**21412**
B: Crocodylus porosus																	
Wild Skins 18 - 51 cm	3000	3600	3900	3500	3500	3900	3100	3100	3400	3900	3400	3200	3900	6365	9424	3936	9296
Wild Skins < 18 cm	3600	3600	3500	2200	400												
Ranched Skins 18 - 51 cm			200	100	400	900	300	2000	1200	500	1100	2300	3100	123	1839	182	5315
Captive Breed 18 - 51 cm											800			305	1100	900	389
Sub-total:	**6600**	**7200**	**7600**	**5800**	**4300**	**4800**	**3400**	**5100**	**4600**	**4400**	**5300**	**5500**	**7000**	**6793**	**12363**	**5018**	**15000**
Grand-total:	**33200**	**38200**	**43500**	**33600**	**19300**	**29600**	**18500**	**26400**	**24400**	**28800**	**28800**	**22700**	**28500**	**36667**	**36312**	**22381**	**36412**

Figure 2: Total number of crocodile skins exported from PNG, 1977 - 1993

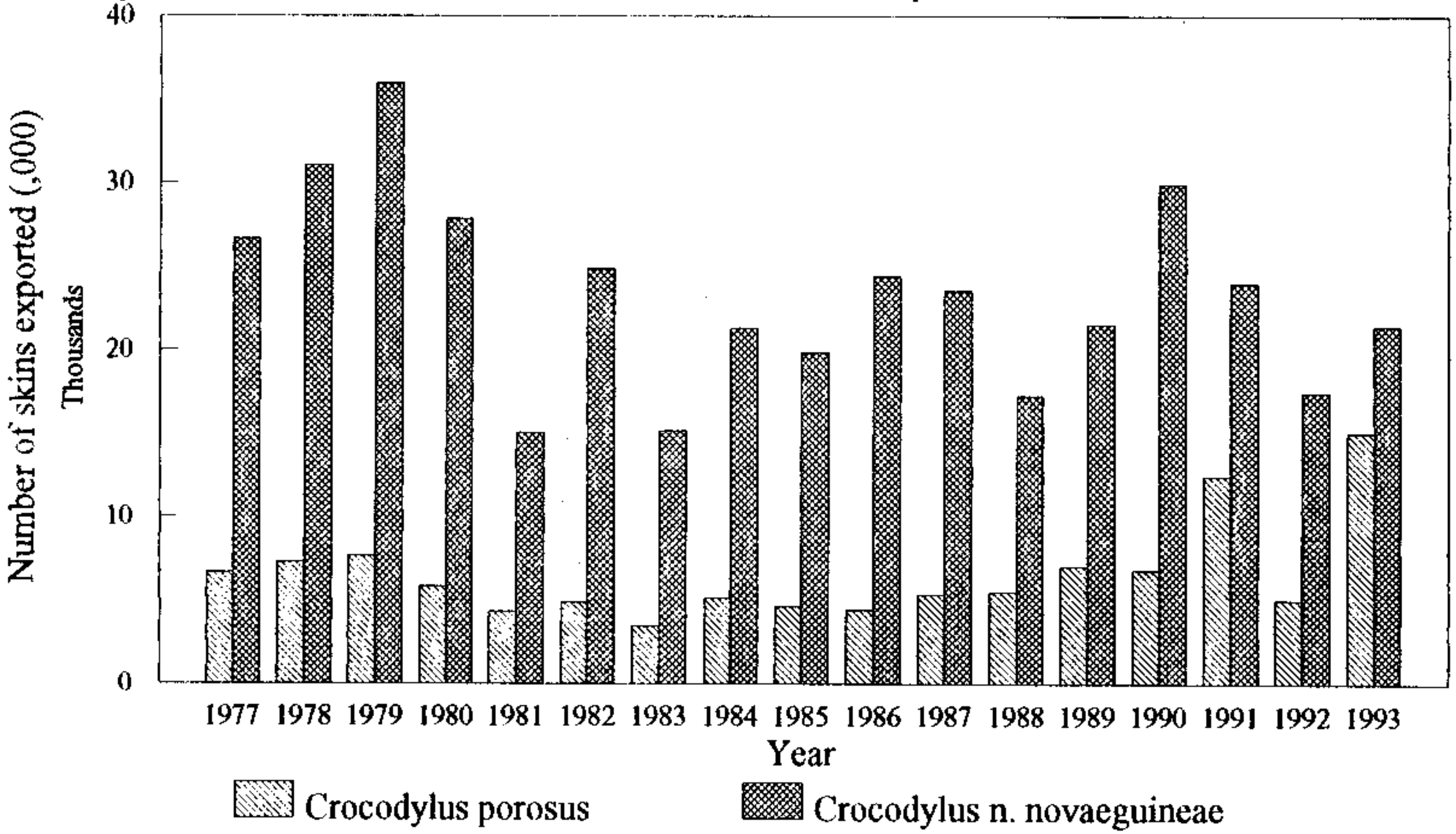


Figure 2a : Export of Crocodylus novaeguineae skins from PNG, 1977 - 1993

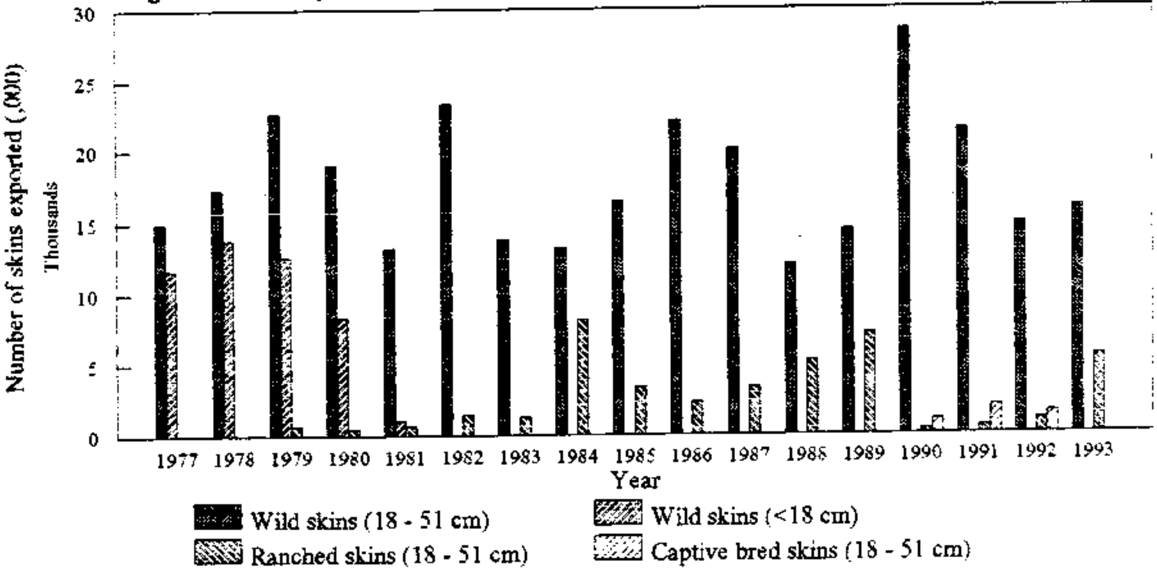


Figure 2b : Export of Crocodylus porosus skins from PNG, 1977 - 1993

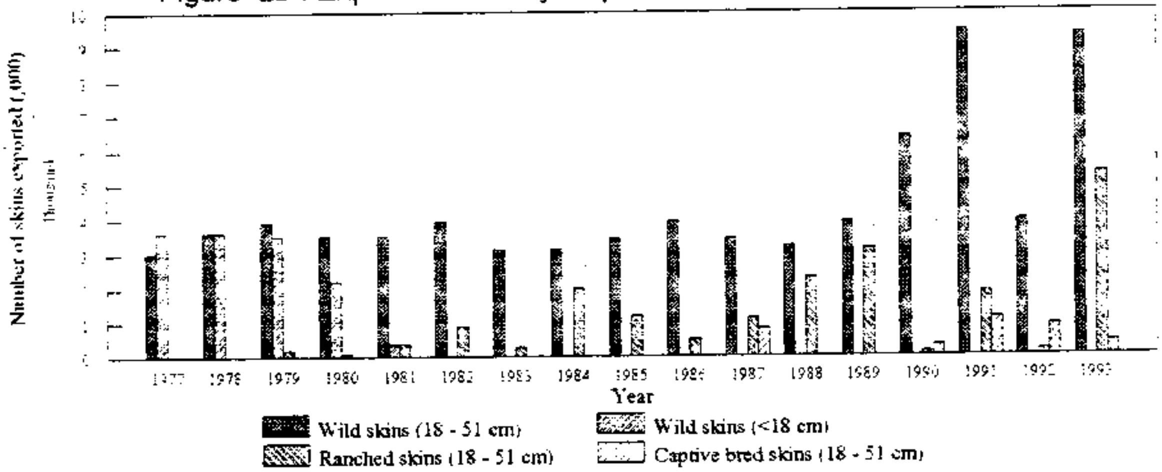
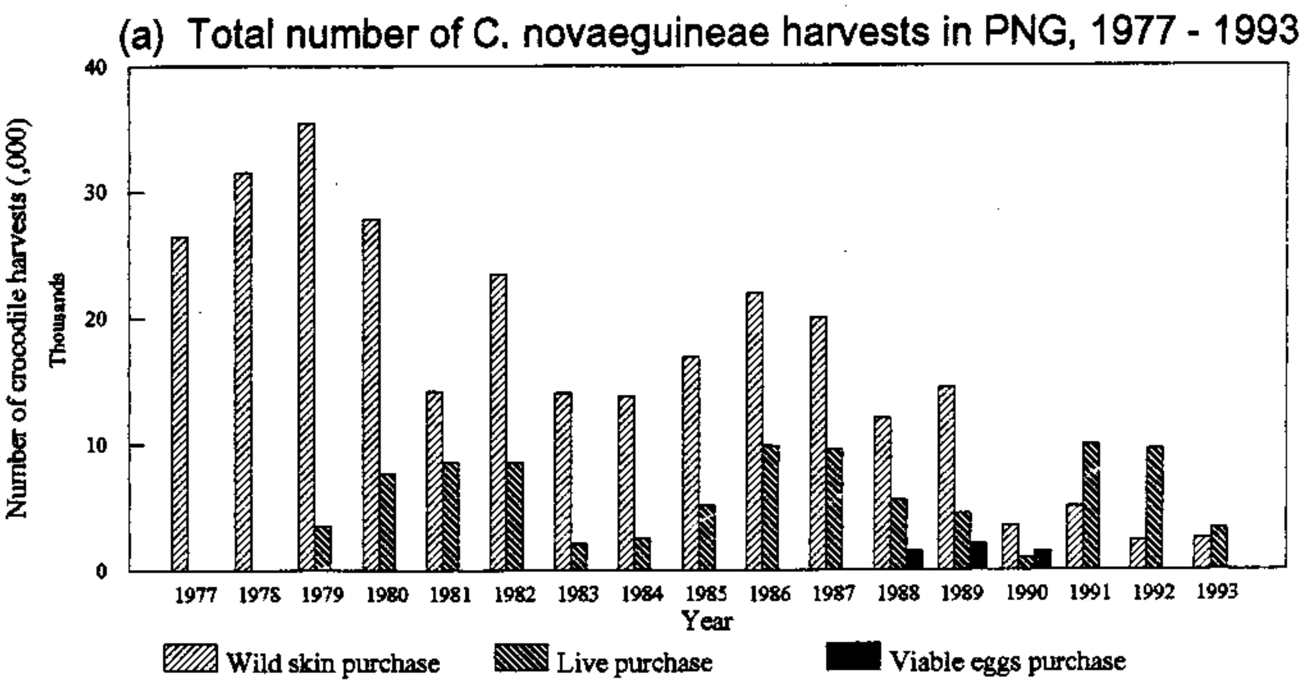


Table 2: Total number of crocodile harvests in Papua New Guinea

Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
(a) Harvest of *Crocodylus novaeguineae*																	
Wild skins (18 - 51cm)	26500	31500	35500	27800	14200	23500	14000	13800	16900	22000	20000	12000	14500	3500	5000	2360	2494
Live purchase			3500	7700	8600	8500	2000	2500	5100	9800	9500	5500	4500	1000	10000	9624	3289
Wild egg purchase												1500	2000	1500			
(b) Harvest of *C. porosus*																	
Wild skins (18 - 51 cm)	8500	7100	7300	5700	3900	3900	3100	3100	3400	3800	3400	3200	3800	500	1300	616	1197
Live purchase			1000	7200	1100	2800	1900	1500	3600	5400	3100	4300	3500	200	5400	1127	3660
Wild egg purchase									600			600	1100	1400	389	2461	621

Figure 3: Crocodile harvests by species in Papua New Guinea



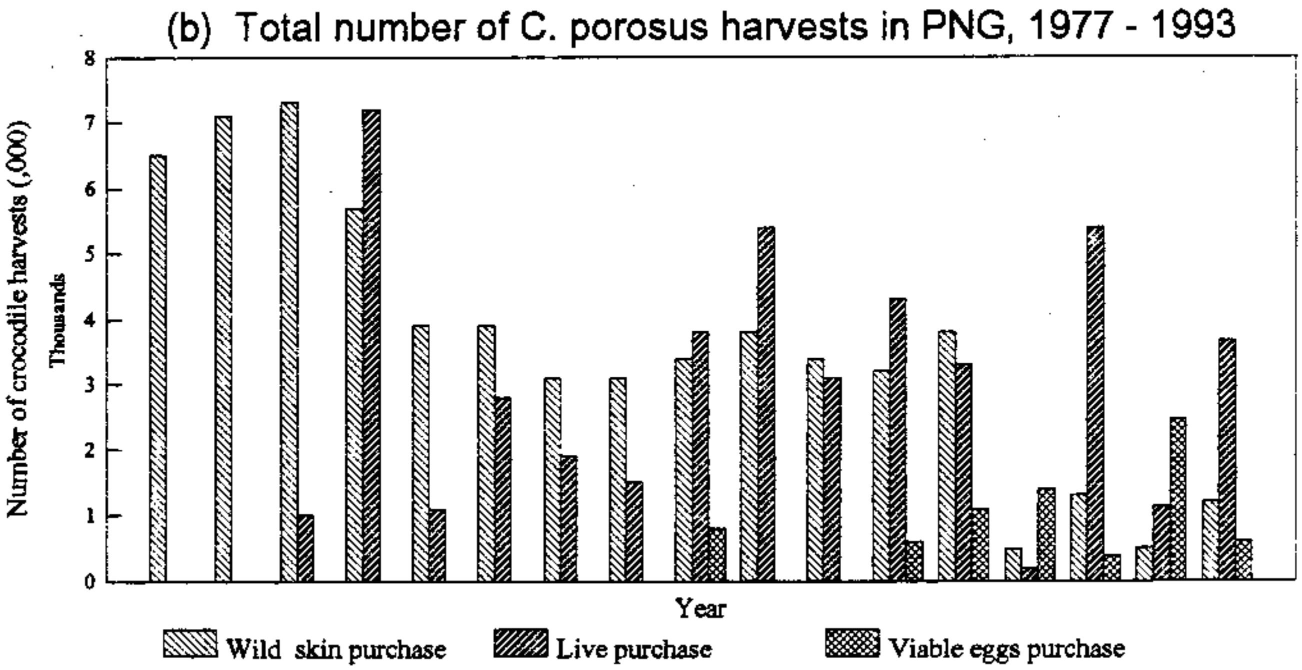


Table 3: Crocodile Stocks on Registered Farms in PNG, 30th March 1994.

Farm	SW	FW	Total
Mainland Holdings, Lae	13800	18454	32254
Geoffrey Ling, Kimbe	308	0	308
Illimo Farm, Port Moresby	513	1307	1820
Madang Crocodile Farm, Madang	130	1200	1330
Mainingulai Import/Exports, Angoran	206	853	1059
Sita Crocodile Farm, Daru	692	630	1322
Total	**15649**	**22444**	**38093**

For this purpose the prime objective of the National Crocodile Management Unit (NCMU) of the Department of Environment and Conservation (DEC) is the population monitoring programme, which is not an attempt for a full inventory of the population size, but to identify the underlying trends resulting from the current management.

3.1 Aerial surveys

On the above note regular aerial nest counts surveys have been carried out for the last thirteen (13) years since 1981, in a number of sites along the flood plains of the Sepik river systems in the north of the country, an area which produces more than half of the live animals (stock) for ranching and contributes up to 40% of the wild skin exports from PNG. It is anticipated that an extra safeguard for the industry is built in by basing the monitoring surveys in one of the heavily crocodile utilised areas and that the goals of monitoring natural animal populations can be generally expressed in terms of population levels and, in the case of exploited populations, the harvested levels. With respect to population size, management efforts can be directed at one of the three possible goals.

1. Increase the size of desirable population that are either declining or persisting at low levels.

2. Maintaining the size of populations observed to be at desirable levels.

3. Decreasing the size of populations for which populations densities are observed to be undesirably high.

   For exploited populations as it is in Papua New Guinea above goals must be considered in conjunction with the additional goal of

4. Maintaining population levels consistent with commercial or recreational interests.

3.2 Nesting Indices: 1992 - 1994

The 1994 report presented the population nesting indices for the period October 1981 to March 1994. Previous reports to the CSG have detailed the methods used in the nest surveys and that this report follows basically the same methods and have not been altered in the last rounds of surveys.

The surveys are conducted on a set of identical routes that are selected that gives a representative mix of habitats and hunting pressures in the area. The surveys are conducted just after the peak nesting periods of each species each year and that the data collected are analysed to date using the methods developed by Hollands (Hollands, 1984).

For the purpose of this meeting calculated results of the annual nesting trends for each species which is presented in Table 4, excludes the raw data and the details of the data analysis. A graphic representation of the habitat-weighted nesting indices for each species (Table 4) is presented in Figure 4.

The nest numbers for C. porosus have shown a decline from 1992 (157) to 1993 (146) (i.e. 7.0%) and a further drop of 12.3% in 1994 (128). Even with the decline the nesting index shows the indices to be still well above the indicator-level of 100 (the initial survey value set in March 1982) (Figure 4). In general the overall trend would indicate a stable population. There have been periodic destruction, loss of nesting habitat through burnings during excessive dry seasons and flooding during extended wet seasons since 1986 and that fluctuation in the nesting index which can be attributed

The C. novaeguineae in contrast indicated a fluctuating trend. The situation is some what more complicated (than C. porosus which prefers open environment) where limits are imposed by habitats which are heavily vegetated. The use of aerial surveys (helicopter) on nest counts is indirect in that the technique monitors the number of nests per survey and not the population per survey (Genolagani/Wilmot 1988). However, it is known from other conditions that a highly variable, and unknown proportion of females bread each year.
For C. novaeguineae there was a decline in 1992 (79) from 1991 (108) by 26.8, however there was an increase in 1993 (96) from 1992 (79) by 21.5%

Table 4: Habitat Nesting Indices of Crocodiles in the Sepik Region, PNG 1981 - 1994

A: Crocodylus novaeguineae

Year		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Habitat	**Weighting**														
Lake Fr	0.19	100	111	122	92	95		73	107	102	123	109	109	87	
Scroll/Sw	0.57	100	120	106	82	138		56	71	71	54	48	20	38	
Ov.Barets	0.14	100	200	275	174	205		267	366	304	226	308	244	305	
Ov.Oxbows	0.10	100	135	157	98	176		137	175	148	133	174	129	154	
Habitat Weighted Indices	**1.00**	**100**	**131**	**138**	**98**	**143**		**97**	**130**	**117**	**99**	**109**	**79**	**96**	

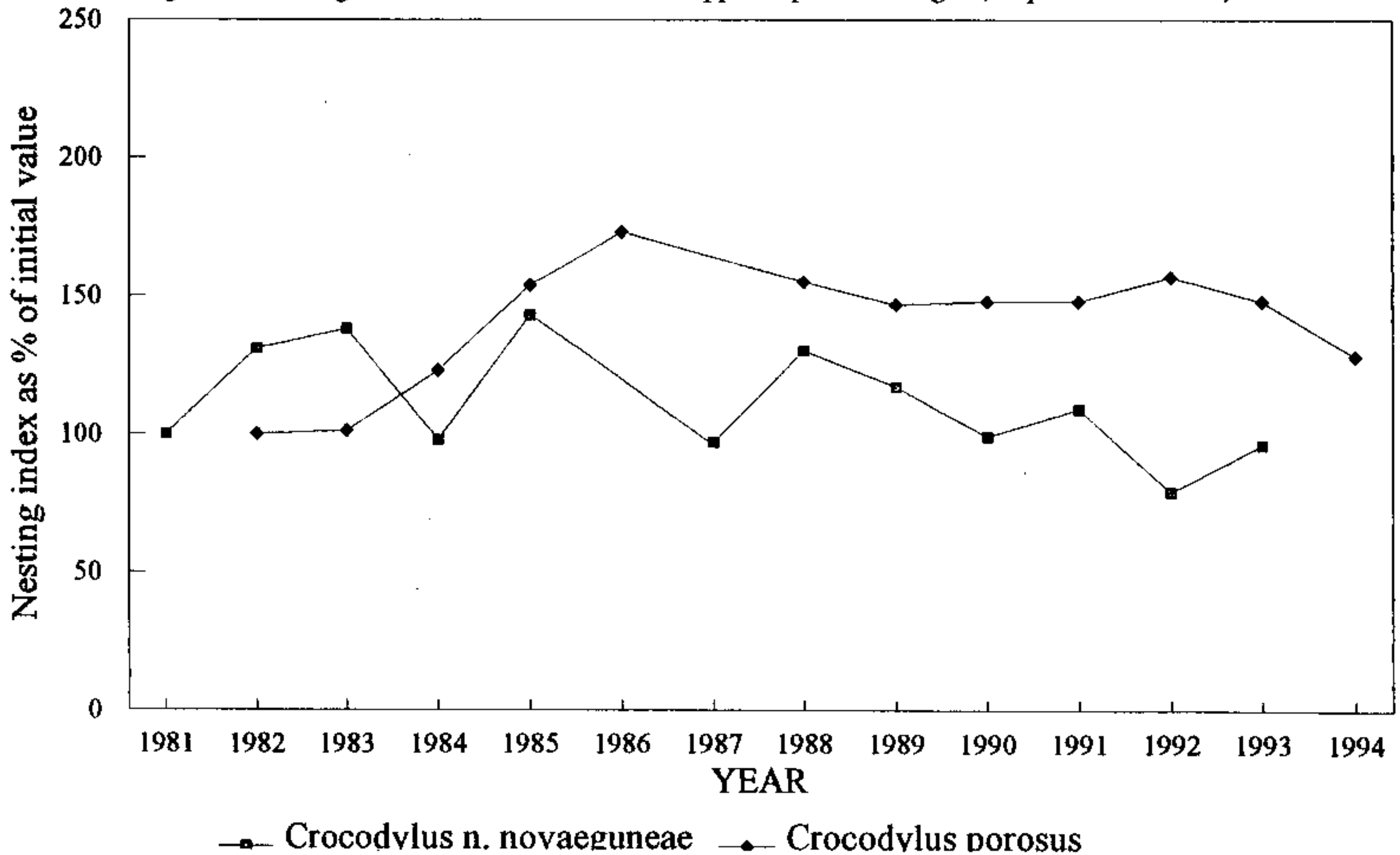
B: Crocodylus porosus

<u>Habitat</u>		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Lake Fr	0.31		100	50	74	76	67		74	105	103	129	125	139	112
Scroll/Sw	0.36		100	100	163	213	322		264	116	111	121	114	151	114
Ov.Ox.Brts	0.33		100	150	125	163	104		111	211	220	190	225	148	161
Habitat Weighted Indices	**1.00**		**100**	**101**	**123**	**154**	**173**		**155**	**147**	**148**	**148**	**157**	**146**	**128**

Note: (i) Nesting indices for C. porosus from 1987 are not used for comparative purpose due to inconsistent nest counts

(ii) N/S = No nesting survey conducted

Figure 4: Nesting trends of crocodilians in the upper Sepik River region, Papua New Guinea, 1981 - 1994



Do note even there was a decline of 4% for the calculated value of 1993 (96) below the level of 100 initial value set in October 1981, the annual nesting decline of 0.30% over the thirteenth year period could presumably as a result of a lower percentage of females breeding as a result of a yet unknown environmental parameters.

The fluctuating trend as indicated by the nesting index is stable in such a heavily exploited population it would seem that both species of crocodiles are responding well to changes in cropping and management, and that the future looks sound for both the crocodile population and the rural populations who are dependent on them as their major source of income.

3.3 Potential of programme expansion

It is highly recommended that DEC and NCMU inject in more funding priority for the continuance of the aerial nesting surveys. In order to resolve uncertainty that the Sepik counts may not be indicative of sub-population trends in other habitats or regions of the country, the programme should be expanded to additional representative areas. However, our knowledge of habitat types and areas is incomplete to employ the same method used in the Sepik flood plain.

One of the systems that merits highest priority for the nests counts surveys was the adjoining Ramu System. The initial surveys done in Ramu was in October 1992 for the C. novaeguineae and March 1993 for the C. porosus (Table 5 and Figure 5).

The C. novaeguineae survey in 1992 recorded a total of twelve nests of which six are sighted on the over grown channels and a further six sighted on the over grown oxbows. The C. porosus survey recorded a total of seven nests from the three sites surveyed, and all are sighted on the scrolls.

The above nests tabulated are given the straight counts, and that no habitat weighting are used. Due to the given environmental conditions which appear much the same as the Sepik system, same habitat weighting could be adopted for use in Ramu system. However that needs to be ascertained by doing follow up ground work to determine individual habitat weighting. Surveys of Ramu system will be conducted bi-annually.

Table 5: Raw data of Ramu River nests counts, PNG, 1992 - 1993

(a) Crocodylus novaeguineae October, 1992

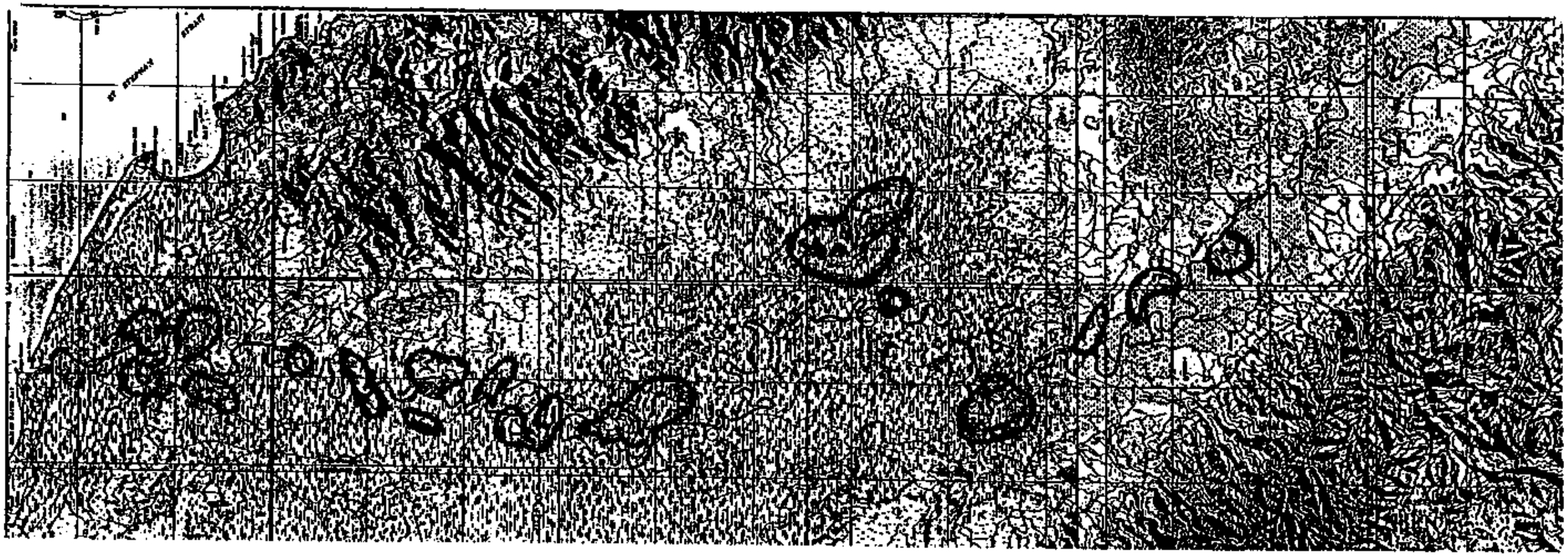
Site	Active Nests	Habitat type			
		Lk Fr	Scroll	Ov. Ox.	Ov. Brts
East Wengabu	6				6
West Wengabu	0				
Keram	0				
Diam	2			2	
Quiaga	1			1	
Attomble	3			3	
Kerangum	0				
Total	**12**	**0**	**0**	**6**	**6**

(b) Crocodylus porosus March, 1993

Site	Active Nests	Habitat Type		
		Lk Fr	Scroll	Ov. Ox .Brts
Zanung Scroll	0			
East Wengabu	7		7	
West Wengabu Lake	0			
Total	**7**	**0**	**7**	0

N/B: No weightings for each sub-habitat has yet been determined, however the breakdown is adopted from the Sepik Region due to its close proximity to the system.
Both species are surveyed biannually

FIGURE 5: <u>RAMU RIVER AERIAL SURVEY AREAS</u>.



NB: 1992 October - C. Novaeguineae
1993 March - C. Porosus

3.4 Wild Egg Harvests

The other monitoring parameter which is conducted in conjunction with the aerial nests counts surveys is the wild egg harvests. Since its inception in 1985 for C. porosus and 1988 for C. novaeguineae the activity has met with mixed responses and that continued follow up meetings with the landowners (nest owners) to get them to agree to protect their nests and have a certain percentage harvested.

With renewed claims by land owners after the 1990 harvests that the activity is detrimental in that wild stock will decline, the government extension officers again had consultative meetings with the nest owners and that it was agreed between the nest owners and the government officers to have the harvests done bi-annually starting March, 1994.

It is assumed that with this trial in place, the monitoring of live animals (harvested) for sales from the area can then be assessed after 12 months and conduct of regular replicate night counts of areas in which the egg harvest was done to determine if the egg harvest is possibly detrimental to the decline in wild stock. However, such a trial needs to be employed over a period of time to give a broader assessment of its validity and hence to enable the programme to either continue, expanded or dropped.

In contrast the important features of the wild egg harvesting programme is in providing indirect and direct data on some aspects of biology and raises more topics for field research for both species (Cox *et al.* 1989, Genolagani *et al.* 1990). Some important information obtained to date has been on evidence of recruitment into the wild populations. This has been through comparative mean clutch sizes and field visual size estimation of size attendant nesting females (Cox *et al.* 1989, Genolagani *et al.* 1990).

With the introduction of the on board Garmin GPS system in the C. porosus March 1994 nest counts survey, it has proved convenient in that it improves the position of stream lining conduct of egg harvest by relocating, drop and retrieval of eggs from survey sites after survey counts are completed days later. All nests sighted are plotted and given GPS numbers, and that includes nest numbers by sites with abbreviation for ease of data analysis (Table 6). Perhaps the most important use of GPS technology may prove to be unveiling of long term nesting patterns for individual survey sites which could assist management efforts.

Table 6: Nest Sites GPS coordinates and associated data

	PERMANENT NEST #	NEST STATUS	LAT/LONG COORDINATES		HARVEST NEST #
1	JPN 001	Ac	S 04 06.24'	E 142 59.67'	
2	LPG 001	Ac	S 04 06.47'	E 142 56.16'	
3	NUM 001	Ac	S 04 05.31'	E 142 54.89'	
4	NUM 002	Ac	S 04 05.29'	E 142 54.66'	
5	NUM 003	SH	S 04 05.22'	E 142 54.90'	
6	NUM 004	Ac	S 04 05.63'	E 142 55.25'	
7	NUM 005	Ac	S 04 05.12'	E 142 55.49'	
8	NUM 006	Ac	S 04 05.20'	E 142 55.60'	
9	NUM 007	Ac	S 04 05.22'	E 142 55.51'	
10	NUM 008	Ac	S 04 06.29'	E 142 54.85'	
11	WAL 001	Ac	S 04 11.19'	E 142 55.67'	
12	WAL 002	Ac	S 04 10.38'	E 142 56.06'	SK 602
13	KWS 001	Ac	S 04 10.27'	E 142 52.16'	SK 603
14	KWS 002	Ac	S 04 10.06'	E 142 51.66'	
15	KWS 003	Ac	S 04 10.01'	E 142 50.57"	
16	KWS 004	Ac	S 04 06.75'	E 142 49.66'	
17	KWS 005	Ac	S 04 10.37'	E 142 49.79'	
18	KWN 001	Ac	S 04 14.01'	E 142 48.12'	
19	KWN 002	Ac	S 04 14.35'	E 142 47.71'	SK 604
20	KWN 003	Ac	S 04 14.30'	E 142 47.20'	SK 605
21	KWN 004	Ac	S 04 14.20'	E 142 48.43'	
22	KNI 001	Ac	S 04 19.63'	E 142 51.63'	HS 060
23	KNI 002	Ac	S 04 19.23'	E 142 51.29'	
24	KNI 003	Ac	S 04 18.42'	E 142 51.63'	HS 061
25	WHB 001	Ac	S 04 17.69'	E 142 50.93'	
26	WSO 001	Ac	S 04 20.35'	E 142 44.94'	
27	WSO 002	Ac	S 04 19.46'	E 142 44.66'	
28	WSO 003	Ac	S 04 19.76'	E 142 45.86'	
29	WSO 004	Ac	S 04 19.45'	E 142 45.52'	HS 063
30	SYR 001	Ac	S 04 19.06'	E 142 42.92'	
31	SYR 002	Ac	S 04 19.22'	E 142 42.66'	
32	SYR 003	Ac	S 04 19.02'	E 142 42.54'	
33	SYR 004	Ac	S 04 19.37'	E 142 42.52'	
34	SYR 005	Ac	S 04 19.84'	E 142 43.43'	
35	YUG 001	Ac	S 04 19.81'	E 142 42.44'	
36	YUG 002	Ac	S 04 19.72'	E 142 42.24'	
37	YUG 003	Ac	S 04 19.60'	E 142 42.19'	
38	YUG 004	Ac	S 04 19.61'	E 142 42.14'	
39	AMR 001	Ac	S 04 17.39'	E 142 46.11'	
40	AMR 002	Ac	S 04 17.26'	E 142 46.05'	
41	WSI 001	Ac	S 04 16.19'	E 142 43.56'	
42	WSI 002	Ac	S 04 16.39'	E 142 43.01'	
43	WSI 003	Ac	S 04 16.14'	E 142 42.76'	
44	WSI 004	Ac	S 04 16.12'	E 142 42.77'	
45	KPR 001	Ac	S 04 16.40'	E 142 42.33'	
46	KRP 002	Ac	S 04 16.27'	E 142 42.63'	
47	KWG 001	FL	S 04 13.02'	E 142 43.57'	
48	WYN 001	SH	S 04 10.55'	E 142 37.43'	
49	WYN 002	Ac	S 04 10.56'	E 142 37.47'	
50	YRK 001	Ac	S 04 15.51'	E 142 35.47'	SK 608
51	KMU 001	Ac	S 04 14.81'	E 142 36.50'	SK 609
52	KMU 002	Ac	S 04 14.51'	E 142 36.59'	
53	KMU 003	Ac	S 04 14.53'	E 142 36.42'	
54	KMU 004	Ac	S 04 14.81'	E 142 36.26'	SK 610
55	KMU 005	Ac	S 04 14.91'	E 142 36.26'	SK 611
56	KBM 001	Ac	S 04 13.96'	E 142 35.05'	SK 606
57	KBM 002	Ac	S 04 14.09'	E 142 34.86'	
58	KBM 003	SH	S 04 13.64'	E 142 34.65'	
59	KBM 004	Ac	S 04 14.11'	E 142 35.02'	
60	KBM 005	Ac	S 04 14.12'	E 142 35.02	SK 607
61	GMB 001	SH	S 04 11.73'	E 142 34.75'	
62	SHP 001	SH	S 04 12.75'	E 142 34.56'	
63	SOB 001	SH	S 04 14.43'	E 142 32.61'	

64	SOB 002	Ac	S 04 14.49'	E 142 32.59'	SK 619
65	SOB 003	Ac	S 04 14.45'	E 142 34.66'	SK 625
66	SOB 004	Ac	no GPS coordinates		
67	SOP 001	SH	S 04 14.55'	E 142 32.22'	
68	SOP 002	Ac	S 04 14.54'	E 142 32.23'	
69	WTK 001	SH	S 04 11.84'	E 142 32.16'	
70	WTK 002	Ac	S 04 11.84'	E 142 32.16' *	
71	WTK 003	Ac	S 04 11.75'	E 142 32.11'	
72	WTK 004	Ac	S 04 11.50'	E 142 31.84'	SK 626
73	NGM 001	Ac	S 04 13.86'	E 142 26.32'	SK 627
74	NGM 002	PD	S 04 14.15'	E 142 26.73'	SK 624
75	NGM 003	Ac	S 04 13.94'	E 142 26.77'	
76	PRM 001	Ac	S 04 14.65'	E 142 27.71'	
77	PRM 002	Ac	S 04 14.45'	E 142 27.67'	
78	PRM 003	Ac	S 04 14.34'	E 142 27.65'	
79	PRM 004	HD	S 04 14.34'	E 142 27.65' *	
80	PRM 005	HD	no GPS coordinates		
81	WOO 001	Ac	S 04 15.59'	E 142 26.86'	SK 622
82	WOO 002	Ac	S 04 15.47'	E 142 26.95'	
83	SK0 001	Ac	S 04 16.65'	E 142 23.07'	
84	KMB 001	Ac	S 04 17.05'	E 142 23.86'	
85	KMB 002	Ac	S 04 17.75'	E 142 23.44'	
86	BGS 001	Ac	S 04 19.40'	E 142 20.96'	SK 615
87	BGS 002	Ac	S 04 19.42'	E 142 20.94'	
88	KBL 001	Ac	S 04 15.47'	E 142 18.97'	SK 616
89	KBL 002	Ac	S 04 15.51'	E 142 19.36'	
90	KBL 003	Ac	S 04 16.62'	E 142 19.47'	SK 617
91	KBL 004	FL	S 04 15.69'	E 142 19.54'	
92	KBL 005	SH	S 04 16.20'	E 142 19.26'	
93	KBL 006	Ac	S 04 19.71'	E 142 18.24'	SK 623
94	KBL 007	Ac	S 04 16.16'	E 142 17.48'	SK 612
95	KBL 008	Ac	S 04 19.01'	E 142 18.31'	SK 613
96	KBL 009	Ac	S 04 19.15'	E 142 18.92'	SK 614
97	NBW 001	Ac	S 04 17.69'	E 142 15.67'	SK 618
98	BWL 001	Ac	S 04 18.10'	E 142 14.97'	
99	HN L 001	Ac	S 04 17.67'	E 142 11.62'	
100	HNL 002	HD	S 04 16.70'	E 142 11.67'	
101	OUM 001	SH	S 04 14.96'	E 142 05.70'	
102	OUM 002	HD	S 04 15.64'	E 142 08.86'	
103	OUM 003	Ac	S 04 15.50'	E 142 08.69'	
104	OUM 004	HD	S 04 15.45'	E 142 08.42'	
105	OUM 005	HD	S 04 14.66'	E 142 08.32'	
106	OUM 006	Ac	S 04 15.64'	E 142 10.20'	
107	OUM 007	HD	S 04 15.61'	E 142 10.18'	
108	OUM 008	SH	S 04 14.99'	E 142 11.21'	
109	OUM 009	Ac	S 04 15.00'	E 142 11.29'	SK 621
110	OUM 010	HD	S 04 15.09'	E 142 11.31'	
111	OUM 011	HD	S 04 15.29'	E 142 11.09'	
112	OUM 012	Ac	S 04 15.07'	E 142 12.97'	
113	KEP 001	Ac	S 04 22.29'	E 142 17.99'	
114	KEP 002	Ac	S 04 22.41'	E 142 18.57'	

Legend:

Ac = active nest with incubating eggs
SH = successful hatch
HD = human depredation
PD = partially or totally depredated by non - human
FL = failed due to flooding
* = nest within 15 m of previous one; same coordinate used

3.5 Other Monitoring activities

In areas where the habitats make aerial nest counts in-efficient other monitoring techniques are being conducted on a periodic basis. These includes (Hollands 1982, 1984);

a) Night spotting and tagging surveys in the Central, Gulf, Western, Northern, Morobe, Madang, East and West Sepik and Islands Provinces.

b) Examining "catch per unit effort" (CPUE)

c) Conducting village interviews

d) Day counts

The night counts method of direct counting animals by reflection of a spotlight, has been applied to population surveys and monitoring of crocodiles in other countries. However, PNGs prohibitively thick tropical swamps which characterise most crocodile habitats favours in particular the C. novaeguineae. It remains so as a result of their inaccessibility.

However, the night counts methods appears more appropriate for the C. porosus population as animals are more confined to open bodies of water and hence available for observer contact. These habitats are the typical tidal river systems featuring mangrove-nipa associations, large rivers, lakes and lagoons which comprises an ideal combination of feeding, nesting and nursery grounds.

The day counts which provides an alternative method of direct counting crocodiles which was developed for the monitoring of C. porosus population in Northern Australia (Bayliss 1986) with the use of a helicopter to periodically count crocodiles on mud flats at low tide along selected sites of tidal river systems.

In Papua New Guinea, the method appears topographically appropriate in the coastal Gulf Province. The area is primarily a complex network of tidal mangrove-nipa swamps which continues to provide a significant amount of saltwater crocodiles. The possible drawback of the day counts method may result from wariness of adult crocodiles in the area unlike the unhunted populations of Northern Territory, Gulf Province animals are under fluctuating degrees of hunting pressures. Thus, there is only one way to really establish the suitability of the method, and that is to try it out (test).

Raw data for various surveys through out PNG are being compiled for analysis, however another major task here is to identify appropriate methods to have the accumulated data analysed from the various survey activities.

4.0 Imports and Manufacturing

Commercial imports of crocodilian products to PNG is currently limited, although the problem of "look alikes" in the retail market has not been studied.

PNG traditionally has always been an exporter of raw wet salted skins for commercial trade. Non-commercial use of manufactured PNG products have been conducted out of the country from raw skins exported and then re-imported as tanned skins and re-exported for manufacturing. The finished products eg: wallets, belts, briefcases are then re-imported. In this process the management levy only applies to the raw skins.

In 1991 down-stream processing of raw materials within PNG was one of the major policies announced. The crocodile industry was one of the targets. In 1992 a Tannery was established in Port Moresby by the Poksy Enterprises which trades now as PNG Fine Leathers to produce leather from reptiles (crocodiles), fish (barramundi) and birds (cassowary). The Tannery came into operation in 1993. The impact of this new development on the PNG raw skins industry has not been studied as well as further down stream processing by local manufacturers to utilise tanned skins for finished products. There are no local manufacturers in PNG dealing in crocodile skins.
Small consignments currently tanned are basically exported as "show pieces" (Table 7). All raw skins acquired by the Tannery are inspected and tagged prior to tanning. Marking procedures for monitoring of species in trade according to CITES requirements are currently been established.

The policy on downstream processing of crocodile raw skins and by products in association with the manufacturing industry have not been studied carefully and warrant urgent deliberations (Genolagani & Solmu, 1993).

Table 7: Tanned Crocodile Skins Exports, 1993

Product	**Species**		**Total**
	C. Novaeguineae	C. porosus	
Belly-width	95	194	289
Hornback	3	1	4
Backstraps	0	607	607
Total	**98**	**802**	**900**

5.0 CONCLUSION

PNG is fortunate in the circumstances of its Crocodile Management Programme. There are some factors which operate in favour of the wild crocodile populations, but for the same reasons they present a severe practical problems when it comes to effective and accurate monitoring work.

Mean while the national policy and accompanying programs which work towards the goal of sustainable yield harvest on a long term basis is being realised and exploitation is being controlled with a lot more emphasis needed on enforcement of regulations. Ranching has developed to a higher degree to enable gradual shift in wild skins. The data presented is significant in that it monitors the export skins in terms of quantity, quality and sizes for the international trade. The amendments to the Crocodile Trade (Protection) Act needs to be critically reviewed to cater for the changes in the industry and that monitoring programs keep the management policy better tuned to the productivity of the resource.

The general trend in commercial exploitation over the last thirteen years appear not to have detrimental impacts by the data presented on the status of the wild populations of both species. The *C. porosus* is still above the set level whilst the fluctuating *C. novaeguineae* levels need more field studies. The present data of *C. novaeguineae* considers the species to be safe as much of the in accessible habitats are not surveyed and hold unaccounted stocks.

PNG does not have a programme which is biologically efficient as is being achieved in some countries but each year refinements and improvements can be made as management is nudged in the right direction. However, one of the monitoring constrains for NCMU is manpower shortage, expertise and resources to successfully implement the programme.

The current levels of both species is considered safe thus achieving the goals of "CITES" in conservation and management of viable populations and that they be maintained in Appendix II of CITES.

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Simulation Model for optimum harvest of Spectacled caiman (*Caiman crocodilus*), in Venezuela.

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Introduction.

The Programme of Commercial Harvest of spectacled caiman (*Caiman crocodilus*) has been performed in Venezuela since 1983 through which only adults males, greater than 1.80 m in total length (class IV), are harvested.

Although this programme have had an extensive scientific background, there have been few studies on abundance, population growth and structure subject to harvest, and assessment of skin sizes obtained from harvested animals, amongst others.

Seijas (1986) was the first who provided data on density and population structure from sixteen farms at where individuals falling into class IV have been harvested since three years ago. Of these aspects, as well as capacity of harvest, a study was carried out by Velasco and Ayarzagüena (1992) on some ecological region, encompassing great of the range of this species.

Only two simulation models of crocodile´s population management have been so far described to assess the effect of different strategies of harvest on the gathering, and the impact on these population.

The main aim of this study is to develop a model that determines the effect of harvest on caiman´s natural population, and predict the harvest impact.

Model of Management.

Based on a relative structure of size classes applicable to any geographic scale, the model is characterized by being of discrete generation and predictive. Ten assumptions defined to develop it are as follows:
1) The population is closed.
2) The recruitment is constant for each size class.
3) Natural mortality are constant for each size class.
4) The harvest takes place from march to april.
5) The number of eggs per nest has a maximum peak at 30.
6) Hactching eggs take place from november to december.
7) The population consists of four size classes, which were categorized by Ayarzagüena (1983).
8) Classes II, III and IV are made up of various cohorts each.
9) Class IV is represented exclusively by males.
10) The ratio of males:females at classes I and II is 1:1, and at class III 20-40%:80-60%.

The variables used are the following:
1) Percentage of actively reproductive females per year.

2) Percentage of survival at the first year old.
3) Percentage of survival at classes II, III and IV.
4) Percentage of individual nonrecruited for each size class.
5) Minimum aquatic surface.
6) Aquatic density of animals per hectare of aquatic surface.
7) The ratio of males:females at class III.
8) Number of eggs per nest.
9) Harvest per size class.

Analysis and Diagram of the model.

Figure 1 shows the diagrammatic representation that is applied to a population of caiman.

Figure 1. Diagrammatic model.

```
              R(II)
    -------------------------
    |        P(II)          |           P(III)              P(IV)
    |        -----          |           -----             ----------
    |       |    |          |           |    |              |        |
    V       V    |          |           V    |              V        |
------------     | (RIII) -------------      | (RIV) ------------    |
| CLASS II |---------->| CLASS III |--------->| CLASS IV |---|
------------              -------------             ------------
    |      |                |       |                 |      |
    |      V                |       V                 |      V
    V    C(II)              V     C(III)              V    C(IV)
  Mn(II)                  Mn(III)                   Mn(IV)
```

R(II), R(III) y R(IV) are the recruitment from each size class; P(II), P(III) y P(IV) represent the fraction of individuals not recruited from the next class; Mn(II), Mn(III) y Mn(IV) are the natural mortality for each size class; C(II), C(III) y C(IV) are the harvest for each size class.

The equation that calculates the number of individuals per size class is defined as $Ni(t+1) = Ri(t) + Pi(t) - [Mni(t) + Pi(t)]$, each factor obtained as follows:

$$RII(t+1) = NIII(t) * (\%HR) * (HN) * [0,03-(0,03/A * DEN) * Pt]$$
$$RIII(t+1) = NII(t) * (\%RIII)$$
$$RIV(t+1) = NIII(t) * [\%MIII * \%RIV]$$

$$PII(t+1) = NII(t) * (\%PII)$$
$$PIII(t+1) = [NIII(t) * (\%HIII)] + [NIII(t) * \%MIII * \%PIII]$$

$$Mni(t,1) = Ni(t,1) * \exp[Ln(\%S) * 0,33]$$
$$Mni(t,2) = [Ni(t,1) - Mni(t,1) - Ci] * \exp[Ln(\%S) * 0,67]$$

where Ci= constant number of individual or a percentage of harvest at each size class, %HR= percentage of reproductive females, HN= number of eggs per nest, A= minimum area of aquatic surface, DEN= minimum density of individuals per pond, Pt= total population, %S= percentage of survival, 0,03= survival at the first year old, and 0.33 and 0.67 are spans of harvest during which it is made before and after the harvest, respectively.

Calculations was made using Quatro Pro 4.0.

Methods
Calibration.

Once the model was defined, a calibration was made using data reported by Thorbjarnarson (1990) in Hato Masaguaral over a period of time of five years (1985-1989) and unpublished data on Hato El Cedral over three years time (1990-1992). This calibration consisted of starting the model from data on the first survey for each case, using as parameters those reported by the literature.

By using the chi-squared test, the percentage of individuals for each size class obtained from the calibration was to compare data reported of both farms with data recorded of surveyed population.

Sensibility.

To determinate which population affect abundance and harvest, resulting of the model, the elasticity of the curve of abundance and harvest versus each parameter were calculated over a legth of time of twenty years by following equation $E = (Q/ P)*(P/Q)$ where Q and P represent the difference between the initial and final values of the abundance and the harvest; P and Q are the mean values calculated starting from the interval of assigned values at the analysis, maintaining constant values of resting parameters.

Simulation.

Starting from abundance and size structure of population reported of the first survey, the simulation was made over a length of time of twenty years only Hato El Cedral. The values defined at the calibration were used as those of the parameters.

Results.
Calibration.

Once the running of the model over five year for the Hato Masaguaral, one population consisted of 2002 individuals with size structure of 24,84% for class II, 56,99% for class III, and 18,17% for class IV was obtained. These percentages were compared with data reported by Thorbjarnarson (1990). Such data on a population of 2089 individuals are as follows: 23,7% for class II, 57,7% for class III and 18,7% for class IV. No significant difference was found both data (X^2=7,8E-2 $p<0.01$).

On the Hato El Cedral, one population consisted of 14339 individuals with size structure of 44,01% for class II, 38,33% for class III and 17,66% for class IV was obtained. These percentages were compared with the expected data of one population of 13375 as follows: 44,19% for class II, 38,12% for class III and 17,70% for class IV. No significant difference was found (X^2= 1,98E-3 $p<0.01$).

Sensibility.

In the sensibility analysis, parameters that most affect proportionally the abundance are the percentages of survival at classes III and II. It is expected so, because the number of reproductive females would be diminished when declined the survival at class III. Consequently, in the class II the number of individual to be recruited from the next class would be affected.

The survival to class III affects the harvest in a way proportional. An explanation to this that the number of individuals recruitable to class IV declines. The another variable that affects the harvest, but in a inversely proportional way is the stay at class II, what imply much more time to reach at the harvest size.

Simulation.

Harvesting to a fixed rate at class IV, it was tested that the number of individual diminish as a consequence of increasing the percentage of harvest. This is due to a greater numbers of individuals is harvested than those being recruited from class III, plus natural mortality.

Conclusions.

Each population of caiman has variables "under/with" its own values, these variables must be defined at the moment of running the simulation by the designed model.

The abundance of population is more proportionally sensible to changes at the survival values of class III and class II.

The harvest is more sensible to changes in a proportional way of the survival of class III and inversely proportional with regards to the stay at class II.

In the model, the optimum harvest is the sum of obtained harvest value plus natural mortality at given class, by which all individuals of the follwing class to be harvested will be recruited. In other words, individuals missed by natural mortality and harvested from the population must be equal the recruiting. Above or below this value would be over- or sub-estimated.

The model is useful, for it recognized changes that would be produced in the population of caiman, abundance and size structure as different strategies of management are used. It is so to predict the decisions to be made.

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Distribution and Relative Abundance of Alligator Nests in Louisiana Coastal Marshes

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ABSTRACT

Annual alligator (Alligator mississippiensis) nest counts were conducted in Louisiana coastal marshlands, 1970-1993. Distribution and relative abundance of nests according to geographic area, land ownership, and wetlands habitat type were projected from aerial transect data. Total coastwide marsh nest projections during 24 years ranged from a low of 6,700 to a high of 34,500. Coastwide nest production data demonstrated a highly significant increasing trend over time for 1970-1993, in conjunction with aggressive wild alligator and egg harvest programs. For the period 1984-93, highest nesting densities were located in southwest Louisiana marshes, which averaged 36.5 ha per nest. Nesting density in southeastern Louisiana coastal marshes averaged 51.9 ha per nest. Nest production was highest in intermediate marsh (31.5 ha per nest), second in fresh marsh (45.4 ha per nest), and lowest in brackish marsh (59.0 ha per nest). Total transect coverage was gradually increased during the 24 years of study to a maximum of 2.2%. Helicopter rental costs, flight speed capability, helicopter refueling logistics, personnel time budgets, and the brief annual time window within which nesting trend data were phased into administrative and management functions of the total alligator program were important considerations which limited sample size. Surface water conditions affected nesting potential more than any other environmental factor but water level factors demonstrated little effect on the mean trends generated over 24 years.

Introduction

The alligator inhabits Louisiana's river and bayou systems, lakes, swamps, and marshes. Coastal marshlands (1.23 million ha) provide the best alligator habitat in the state and contain the bulk of the statewide population. The marsh alligator population can be censused by aerial nest inventory (Chabreck 1966, Joanen and McNease 1972, McNease and Joanen 1978). This report presents nesting trend data for 24 years and shows how habitat can be subdivided, quantified, and qualified relative to alligator abundance. Our aerial census data formed the data base for formulating guidelines governing a closely regulated alligator harvest, 1972-1993, and wild egg collections from private wetlands, 1986-1993.

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Methods and Materials

Aerial nest censuses were conducted annually in early July, 1970-93 in the coastal marshes of the southernmost part of the state. Alligator nests were counted from a helicopter flying permanently established transect lines. A Bell Model 47G4A was used from 1970 through 1978 and since 1979 a Bell Jet Ranger Model 206B was used. Transect lines (N=39), established for a 1968 vegetative type-map salinity study (Chabreck et al. 1968), were used for this investigation with additional lines being added between the 'bench mark' lines. Sampling intensity was greater in southwest Louisiana during the 1970's because an experimental harvest program began there in 1972 and also because population levels were higher than in southeast Louisiana. Census lines were simply north-south transects (longitude lines) which by 1982 were spaced to give the sampling intensity presented in Table 1. Each line extended from the marsh-swamp demarcation to a cutoff point in brackish marshes where nesting did not occur.

Total transect coverage (sampling intensity) was gradually increased during the beginning 13 years of study to a maximum of 2.2% annually for 1982-1993 (Table 1). Sampling intensity in 1970-71 amounted to 0.76% for 1.3 million ha of coastal marsh. Personnel time budgets, the brief annual time window within which nesting trend data were phased into administrative and management functions of the total alligator program, and helicopter rental costs, flight speed capability, and refueling logistics were important considerations which limited sample size.

A flight speed of 100 km/h, altitude of 60 m, and transect line width of 105 m were chosen as optimum, considering sample size and nest perceptibility. Nests observed within the 105 m sample area were recorded according to parish (county), marsh type, land ownership, and line number designation. In order to reduce sampling bias, 3 observers did all nest counting during the 24 year study (11, 10, and 3 years per observer). The availability of navigational aids were rather limited for the years 1970-1980; consequently a record keeper/navigator followed the transect line course with the aid of a compass and charted landmarks. During 1981-92, the Loran C navigation system was an indispensable aid for tracking lines. In 1993, the Global Positioning System (GPS) navigation system was incorporated into the nest survey.

The marsh zone and vegetative type classifications as described by Chabreck (1970), Chabreck, et al. (1968), Chabreck and Linscombe (1978 and 1988) were used for ecological aspects of the project. For management purposes, the Sub-Delta and Active Delta Zones were combined into a Southeast Coastal Zone. This classification scheme formed the basis for qualitative and quantitative habitat-nest density analyses.

Coastal marsh habitat degradation occurred during the past 24 years. In 1970, 1,298,485 ha of marsh habitat were utilized for alligator nesting (Chabreck 1970); whereas, in 1993 nesting habitat was calculated to be 1,231,429 ha (Chabreck and Linscombe, 1988). Due to geologic origin this vast area was divided into: the Southwest Coastal and Southeast Coastal Zones (Fig. 1). The Southwest Coastal Zone presently makes up 457,735 ha of which 352,157 ha is privately owned and 105,578 ha is under public ownership (Table 1). The Southeast Coastal Zone presently comprises 773,694 ha and extends from the Vermilion Bay complex to the Mississippi-Louisiana border (Table 1). Private ownership makes up 86% of the southeast zone or 662,894 ha (110,800 ha are publicly owned).

The vegetative types of brackish, intermediate, and fresh were used for purposes of marsh classification (Chabreck 1970). Generally the brackish marsh was located nearer the Gulf of Mexico and experienced higher salinity levels than did the other two types. The brackish marsh, minus marshes over 10 ppt salinity, comprised 37% or 0.48 million ha in 1970 and 37% or 457,007 ha in 1993. The intermediate marsh generally was a band separating fresh from brackish. The intermediate marsh comprised 22% or 0.28 million ha in 1970 and 23% or 284,055 ha in 1993. Fresh marshes lie farther inland and are not usually affected by tidal action. The fresh marsh made up 41% of the area (0.53 million ha) in 1970 and 40% or 490,448 ha in 1993 included in our survey (Chabreck and Linscombe 1988). Alligators do not utilize the saline marsh type; hence, the 0.4 million ha of this type were disregarded. Coastal marshes comprise about 70% of statewide wetlands inhabited by alligators and therefore are vital to Louisiana's alligator management program (Joanen et al. 1984, Joanen and McNease 1987). Approximately 91% of the wild alligators harvested (1972-1993) and 87% of wild eggs harvested (1987-1993) came out of the coastal zone.

A data entry and manipulation software package entitled "Paradox" by Borland, Inc. was utilized for summary and analysis of the nest survey data. A supporting data base, which does not change annually, contains information related to land ownership, and total area and ha transected by marsh type and management unit. Nest survey results are entered annually. Data analysis involved the simple computation of transected nest density figures and the extrapolation of these data according to distinct geographic areas (16 coastal parishes) which then became the basic coastal marsh alligator management units. The number of nests transected by marsh type, land ownership, parish, and region of the state (zone) were converted to area (# ha) per nest [a two part computation involved: (1) length of transect line segment according to marsh type and ownership X width of transect coverage = number ha transected, and (2) number ha transected ÷ by number nests observed in transect sample = ha/nest]. For management purposes, especially wild harvest of eggs and alligators, the ha/nest figure could then be divided into total size of each individual management unit to derive an estimate of total nests and nesting females.

The key element upon which to base harvest quotas then became the number of nests projected by habitat type within management units. Due to considerable variability in single year nest estimates, especially on isolated wetlands; for example, privately owned brackish marsh in a particular parish, a moving average of the most recent 5 years nest number projections provided a 'stabilized data base'. This average could then be compared to current year data for making final 'adjusted harvest determinations', expressed as ha/nest. In the case of the ranching program, a reasonable estimate of total egg production on a landowner's marsh can be developed by dividing ha per marsh type by the adjusted harvest determination figure (ha/nest) for that type and then multiplying that answer (# nests) by the projected number of fertile eggs per clutch. Practical application of the 'stabilized data base' nest projections to derive wild alligator harvest quotas involved using the number of nesting females per management unit and applying these data to a nest multiplier to extrapolate total numbers of alligators per unit (Chabreck 1966, McNease and Joanen 1978, Taylor and Neal 1984, Taylor et al. 1991). Size class frequency distribution modeling of a population can then be used to estimate targeted harvest percentage (quotas) which are then applied against the extrapolated numbers of alligators per management unit.

Regression analysis was used to evaluate trends (1984-1993) in estimated statewide nest production and nest densities by habitat type within each coastal zone (Steel and Torrie 1960). We expressed alligator nest densities and available habitat as a percentage function to more graphically point out the quantity and quality of the different habitat types.

Results and Discussion

Environmental Factors Affecting Nesting.

Ambient temperatures affect the timing of nesting and egg laying activity (Joanen and McNease 1979). During years with warm springtime air temperatures, egg laying was completed by the end of June; whereas, laying extended into the second week of July during years with cooler springs. This factor must be taken into account when establishing flight times for nest censusing, to insure that all nests are built prior to initiation of the census.

Extremes in water levels, drought and flooding, adversely affect nesting of the alligator (Joanen and McNease 1972, McNease and Joanen 1978). Surface water conditions affected nesting potential more than any other environmental factor but water level factors demonstrated little effect on the mean trends generated over 24 years (Fig. 2). Therefore, extreme caution should be exercised in interpreting nest transect data on an annual basis (long term trend data is better), or for relatively small geographic units.

Surface water salinity influences alligator nesting potential. Nesting was not observed in areas characterized by salinities >10 ppt, therefore these areas are not surveyed.

Nest Projections by Year.

Total coastwide marsh nest projections during 24 years ranged from a low of 6,700 to a high of 34,500 (Fig. 2). The dramatic jump in numbers of nests over time amounted to a 300% increase; or, on average 13% per year. Coastwide nest production data demonstrated a highly significant increasing trend over time for 1970-1993 (R^2 = 0.8640, P = 0.0001), in conjunction with aggressive wild alligator and egg harvest programs. During the past 7 years (1987-1993), 930,000 wild eggs were collected from marshes for ranching purposes and since 1972 approximately 327,000 wild alligators were harvested. These data demonstrate that a reliable index of annual reproductive success can be achieved which will form the basis for: long-term population dynamics study, calculating wild alligator harvest quotas, calculating wild egg collection quotas, and computing/refining juvenile returns to the wild compensation rate percentages for wild egg collections.

Nest Densities and Distribution by Zone.

A comparison of the 10-year average nesting density (1984-1993) by marsh zone showed the Southwest Zone had the highest nest density of 36.5 ha per nest (Table 2). This zone comprises 37.2% of coastal marshlands and produced a disproportionally high 46.5% of the coastwide estimated nests. The Southeast Zone accounted for 62.8% of Louisiana's marshes and contained 53.5% of total coastal nests. The Southeast Zone nest density averaged 51.9 ha per nest (Table 2).

In the Southwest Coastal Zone, annual nest density during 1984-1993 improved (R^2=0.58, P=0.01) for brackish marsh but remained stable for intermediate and fresh marsh (Fig. 3). In the Southeast Coastal Zone, annual nest density decreased for brackish marsh and progressively increased for intermediate and fresh marsh (Fig. 4). The intermediate and fresh marshes of Louisiana's coastal wetlands provided stable high quality alligator habitat. Brackish marshes in the Southeast Coastal Zone suffer from subsidence, salt water intrusion and storm damage resulting in deteriorating habitat conditions which act to decrease nest density.

During two early years of study, the Southwest Zone comprised 34.9% of marsh habitat and contained on average 60.6% of coastal nests and the Southeast Zone made up 65.1% of habitat and housed 39.4% of nests (McNease and Joanen 1978). In general, the long-term nest density outlook for Southeast Zone fresh and intermediate marshes has been to gradually 'catch-up' with those in the southwest. This became especially significant in 1992 and 1993 (Table 2).

Nest Densities by Marsh Type.

On a coastwide basis, the intermediate marsh type demonstrated the highest 10 year average nest density, 1 nest to 31.5 ha, comprised 23.1% of coastal marshlands and contained 32.8% of nests (Table 2). Fresh marsh averaged 1 nest to 45.4 ha, made up 39.8% of the area and accounted for

40.9% of nests. Brackish marsh averaged 1 nest to 59.0 ha for the period 1984-1993 (Table 2), occupied 37.1% of the area and carried 26.3% of total nests. Average nest density according to marsh type for 1992 and 1993 are compared to the 10 year average in Table 2. These data showed the same general trend in nest productivity as did the 10-year average except that with time nest densities improved (ha per nest decreased).

A comparison of nest densities by marsh type according to zone revealed some striking improvements in nest production for the fresh and intermediate types in the Southeast Zone during the past 10 years (Table 2) when compared to 1970's data (McNease and Joanen 1978). The 10-year average nest density for fresh marsh was equal at 45 ha per nest in each marsh zone. For intermediate, the Southwest Zone was better and averaged 26 ha per nest in comparison to 38 for the Southeast. Brackish nest production was two times better in the Southwest Zone (40 ha/nest) than in the Southeast (82 ha/nest). In 1992 and 1993, nest production in fresh marsh was better in the Southeast Zone than the Southwest (Table 2). Intermediate nesting densities were equal for each zone in 1992 (24 ha/nest) and slightly superior in the Southwest in 1993 (30 ha vs. 34 ha per nest). Brackish marsh nest production was far superior in the Southwest Zone; 30 and 39 ha/nest in 1992 and 1993 respectively as compared to the Southeast (70 and 88 ha/nest in 1992 and 1993).

Nest Densities According to Land Ownership.

A comparison of nest densities by ownership according to zone revealed that highest nesting densities occurred on publicly owned marshes in the Southwest Zone where densities averaged 21.3, 23.4, and 23.6 ha per nest for 1992, 1993 and the 10 year average, respectively (Table 3). Privately-owned marshes in southwest Louisiana came in second best at 37.2 ha/nest in 1992, 48.0 ha/nest in 1993, and 45.7 ha per nest for the 10 year average. Southeast private property occupied third place at 36.8, 43.4, and 54.1 ha per nest respectively for 1992, 1993, and the 10 year average. Southeast publicly owned marsh occupied last place with values of 44.2, 61.2, and 45.4 ha/nest for 1992, 1993, and the 10 year average.

A direct comparison of marsh type and ownership vs. nest density according to zone is expressed in the two columns under the 10 year average heading in Table 3. A superior nest density is indicated where the percent of nests value exceeds the percent of land value (designated by a '+' in the percent of nests column). Percent of nests occurrence in the Southwest Zone private intermediate marsh and all three marsh types under public ownership were projected to occur at a rate higher than the percent of land availability value. Percent of nests occurrence in the Southeast Zone privately-owned fresh and intermediate and public intermediate and brackish were projected to occur at a rate higher than the percent of land availability value. Southeast public fresh marsh percent of nests equaled the percent of land value.

In summary, the subtotal values in Table 3 indicate the occurrence of nesting in southwest privately owned marshes occurred at a rate just slightly above the percent of land availability value on the strength of strong intermediate marsh nesting densities. The occurrence of nesting in southeast privately owned marshes occurred at a rate significantly below the percent of land availability value due to low brackish marsh nesting densities. The occurrence of nesting in southwest public marshes occurred at a rate double that of the land availability value. Southeast public marshes percent of land availability and percent of nests values were about equal.

Seventy-seven percent of coastal alligator nest production was calculated to be on privately owned lands in 1993 as compared to 75% for the 10 year average, 1984-1993 or 63.5% average for 1970 and 1977 (McNease and Joanen 1978). The approximately 25% located on publicly owned lands were all on state and federal refuges, or state-owned wildlife management areas. Management implications inherent in Louisiana's coastal land ownership scheme are obvious; private landowners control the majority of alligator habitat and alligators. Management programs must be designed with the private sector foremost in mind, as they hold the key to the well-being of our marsh resources. The catalyst for Louisiana's rapidly expanding alligator farming program has been the availability of wild produced eggs on privately owned property and the willingness of private landowners to pioneer a fledgling industry.

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TABLE 1. Louisiana coastal marsh alligator habitat data (ha) and nest survey sampling intensity (%), 1982-1993.

Habitat Type	Southwest Coastal		Southeast Coastal	
	Public	Private	Public	Private
Fresh	27,798 (2.6)	115,244 (2.4)	50,191 (3.2)	297,215 (2.0)
Intermediate	17,215 (2.7)	123,562 (2.3)	22,665 (1.7)	120,532 (1.9)
Brackish	60,565 (2.6)	113,351 (1.9)	37,944 (5.3)	245,147 (1.7)
Total	105,578 (2.6)	352,157 (2.1)	110,800 (3.6)	662,894 (1.9)

TABLE 2. Louisiana coastal marsh alligator nest density projections based on marsh type (ownership combined); a comparison of 1992 and 1993 data to the average for 1984-1993.

Marsh Zone	Marsh Type	Size (ha)	Average Nest Density (ha per Nest) 1992	1993	1984-1993
Southwest	Fresh	143,042	45.0	48.7	45.1
Southwest	Intermediate	140,777	24.1	29.7	26.2
Southwest	Brackish	173,916	30.2	38.6	40.1
Southwest	Total/Ave.	457,735	31.1	37.7	36.5
Southeast	Fresh	347,406	33.2	37.2	45.6
Southeast	Intermediate	143,197	23.9	34.2	37.6
Southeast	Brackish	283,091	70.1	88.1	81.9
Southeast	Total/Ave.	773,694	38.4	46.7	51.9
Coastal Zone	Fresh	490,448	36.2	40.2	45.4
Coastal Zone	Intermediate	283,974	24.0	31.5	31.5
Coastal Zone	Brackish	457,007	46.8	59.3	59.0
Coastal Zone	Grand Total/Ave.	1,231,429	35.2	42.7	44.7

TABLE 3. Louisiana alligator nest density projections based on ownership and marsh type; a comparison of 1992 and 1993 data to the average for 1984-1993.

			Average Nest Density (ha per Nest)			10 Year Average	
Marsh Zone	Ownership	Marsh Type	1992	1993	1984-93	% of Nests	% of Land
Southwest	Private	Fresh	54.6	61.9	*56.2	7.7-	9.4
Southwest	Private	Intermediate	27.3	34.6	**31.8	14.6+	10.0
Southwest	Private	Brackish	40.0	61.6	**53.3	8.0-	9.2
Southwest	Private	Sub-Total	37.2	48.0	45.7	30.3+	28.6
Southeast	Private	Fresh	32.7	35.3	*45.5	24.5+	24.1
Southeast	Private	Intermediate	22.7	33.5	**36.2	12.5+	9.8
Southeast	Private	Brackish	77.2	85.0	**127.1	7.3-	19.9
Southeast	Private	Sub-Total	36.8	43.4	54.1	44.3-	53.8
Southwest	Public	Fresh	26.8	26.8	*23.1	4.6+	2.3
Southwest	Public	Intermediate	13.8	15.7	*16.9	3.8+	1.4
Southwest	Public	Brackish	22.6	25.5	**29.1	7.8+	4.9
Southwest	Public	Sub-Total	21.3	23.4	23.6	16.2+	8.6
Southeast	Public	Fresh	35.3	46.7	*46.2	4.1=	4.1
Southeast	Public	Intermediate	35.3	38.9	*46.1	1.9+	1.8
Southeast	Public	Brackish	58.8	95.3	**44.7	3.2+	3.1
Southeast	Public	Sub-Total	44.2	61.2	45.4	9.2+	9.0

*No significant difference
**Significant difference

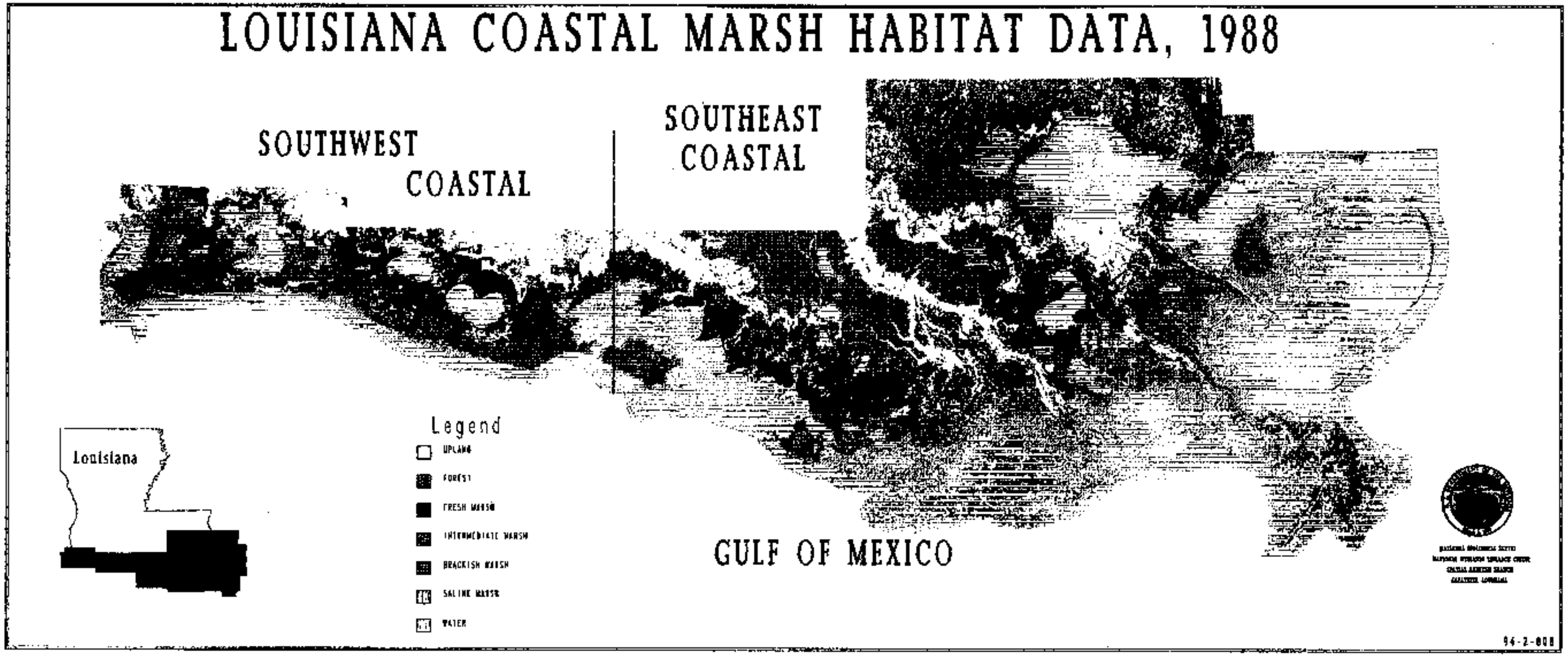

Fig. 1 Vegetative type map of Louisiana coastal marshes (Chabreck and Linscombe 1988).

SURVEY OF THE STATUS OF THE CROCODILIANS OF NICARAGUA

A REPORT FROM

BIODIVERSITY SERVICES, INC.,

TO THE

INSTITUTO NICARAGUENSE DE RECURSOS NATURALES Y DEL AMBIENTE

AND THE

SECRETARIAT OF THE CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES

OF WILD FAUNA AND FLORA

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INTRODUCTION. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), administered by the United Nations Environment Programme, has the responsibility of regulating international trade in wildlife in a manner that it does not endanger or deplete the exploited populations of wild plants and animals. This is accomplished in part by supporting scientifically grounded and rigorously implemented programs that utilize wildlife on a fully sustainable basis. One of the best examples of how legal, sustainable use can benefit a wildlife species is seen in the crocodilians.

Historically, the world's 24 species of alligators, caimans, crocodiles, and gharials have been treated as toothy predators that attack man and livestock and therefore should be eliminated at every opportunity, or they have been viewed as a ready source of a skin that is used to produce a high fashion leather. The combination of being killed as vermin or slaughtered for their hides depleted or endangered virtually every species of crocodilian by the end of the 1960's. Hunting prohibitions and bans on trade allowed many populations to recover, but the single greatest factor in gaining governmental and public support for crocodilian conservation was the establishment of scientifically grounded, carefully implemented, and rigorously enforced programs that can supply legal crocodilians and crocodilian products to the marketplace on a sustainable basis.

These sustainable utilization programs usually produce crocodilians from one of three methods: 1) either harvesting them direct from the wild, or 2) harvesting eggs or hatchlings from the wild and rearing them in captivity for later use (this open-cycle operation that depends on a healthy wild population to provide eggs or hatchlings is called 'ranching'), or 3) rearing them from eggs produced from the captive mating of adult crocodilians (closed-cycle 'farming'). Unless carefully implemented, harvest direct from the wild has the potential of depleting the wild stocks as happened in the 1960's, especially if the harvest removes breeding females, and farming does little directly to protect the wild crocodilians or their habitats apart from providing legal competition to the suppliers of illegal hides. Of the three methods, ranching has the greatest conservation impact because to be successful the wild populations and their habitats must be protected. Without that protection there will be no breeders to produce the eggs or hatchlings needed by the ranches. In addition, in the wild a relatively high percentage of eggs and hatchlings are lost to predators, disease, and other natural factors, often resulting in a combined loss of more a than 70% in the first year. In captivity the loss can be significantly reduced, frequently to less than 10% total. The difference between the numbers that would have been lost if the eggs or hatchlings had remained in the wild and the increased numbers that survive in captivity can be harvested with no negative impact on the wild populations. For this reason, collecting eggs and hatchlings has less of an impact on the wild population than does the direct removal of adult breeders. Even so, ranchers often are required to return a small percentage of their yearlings to the wild to compensate for the ones that would have survived in the wild had the eggs not been collected.

Today, roughly two-thirds of the world's crocodilians have recovered sufficiently that they are no longer in immediate danger of extinction, and eight species are harvested in sustainable utilization programs that meet the requirements of CITES. Hides from these legal sources are used in the manufacture of high quality, high fashion leathergoods—wallets, purses, handbags, belts, shoes, boots, cosmetics cases, pocket secretaries, key cases, watch bands, attaché cases, and luggage. In many countries these sources also provide a high protein, low saturated fat, low cholesterol meat for human consumption.

In 1992, the IUCN/SSC Crocodile Specialist Group published the Action Plan for the Conservation of Crocodiles which documents the conservation status of all the species of crocodilians and the importance of sustainable use to that conservation. It also summarizes the general biology of crocodilians which provides the foundation of every sustainable utilization program. This publication is available from the IUCN–The World Conservation Union Publications Unit, 219c Huntington Road, Cambridge CD3 0DL, United Kingdom.

No sustainable utilization program can long continue without monitoring the status of the wild populations. If the populations are remaining stable or are increasing, the program is a success. If they are declining, the program must be adjusted to allow the populations to recover.

Historically, Nicaragua has been one of the largest suppliers of crocodilian hides from Central America, but no systematic survey had been done to determine the size of the wild populations. In the late 1980's, the CITES Secretariat began discussions with the staff of the Instituto Nicaraguense de Recursos Naturales y del Ambiente (IRENA) concerning the desirability of surveying Nicaragua's two species of crocodilians: *Caiman crocodilus chiapasius*, the Central American caiman (English common name), cuajipal (local Spanish name), crocodile (Atlantic coast Creole name), or tura (Miskito Indian name), and *Crocodylus acutus*, the American crocodile (English), lagarto (Spanish), alligator (Atlantic coast Creole), or karas (Miskito).

Preliminary plans for the survey were drawn up by the CITES Secretariat and reviewed by IRENA. In May 1991, at the request of the CITES Secretariat, Professor King met in Managua with the officials in IRENA's CITES Scientific Authority and Fauna Silvestre offices to finalize the plans. A second meeting in Managua took place in May 1992, between Dr. Ross and Orlando Gomez and Gutemberg Castro of IRENA to confirm details of the final plan. On 18 August 1992, the CITES Secretariat contracted with Prof. King and Biodiversity Services, Inc., to conduct the survey. The actual project was initiated on 25 January 1993, with the arrival of Dr. Ross in Nicaragua at the end of the rainy season. Prof. King arrived 5 days later.

In this report, we summarize our activities and results of the first phase fieldwork in the period 25 January-5 March. A full report, including detailed recommendations, will be prepared when fieldwork is complete.

ACKNOWLEDGMENTS. The survey was funded by the CITES Secretariat in Lausanne, Switzerland, by NORAD, and by Reptiles de Nicaragua—special thanks are due Dr. Obdulio Menghi, Scientific Coordinator of CITES; Desiree Elizondo C., Asesora in NORAD's Managua office; and Kurt Preiss of Miami, Florida, and Granada, Nicaragua, without whose administrative or financial support this survey would have been impossible. We are pleased to acknowledge the support of Dr. Jaime Incer, Minister for Natural Resources, and his Vice Minister, Mr. Patricio Jerez.

If one individual deserves special recognition it is Carlos Morales, Jefe (Head) of IRENA's CITES Nicaragua Office, who managed to cut through the bureaucratic maze and arrange logistical support for us from IRENA's many regional offices.

We thank the staff of the IRENA field offices for their extensive assistance in arranging boats, fuel, drivers, and other logistical support. In Puerto Cabezas, Mr. Rodolpho Jaenschke and Fatima Castillo; in Bluefields, Mr. Elmer Jackson and Mr. Raoul Castillo; in San Carlos, Mr. Lionel Ubao, Lic. Julien Pobreda and Mr. Joaquin Montiel. We must also thank the guides and boat drivers, Christopher Bodin, German Hernandez, Felix Guadamuzand, and Silvio Leon, who enabled us to travel many hundreds of kilometers by boat into some of the more remote locations in Nicaragua and ensured our safety, and often, our comfort as well.

We also acknowledge the support readily given by the Mikupia office in Puerto Cabezas, and especially by Denise Castro, who accompanied us in the field and introduced us to many Miskito communities and individuals.

Mr. Juan Sequeira, manager of the Reptiles de Nicaragua tannery in Granada, and Dr. Alvaro Valenzuela, of Nueva Era, provided logistical support in San Carlos and the Pacific coast, respectively. They also demonstrated marvelous hospitality by welcoming us into their homes.

In an enthusiastic demonstration of camaraderie and regional coordination, Lic. Earl Junier Wade, Servicio de Vida Silvestre, Ministerio de Recursos Naturales, Energía y Minas, Costa Rica, joined us for surveys of the Río San Juan and tributaries flowing out of Costa Rica. Ms. Terhi Wermundsen, a Danish biologist working in IRENA's National Parks office, accompanied us on the Pacific coast surveys at Salinas Grandes and Puerto Sandino.

Finally, numerous citizens of Nicaragua extended myriad courtesies to us in the course of the fieldwork, often with little or no introduction. We regret that there is insufficient space to acknowledge them all by name.

METHODS. The survey methods for systematic and repeatable night spotlight censusing of crocodile populations are described in Messel *et al* 1981, and summarized and discussed in Bayliss 1987 and Graham 1987. Refer to these publications for details of the survey methods.

An estimation of the density of crocodilian populations was obtained by traveling representative sample sections of waterways at night and counting the crocodilians sighted with a spotlight. Where possible, an estimate was made of the size of the individuals sighted from which size distribution of the population can be estimated. It is not expected that all the crocodilians in an area will be sighted and counted in such brief sample surveys. However, extensive repetitive sampling by Professor Messel and colleagues in Australia (involving thousands of such surveys over a period of 11 years) has established a very sound statistical basis from which the results of single night spotlight counts can be interpreted with confidence. A strict protocol of procedures to conduct such surveys, developed by Professor Messel, is followed. By following the procedure exactly, the results can be compared with similar survey results in other places and interpreted with confidence. Comparisons between locations and between different sample periods can also be made.

This technique has been used in crocodilian surveys in numerous countries involving several different species. In several studies additional repetitive sampling, and population estimation by other techniques such as mark and recapture studies, confirm the validity of the results of single night spotlight surveys. The technique has been widely applied to the quantitative survey of crocodilian populations in Latin America, e.g., Honduras (King *et al* 1990), Venezuela (Gorzula and Seijas 1989), Guyana (Gorzula and Woolford 1990), Argentina (Waller and Micucci 1993), Bolivia (Pacheco 1993), Costa Rica (Mahmood and Chaves 1992), Haiti (Thorbjarnarson 1988), and elsewhere in the world (see Bayliss 1987). Of particular relevance to this survey is work conducted in Venezuela (Thorbjarnarson 1991), which confirmed the validity of the technique for *Caiman crocodilus* in habitats similar to those in Nicaragua.

The essential elements of the procedure are that careful note is made of the exact position of start and end points of each survey and of the distance surveyed, and these are reported in subsequent publications so the surveys can be duplicated by independent researchers. Physical variables are recorded such as wind, tide or water level, vegetation, water and air temperature, which are known to affect the proportion of crocodilians sighted. Surveys are conducted at high speed to cover distances of 20-50 km in a night after preliminary reconnaissance has been made of the waterway in daylight to identify hazards and verify positions and distances.

The 1:50,000 series of topographic maps produced by the Instituto Nicaraguense de Estudios Territoriales (INETER) were used throughout these surveys. A majority of these maps were first produced in 1987, and a several were revised in 1988 and 1989. This series of maps is superb for the accuracy of the information they provide on the waterways and surrounding vegetation communities. All map sheets referred to below are in this series. Accurate latitudes and longitudes of start and end (finish) points for the majority of the individual surveys were determined using a Magellan GPS NAV 1000 PRO. When two teams surveyed separate waterways concurrently on the same night, one of the surveys had to be done without the Magellan GPS. When this occurred, the start and end point latitudes and longitudes on the survey without GPS instrumentation were determined directly from the INETER maps. It should be noted that all the margins of this series of maps are printed with degree, minute, and second scales that allow latitude and longitude to be read accurately, without interpolation, and with great ease. The distances covered were measured using the km scale on the maps. Water salinities were documented using a Reichart temperature compensated salinity refractometer. Wind speed was determined using a Davis Instruments Wind Wizard. Temperatures were recorded using a Cole Parmer Model 90200-30 electrical thermometer with a 1 m external probe. Spotlight surveys were run using a Brinkmann Q-Beam 1,000,000 candlepower spotlight powered by a 12-volt automobile battery, and 6-cell Mag-Lites provided back up lights when the Q-Beams failed. Laptop computers and portable printers allowed rapid data analysis and production of the progress report.

Original field data records of the surveys are stored in the files of the IRENA CITES Nicaragua office, and of the IUCN/SSC Crocodile Specialist Group and Biodiversity Services, Inc.

The survey was conducted in February and March 1993, which is the dry season in Nicaragua. Surveying during the summer rainy months is virtually impossible. Many rivers are in flood and inundate surrounding lowlands and caiman populations may be highly dispersed and inaccessible. Torrential rains also obscure the spotlight beam making sighting difficult. By February, the floods have begun to subside and the rivers return to their banks and nighttime rains are less frequent.

On 3 and 4 February 1993, aerial reconnaissance of habitat was flown from Puerto Cabezas north to the Coco river that forms Nicaragua's northern border with Honduras, west to the mountains, and south to Laguna de Perlas and most major rivers and wetlands in between. Aircraft (a Cessna Skymaster, topwing) and pilots were made available to the survey by Lighthawk Inc., a non-profit NGO that provides air survey support to conservation projects. Flight paths were planned along major rivers and significant wetland areas. These were inspected at approximately 1000' (360 m) elevation for habitat suitability, human settlement density, and accessibility. From this information, representative, accessible locations for night spotlight surveys were identified. A total of 10 hours was spent flying more than 2,000 km of habitat transects.

Riverine waterways were surveyed from an upstream start point, usually determined by rocks, logs, or other obstruction that prevented further passage upstream, to a downstream zero end point, usually at the mouth of the river. Lagoons were surveyed around their perimeter from a zero starting point on the shore and ended back at that same point. However, to survey the entire length of the larger Nicaraguan rivers would have required weeks, an impossible undertaking because of limited time, and an undesirable one because large stretches of many rivers are heavily settled with the result that the crocodilians and their habitats are gone. The surveys reported here are not meant to be an exhaustive catalogue of all of Nicaragua's crocodilian populations, rather they are a representative sample of those populations.

The IRENA regional offices served as our fieldbases in Puerto Cabezas during the period 2-12 February; in Bluefields during 14-19 February; and in San Carlos during 22-27 February (see Figure 1). During 28 February-4 March, we operated out of the IRENA national office in Managua. Following the return of the CITES coordinators (F. Wayne King and J. Perran Ross) to the U.S.A. on 5 March 1993, subsequent surveys were conducted by IRENA personnel (Jose V. Morales and D. Gutierrez).

RESULTS. Table 1 summarizes the fieldwork.

Table 1. Summary of Activities

Survey nights	19
Surveys[a]	33
Localities surveyed[b]	28
Kilometers of waterway surveyed	529
Crocodilians sighted:	
Caiman crocodilus chiapasius	1,160 in 413.6 km
Crocodylus acutus	69 in 115.7 km

[a] For convenience of analysis some surveys conducted on a single night were subdivided to reflect different localities and habitats, e.g., we separated the freshwater Wark Wark river from the saline Lamlaya lagoon.

[b] Some localities were surveyed on more than one night.

Our findings are presented and discussed for each of the general survey areas:

PUERTO CABEZAS AREA

1. Wark Wark River to Lamlaya.

Map sheets Puerto Cabezas 3558-III, Wawa 3557-IV, Klingna 3457-I, and Haulover 3457-II were used for this survey. On the nights of 3 February 1993, 48.5 km of waterways were surveyed between the upstream starting point on the Wark Wark river, the Estrecho Pika Bila, passage across Laguna Karata, the lower end of the Wawa river, through Laguna Kauhru Pura, Laguna TumTum, the Lamlaya river and canal, and ending at the public docks in Lamlaya. The same waterways and exact same route was resurveyed on 4 February 1993.

	Latitude	Longitude
Wark Wark upstream starting point	13°49'30" N	83°38'52" W
Estrecho Pika Bila	13°56'51" N	83°29'53" W
Lamlaya Village public dock and end point	14°01'24" N	83°25'27" W

This series of waterways appears to be good habitat. The salinity of the water varies from fresh (salinity 0 ‰) in Wark Wark and Lamlaya rivers to very slightly brackish (salinity 3‰) in Laguna Karata and the mouth of Estrecho Pika Bila and brackish (salinity 12‰) in Laguna Kauhru Pura. All but the upper reaches of the Wark Wark are fringed by *Rhizophora* mangroves, which is suggestive of a saline habitat. Despite the fact that Laguna Karata opens to the Caribbean Sea through the Barra de Wawa (Wawa Bar), at least eight freshwater rivers drain into this series of coastal lagoons, so the surface water probably is a freshwater lens floating on top of a heavier saltwater layer. There is considerable boat traffic along the survey route. Lamlaya is Puerto Cabezas's public dock and access to inland waterways. While sea-going freighters and trawlers can tie up at the wharf on the beach at Puerto Cabezas, smaller craft dock at Lamlaya, even those that haul goods to villages up and down the coast. All these vessels pass through Barra de Wawa. A sizable village is located at Barra de Wawa, and there are farms along the Wark Wark river.

DISTANCES COVERED

Waterway	km
Lamlaya canal and river and Laguna Tum Tum	6.5
Laguna Kauhru Pura	4.0
Wawa river	3.0
Laguna Karata crossing	2.75
Estrecho Pika Bila	1.0
Wark Wark river	31.25
Total km surveyed	48.5

The distances recorded for the lagoons are midline distances, not the usual shoreline perimeter distances. Shallow mudbars, stranded logs and imbedded tree snags prevented us from surveying the western shores of Laguna Tum Tum and Laguna Kauhru Pura. Size alone prevented us from surveying Laguna Karata in the time available, so it was crossed in a straight line from the mouth of the Wawa river to the south entrance of Estrecho Pika Bila.

On 3 February 1993, a total of 23 *Caiman crocodilus chiapasius* sighted were in the following size classes: 0 (Hatchlings), 4 (2-3'), 7 (3-4'), 8 (4-5'), 3 (5-6') and 1 (Eyes Only). No *Crocodylus acutus* was detected.

On 4 February 1993, a total of 12 *Caiman crocodilus chiapasius* were sighted: 1 (Hatchling), 6 (2-3'), 2 (3-4'), 1 (4-5') and 2 (Eyes Only). No *Crocodylus acutus* was detected.

2. Bambana River.

Map sheets Río Prinzipolka 3456-III and Lagunas Narlaya 3456-IV were used for this survey. On the night of 6 February 1993, 33.8 km of this river were surveyed from the upstream start point to its confluence with the Prinzipolka River. The upstream terminus was selected arbitrarily because of the time available, not because the river was impassable at that point.

	Latitude	Longitude
Bambana River upstream start point at km 83	13°35'40" N	83°54'51" W
Bambana River end point at confluence with Prinzipolka River at km 49.2	13°27'18" N	83°49'45" W

The Bambana river is a sizable freshwater river (salinity 0‰) surrounded on its lower stretches by adjacent lagoons and marshes. The river itself is not prime caiman habitat solely because its lateritic banks are steep (almost vertical), from 2 to 4 meters high; and offer little in the way of cover. The tops of the banks are covered with gallery forest and bamboo. The lower portions of the bank are devoid of vegetation. There are relatively few logs or brush piles.

DISTANCES COVERED

Waterway	km
Bambana River	33.8
Total km surveyed	33.8

A total of 6 *Caiman crocodilus chiapasius* were seen in the following size classes: 2 (Hatchling), 2 (3-4'), 1 (4-5'). No *Crocodylus acutus* was detected.

3. Laguna Narlaya, Narlaya Bila River, and lower Bambana River.

Map sheets Río Prinzipolka 3456-III and Lagunas Narlaya 3456-IV were used for this survey. On the night of 7 February 1993, 22.6 km of river and lagoon perimeter shoreline were surveyed from the start point in the headwaters of the Narlaya Bila river in a seasonally flooded lagoon with no in-flowing upstream channel, downriver to the Narlaya lagoon, then around the entire lagoon perimeter, and then on down the Narlaya Bila river to the end point at its confluence with the Bambana river, and then down the Bambana river to its confluence with the Prinzipolka river.

	Latitude	Longitude
Narlaya Bila River upstream start point at km 66	13°30'31" N	83°55'42" W
Laguna Narlaya outlet to the Narlaya Bila river at km 60.8	13°30'34" N	83°53'13" W
Narlaya Bila River confluence with Bambana River at km 55.2	13°29'09" N	83°51'05" W
Bambana River end point at confluence with Prinzipolka River at km 49.2	13°27'18" N	83°49'45" W

The Narlaya lagoons are energy-rich, permanent freshwater bodies of water which are surrounded by seasonally flooded marsh and savanna. During the rainy season they expand into the surrounding basin and retreat during the dry season. The survey period was during the early part of the dry season so the lagoons were still quite large with shallow perimeter waters covering mud flats. Huge flocks of tree ducks and whistling ducks crowd into the lagoons to feed on mayflies and other insects. Large numbers of woodstorks, herons and egrets flock to the lagoons to feed on the crowded fish in the shrinking bodies of water. Similarly, fishermen flock to the lagoons to gill net the cichlid fish and snook (*Centropomus undecimalis*) that apparently enter the lagoons to feed and spawn. The fish caught are dried or shipped on ice and sold in Puerto Cabezas. On the night of the survey, 10 separate groups of fishermen were camped near the entrance to the lagoon. They set 2 gill nets across the upstream portion of the Narlaya Bila River, 2 were set in the lagoon proper, and 8 were set across the lower portion of the Narlaya Bila River between the lagoon and the Bambana River. Undoubtedly caimans are drowned in these nets, but it was not possible to determine the numbers or frequency at the time of the survey. It is not clear to us whether or not the Narlaya lagoon area is as heavily visited throughout the year as it is during the early dry season. The edges of the main lagoon are vegetated with floating grasses and a grassy cane. The water was too shallow to be surveyed using a skiff and outboard motor, so it was surveyed from a paddled cayuca (dugout canoe).

DISTANCES COVERED

Waterway	km
Narlaya Bila River from the upstream start point to the lagoon	5.2
Narlaya Lagoon perimeter	5.8
Narlaya Bila River between the lagoon and the Bambana River	5.6
Bambana river	6.0
Total km surveyed	22.6

A total of 34 *Caiman crocodilus chiapasius* were sighted in the following size classes: 6 (Hatchlings), 13 (2-3'), 3 (3-4'), 1 (5-6'), and 11 (Eyes Only). No *Crocodylus acutus* was detected.

4. Prinzipolka and Kusaia Rivers and Lagunas Kahru and Kisa.

Map sheet Río Prinzipolka 3456-III was used for this survey. On the night of 8 February 1993, 29.95 km of rivers and lagoons were surveyed from the upstream start point on the Kusaia River at the village of Mango and continued downstream through the Lagunas Kahru and Kisa to the confluence with the Prinzipolka River and then downriver to the end point at km 39.25. Kahru and Kisa lagoons are sufficiently narrow that it was possible to survey opposite shores from the middle of the lagoon, so straightline distances, rather than perimeter shoreline distances, were used for these two lagoons. It was our original intention to continue the survey to the mouth of the Prinzipolka at km 0.0, but after surveying just over 20 km, we struck a log and were forced to terminate the survey at km 39.25.

	Latitude	Longitude
Kusaia River upstream start point at km 69.2	13°23'32" N	83°56'23" W
Laguna Kahru downstream outlet to Kusaia River at km 67.4	13°23'27" N	83°55'43" W
Laguna Kisa downstream outlet to Kusaia river at km 65.6	13°24'00" N	83°54'56" W
Kusaia River confluence with Prinzipolka River at km 61.5	13°25'15" N	83°53'39" W
Prinzipolka River downstream end point at km 39.25	13°24'04" N	83°46'26" W

The Kusaia river and Kahru and Kisa lagoons are prime crocodilian freshwater habitat (salinity 0‰). Much of the water in the river originates in a savanna west of the village of Mango. The banks of the river are overgrown with vegetation. Forest is set back from the lagoons about 100 meters, with the intervening sloping shore covered with 1 m high grasses and sedges. The lagoons support a rich fish fauna and there is an abundance of emergent grasses along the margins of the lagoons to offer cover to young crocodilians.

DISTANCES COVERED

Waterway	km
Kusaia River and straight midline distances in Laguna Kahru and Laguna Kisa	7.7
Prinzipolka River	22.25
Total km surveyed	29.95

A total of 13 *Caiman crocodilus chiapasius* were sighted on the Kusaia river and Kahru and Kisa lagoons in the following size classes: 6 (2-3') and 7 (Eyes Only). No *Crocodylus acutus* was detected.

Seven families live in Mango and an additional 20 families live in three other communities within a few minutes walk of Mango. As a consequence the lagoons are heavily fished. In the village of Mango, a 67 year-old former hunter whose family moved into the area more than 40 years ago, reported that hide hunting started in these rivers and lagoons in 1950. He stated that both *Caiman crocodilus chiapasius* and *Crocodylus acutus* were abundant at that time. Both species were found in the same habitats, though the crocodiles tended to occur in the deeper waters and the caimans in the shallows and in the savanna. He says hundreds were killed and that there are few left in the area, which our own observations confirmed. He further stated that in this area *Crocodylus acutus* nested in March and *Caiman crocodilus chiapasius* nested in September and October. The largest *Crocodylus acutus* he ever killed was reported to be 16 feet long.

5. Kayubila Tingni (Creek), Kukalaya Lagoon, Pusalaya Tingni (Creek), Kukalaya River and Wouhnta Lagoon.

Map sheets Wouhnta 3457-II and Haulover 3456-I were used for this survey—on other maps the name of the lagoon and the village is spelled 'Wounta.' On the night of 10 February 1993, 31.9 km of rivers, creeks and lagoons were surveyed from an upstream start point on Kayubila creek down the creek to its inlet into Kukalaya lagoon, around the entire perimeter of the lagoon, down Pusalaya creek from its outlet from Kukalaya lagoon to its confluence with the Kukalaya river, and hence downstream to the mouth of the Kukalaya river on Wouhnta lagoon, and along the lagoon shore east of the river mouth to km 7.0. The survey should have continued along the Wouhnta lagoon shore to km 0.0, but thick submerged rooted vegetation exposed by low tide repeatedly fouled the propeller and forced an premature end.

	Latitude	Longitude
Kayubila Tingni (Creek) upstream start point at km 19.8	13°42'22" N	83°43'40" W
Kayubila Tingni inlet into Laguna Kukalaya at km 15.8	13°43'17" N	83°39'01" W
Lag. Kukalaya outlet to Pusalaya Tingni (Creek) at km 14.4	13°43'04" N	83°41'05" W
Pusalaya Tingni confluence with Kukalaya River at km 8.7	13°42'16" N	83°39'01" W
Kukalaya River mouth on Laguna Wouhnta km 0.0	13°38'54" N	83°36'52" W
Laguna Wouhnta start point at km 0.0	13°40'53" N	83°33'00" W

This is some of the best crocodilian habitat seen during this survey project. The area is rich in fish and wading birds. Kayubila Creek is surrounded by an excellent freshwater marsh; open grassy marsh with scattered tree islands. The water of the creek is dark with tannin, but is clear. There are numerous rooted submerged aquatic plants, including water-lily. The Kukalaya Lagoon has grassy margins in many places and in others the forest reaches the shore. There are enormous beds of at least two species of water-lily, particularly in the embayments. It was in these water-lily beds that most of the caimans were found. Pusalaya Creek is a clear, black water stream with heavily forested banks. Near its outlet from Kukalaya Lagoon, a 5–10 hectare tract of *Rhizophora* mangrove lines the banks of the creek. This is a surprising anomaly since this is a completely freshwater (0‰ salinity) habitat and mangroves are found nowhere else along the upstream or downstream portions of the creek. They are also missing from the Kukalaya river right down to its entrance into Wouhnta Lagoon. The Kukalaya River has 1-3 m banks that are covered with Raffia palms, bamboo thickets, large tropical hardwood trees, and many flowering vines. Floating grass mats extend into the river from the bank. These mats would provide cover for young crocodilians. At its mouth, the Kukalaya river is essentially freshwater (2‰ salinity), while Wouhnta Lagoon is brackish (10‰ salinity). The shore of Wouhnta Lagoon is lined with mangroves and palms. Wouhnta Lagoon is shallow along its western shore and its rooted submerged aquatic plant beds support a sizable manatee population.

DISTANCES COVERED

Waterway	km
Kayubila Tingni (Creek)	4.0
Kukalaya Lagoon	8.8
Pusalaya Tingni (Creek)	5.7
Kukalaya River	8.7
Wouhnta Lagoon	4.7
Total km surveyed	31.9

A total of 189 *Caiman crocodilus chiapasius* were sighted in the following size classes: 7 (Hatchlings), 27 (2-3'), 9 (3-4'), 2 (4-5'), 2 (5-6'), and 141 (Eyes Only). No *Crocodylus acutus* was detected. Most of the caimans were found in the water-lily beds in Kukalaya Lagoon and it was the stems of the lily pads that fouled our propeller and prevented us from approaching the caimans close enough to estimate their sizes; hence the large number of 'Eyes Only' recorded.

Some crocodilian hunting occurs in these waterways and the area is heavily traveled. Boats regularly move between Haulover village on the eastern shore of the Laguna Wouhnta and Wounta village at the southern end of the lagoon and farms and villages inland. The village of Kukalaya is located on the south shore of Laguna Kukalaya, and farms are scattered along the Kukalaya river.

BLUEFIELDS AREA

6. Río Kukra River, Caño Negro, and Las Pavas Creeks.

Map sheet Rama Cay 3451-IV was used for this survey. On the night of 16 February 1993, a total of 28.6 km of waterways was surveyed from an upstream starting point on the Kukra river to an end point at its mouth, and including Caño Negro from an upstream start point to its confluence with the

Kukra, and Las Pavas creek from an upstream start point to its confluence with the Kukra. Originally the survey was to include 18 km of mangrove fringe facing Bluefields Bay between the mouth of the Kukra River and Bluefields, but the combination of a dying spotlight battery and exposed mud flats forced cancellation of this portion.

	Latitude	Longitude
Kukra River upstream start point at km 19.2	11°53'30" N	83°54'51" W
Kukra River mouth at km 0.0	11°53'37" N	83°49'26" W
Caño Negro upstream start point at km 22.5	11°57'17" N	83°54'25" W
Caño Negro mouth at km 14.5	11°54'27" N	83°53'36" W
Las Pavas creek upstream start point at km 12.2	11°54'54" N	83°52'58" W
Las Pavas creek mouth at km 10.8	11°54'19" N	83°52'46" W

This series of waterways would be good crocodilian habitat were it not for the number of farms scattered along the banks. The entire system is freshwater (salinity 0‰), including the Kukra River right down to its mouth on the saltwater Bluefields Bay. The banks are covered with many Raffia palms and leatherleaf ferns (*Acrostichum* sp,). Floating mats of grass extend out from the shore and would provide excellent cover for young caimans. *Rhizophora* mangrove are largely absent from the system except for the headwaters of Caño Negro, where extensive stands of small (2-5 m high) *Rhizophora mangle* occur. Though black with tannin, the water is clear.

DISTANCES COVERED

Waterway	km
Kukra River	19.2
Las Pavas creek	1.4
Caño Negro	8.0
Total km surveyed	28.6

A total of 11 *Caiman crocodilus chiapasius* were sighted in the following size classes: 6 (2-3'), 2 (3-4'), 1 (4-5'), 1 (5-6'), and 1 (Eyes Only). No *Crocodylus acutus* was detected.

7. Ñari River and Big Lagoon.

Map sheets La Fe 3453-III and Carlos Fonseca 3452-IV were used for this survey. On the night of 17 February 1993, a total of 30.5 km of river and lagoons was surveyed from an upstream end point at km 30 km 2.5 to its the mouth on Lagunas de Perlas, and including 3 km of perimeter shore in Papta and Big lagoons.

	Latitude	Longitude
Ñari upstream start point at km 30	12°19'35" N	83°48'39" W
Big Lagoon mouth at km 6.8	12°26'09" N	83°46'12" W
Ñari River mouth at km 2.5	12°28'05" N	83°46'22" W

This is an entirely freshwater system (salinity 0‰). There were many logs above km 18 on the Ñari, which slowed the survey a bit. In addition, the 12-volt spotlight failed and the survey was finished using the backup 6-cell Mag-Lite. The water level reached the top of the bank and extended into the surrounding palm forest. Big Lagoon is fringed with *Rhizophora* mangroves.

DISTANCES COVERED

Waterway	km
Ñari River	27.5
Big Lagoon	2.0
Papta Lagoon	1.0
Total km surveyed	30.5

A total of 16 *Caiman crocodilus chiapasius* were sighted in the following size classes: 1 (Hatchling), 5 (2-3'), 1 (4-5'), 1 (5-6'), and 8 (Eyes Only). No *Crocodylus acutus* was detected.

The Ñari and all the surrounding rivers, creeks and lagoons are heavily hunted. We interviewed three crocodilian hunters in La Fe, near the mouth of the Ñari, who told us that they each killed between 200 and 400 caimans and crocodiles a year, primarily in lagoons that could not be entered directly from the rivers but could only be reached by dragging a cayuca (dugout canoe) to them across land. Most of the hides reportedly were 2-3' in length.

8. Wawashang River.

Map sheets San Vicente 3453-IV, Río Wawashang 3454-III and Orinoco 3453-I were used for this survey. On the night of 18 February 1993, 20 km of the Wawashang River was surveyed between the upstream start and downstream end point. Other maps and reports in the literature spell name of the river as 'Wawasang.' The spelling is further confused by the area being part of the Wawashan Forest Reserve.

	Latitude	Longitude
Wawashang River upstream start point at km 37	12°41'42" N	83°50'31" W
Wawashang River end point at km 17.25	12°39'27" N	83°45'01" W
Wawashang River mouth at km 0.0	12°33'12" N	83°44'45" W

The end point is 1.25 km above Trinkulang, which, with over 30 houses, is the largest village on the Wawashang. There are farms upstream of this point, but many more are found downstream. The Wawashang is a freshwater river and excellent crocodilian habitat. It is a clear, slightly milky, black water river. The banks vary from 2 to 6 meters high, most covered with vegetation. Along the lower stretches, the banks are covered with Raffia palms, stands of bamboo, and second growth vegetation that is reclaiming old farms. There are many vines. Floating grass mats extend out several meters from the bank. Upstream where the original forest remains uncut, the banks are shaded by primary canopy trees 100 feet or taller. Many massive hardwood trees lean out over the river from the banks to shade the water. Under the trees the bank is bare or with a thin cover of herbaceous vegetation. Above km 30, many logs and brush piles partially obstruct the river. In addition, above about km 36, pebble shoals impede travel by outboard motor. It was one such rocky shoal that determined the upstream terminus. There are 20+ lagoons, former oxbow lakes, off the main river. Most are not connected to the river. Tapir, white-lipped peccary, deer, panther (*Felis concolor*), jaguar, ocelots, and paca are found in the area.

DISTANCES COVERED

Waterway	km
Wawashang River	20.0
Total km surveyed	20.0

A total of 2 *Caiman crocodilus chiapasius* were sighted in the following size classes: 1 (2-3') and 1 (Eyes Only). No *Crocodylus acutus* was detected.

Since most of the farms are downriver from the survey route, almost certainly the scarcity of crocodilians is the result of hunting pressure. We interviewed a hunter on the Wawashang who reported killing 300-350 caimans a year. Most are found not in the river proper, but in the lagoons associated with the river. Reportedly, the caimans are found in the lagoons during the high water and do not enter the river until the water in the lagoons falls during the dry season. They are hunted by dragging a cayuca (dugout canoe) into the lagoon from the river.

9. Black Water Creek.

Map sheet Bluefields 3452-III was used for this survey. On the night of 19 February 1993, 29.05 km of river was surveyed from an upstream start point on Black Water Creek to its mouth on the Escondido River, including La Linea and Los Frijoles creeks from upstream start points to their confluences with Black Water Creek. Black Water Creek is the first name on the maps, but the creek also bears the second name of 'Caño Negro'. Many Caño Negro's can be found throughout the country (e.g., see locality 6 above), this one is immediately northwest of Bluefields and is a tributary of the Escondido river. To avoid confusion, we used the English name here—the reader is also referred to the latitude and longitude start and endpoints.

	Latitude	Longitude
Black Water Creek upstream start point at km 27.25	12°02'51" N	83°54'31" W
Black Water Creek mouth and end point at km 0.0	12°08'08" N	83°46'10" W
La Linea creek upstream start point at km 27.0	12°02'06" N	83°54'08" W
La Linea creek mouth at km 26.0	12°02'31" N	83°54'16" W
Los Frijoles creek upstream start point at km 22.9	12°02'34" N	83°52'07" W
Los Frijoles creek mouth at km 22.1	12°02'47" N	83°52'20" W

This is a freshwater river (salinity 2‰ at the upstream end point of Black Water Creek and 0 ‰ throughout the rest of the system). Mangroves are largely absent from its banks. The river has been heavily settled in the past, but many of the riverside farms shown on the 1988 edition map sheets are gone, destroyed by that year's hurricane. More of the farms on the hill tops seemed to have survived the hurricane, but the ones along the river's edge are gone. Much of the river swamp forest also is dead as a result of the hurricane. Tall groves of dead limbless trunks surrounded by a dense, 3-5 m high, thicket of secondary growth is a reminder of the former forest. There banks are covered with many Raffia palms, leatherleaf ferns (*Acrostichum* sp.), spider lilies, and yellow allamanda vines. The banks are covered with vegetation right down to the water with no exposed banks except at active farms.

DISTANCES COVERED

Waterway	km
Black Water Creek	27.25
La Linea creek	1.0
Los Frijoles creek	0.8
Total km surveyed	29.05

A total of 20 *Caiman crocodilus chiapasius* were sighted in the following size classes: 11 (2-3'), 4 (3-4'), 2 (4-5'), and 3 (Eyes Only). No *Crocodylus acutus* was detected.

The proximity of Black Water Creek to Bluefields and the heavy boat traffic along this river may account for the scarcity of crocodilians. Hunting undoubtedly is another reason. Caiman were sparse in the middle stretches of the river where there are several large working cattle and horse ranches. However, it is interesting to note that many of the caimans sighted were directly in front of active farms along the lower stretches of the river. They might be there to scavenge fish entrails cleaned at the water's edge, or hunters might be reluctant to kill caimans directly in front of someone's house. In any event, the majority of these caimans were small (2-3') and well hidden in floating grass mats.

SAN CARLOS AND THE RIO SAN JUAN AREA

10. Río Guacalito Viejo and shore of Lake Nicaragua.

Map sheets San Carlos 3249-III and Colon 3149-II were used for this survey. On the night of 23 February 1993, a total of 7.5 km of river and lake shore were surveyed, including the Río Guacalito Viejo from the upstream start point (where floating vegetation blocked further passage) to its mouth on Lake Nicaragua (= Lake Cocibolca) and 3.5 km of Lake Nicaragua shore starting extending east from the mouth of Guacalito Viejo.

	Latitude	Longitude
Río Guacalito Viejo upstream start point at km 4.0	11°01'30" N	84°59'50" W
Río Guacalito Viejo mouth and end point at km 0.0	11°02'50" N	84°58'45" W
Lake Nicaragua shore start point at mouth of Río Guacalito Viejo at km 0.0	11°02'50" N	84°58'45" W
Lake Nicaragua shore end point at km 3.5	11°03'35" N	84°56'53" W

The Guacalito Viejo is a freshwater river (salinity 0‰) draining a wide marsh. Mats of floating vegetation from 5 to 10 m wide obscured the actual width of the river and left an open channel 5 to 10 m wide. The banks were made up of floating camelote grass, sawgrass, and hydrocotyle. The water was muddy.

The Lake Nicaragua (salinity 0‰) survey was made ±100 m offshore through shallow water and emergent brush. Sighting quality was inconsistent because of rising mist and increasing wind. The survey was terminated when the outboard motor became entangled in a gill-net staked out in the shallows and the 12-volt spotlight battery died.

DISTANCES COVERED

Waterway	km
Río Guacalito Viejo	4.0
Lake Nicaragua shore	3.5
Total km surveyed	7.5

In the Guacalito Viejo river a total of 41 *Caiman crocodilus chiapasius* were sighted in the following size classes: 7 (Hatchlings), 4 (2-3'), 5 (3-4'), 2 (4-5'), and 23 (Eyes Only). No *Crocodylus acutus* was detected.

The number of caimans sighted clearly indicates that Río Guacalito Viejo provides good habitat. The floating vegetation provides cover for young and adult animals alike; and a majority of the caimans sighted (37 animals) were in vegetation in the water.

Along the shore of Lake Nicaragua a total of 2 *Caiman crocodilus chiapasius* were sighted in the following size class: 2 (Eyes Only). No *Crocodylus acutus* was detected.

While the distance was short, the number of caimans found during the lake shore survey is significant in light of the number of fishermen (both net and hook and line) working the area. There also is considerable traffic from pleasure and passenger boats in the lake, though the shallows and rooted vegetation keeps a good bit if it further offshore.

11. Río Zapote.

Map sheets San Carlos 3249-III and Río Zapote 3248-IV were used for this survey. On the night of 23 February 1993, 9.7 km of this river was surveyed, from the international border with Costa Rica upstream to its mouth in Lake Nicaragua. The river is still navigable well beyond the Costa Rica/Nicaragua border, but the survey did not cross the border.

	Latitude	Longitude
Río Zapote upstream endpoint at km 9.7	10°58'04" N	84°53'12" W
Río Zapote mouth and end point at km 0.0	11°01'57" N	84°53'24" W

This is a freshwater river (salinity 0 ‰) flowing out of an extensive marshy floodplain. The maps show the river being relatively straight, but the floating mats of camelote grass extending out from the banks narrow the width by ½ and turn it into a winding course. Banks are almost non-existent downstream, their relative position being marked by 1-3 m high *Maranta*-type herbaceous marsh plants. Upstream the banks are 0 to 1 meter high and are quite peaty. There they support a narrow gallery forest of *Ficus*, ceibas, some *Raffia* palms and other trees, most are covered with vines, including a climbing grass. A papyrus-like *Cyperus* also occurs in the upstream camelote.

DISTANCES COVERED

Waterway	km
Río Zapote	9.7
Total km surveyed	9.7

A total of 21 *Caiman crocodilus chiapasius* were sighted in the following size classes: 1 (Hatchling), 9 (2-3'), 5 (3-4'), 2 (4-5'), 1 (5-6'), and 3 (Eyes Only). No *Crocodylus acutus* was detected.

Despite this river being relatively close to San Carlos, it supports a fair population of caimans. This may be a consequence of the river being part of the Los Guatuzos Wildlife Refuge or a reflection of the scarcity of hunters in this area.

12. Río Sabalos.

Map sheet El Castillo 3349-III was used for this survey. On the night of 24 February 1993, 5.5 km of this river was surveyed from the upstream start point to its confluence with the Río San Juan. Were it not for the presence of multiple logs in the river and rocky shallows, more of the river could have been surveyed.

	Latitude	Longitude
Río Sabalos upstream end point at km 49.7	11°04'28" N	84°27'47" W
Río Sabalos mouth at km 44.2	11°02'27" N	84°28'32" W

This is a freshwater (salinity 0‰) river. The river is heavily settled. Farms line the lower stretches of the river. None of the original forest vegetation remain. Pasture grasses cover the banks right down to the water. There is little floating vegetation, save for a thin fringe of water hyacinth (*Eichhornia*). At km 4.5 there is a enormous sawmill, now inactive. Above the mill the river is strewn with sunken logs. Above km 5.0, there is a thin fringe of gallery forest composed of *Ficus* and an occasional ceiba. Under the trees the banks are covered with a small-leafed fern. The water is clear and slightly milky.

DISTANCES COVERED

Waterway	km
Río Sabalos	5.5
Total km surveyed	5.5

A total of 2 *Caiman crocodilus chiapasius* were sighted in the following size classes: 1 (3-4') and 1 (5-6'). No *Crocodylus acutus* was detected.

While the number of km surveyed is not great, the scarcity of caimans on this river reflects the loss of most of the qualities that would make it good crocodilian habitat; vegetative cover is missing, the river is heavily traveled, and many human settlements line its banks.

13. Río Isla Chica.

Map sheet La Azucena 3249-II was used for this survey. On the night of 24 February 1993, 6 km of this small river was surveyed from the upstream start point near the Costa Rican border to its confluence with the Río San Juan.

	Latitude	Longitude
Río Isla Chica upstream start point at km 39.7	11°02'45" N	84°34'20" W
Río Isla Chica mouth and end point at km 33.7	11°04'06" N	84°33'00" W

This is a freshwater (salinity 0‰) river with clear water. The upper section is approximately 10 m wide with mud banks 0.5-2 m above the water, numerous logs and overhanging vegetation. The lower 3 km flowed between low grassy banks with extensive mats of floating camelote grass.

DISTANCES COVERED

Waterway	km
Río Isla Chica	6.0
Total km surveyed	6.0

A total of 9 *Caiman crocodilus chiapasius* were sighted in the following size classes: 3 (Hatchlings), 2 (2-3'), 1 (3-4'), and 3 (Eyes Only). No *Crocodylus acutus* was detected.

Despite the favorable appearance of this river and the absence of human occupation, the density sighted was relatively low with most of the animals being near to the confluence with the San Juan.

14. Río San Juan.

Map sheets El Castillo 33489-III, La Azucena 3249-II, and San Carlos 3249-III were used for this survey. On the night of 24 February 1993, 43.75 km of this river were surveyed upriver from the downstream start point at the mouth of the Sabalos river to the public dock in San Carlos (the usual convention of measuring distances upstream from the mouth of the river was not followed here because of the enormous distance between the mouth of the Río San Juan on the Atlantic coast and the survey start point).

	Latitude	Longitude
Río San Juan downstream start point at mouth of Río Sabalos at km 44	11°02'27" N	84°28'32" W
Río San Juan end point at San Carlos public docks at km 0.25	11°07'14" N	84°46'39" W

The Río San Juan is Lake Nicaragua's outlet to the Atlantic Ocean. It is one of the largest rivers in Nicaragua, 100-200 m in width, and one that supports major passenger and freight boat traffic between Lake Nicaragua and downstream communities. Large towns and villages are scattered along its banks, as are numerous farms. Yet despite this development, much of the river remains in relatively natural conditions. The banks are cleared near centers of human activity. Here banks may be bare or covered with pasture grasses. Elsewhere, floating mats of camelote grass extend 10 or more meters out from the bank into the river. Around the mouths of tributaries, gallery forest remains. All this vegetation provides cover for crocodilians, particularly young animals.

We would have preferred to have conducted this survey with two boats, one surveying one side of the river and the companion boat surveying the opposite side. However, continued problems with 12-volt spotlight batteries forced us to conduct most of this survey from one boat running down the middle of the river. This, plus the width of the river and the length of the survey and the number of crocodilians sighted, made it impractical to run back and forth between the opposite banks to estimate size of the animals sighted. As a consequence, this survey was divided into two distinct sections: size classes were recorded for all the crocodilians sighted in one 4.5 km stretch, and a simple total of all the crocodilians sighted between the start and end points was recorded without regard to size classes for the remaining 39.25 km of the survey.

DISTANCES COVERED

Waterway	km
Río San Juan	43.75
Total km surveyed	43.75

A total of 650 *Caiman crocodilus chiapasius* were sighted between the end point at km 0.25 and the start point at km 44, including 120 *Caiman crocodilus chiapasius* in the following size classes sighted in the 4.5 km stretch between km 38.3 and km 33.8: 24 (Hatchlings), 29 (2-3'), 2 (3-4'), 1 (4-5'), and 64 (Eyes Only). No *Crocodylus acutus* was detected.

The number of groups of hatchling sized animals indicates that active nesting continues at many locations along the river, although relatively few adult sized animals were seen.

15. Río Frio.

Map sheets San Carlos 3249-III and Azucena 3249-II were used for this survey. On the night of 25 February 1993, 11.5 km of this river were surveyed from the upstream start point on the Costa Rican border to its mouth on the Río San Juan.

	Latitude	Longitude
Río Frio upstream start point at Costa Rican border and km 11.5	11°02'49" N	84°44'39" W
Río Frio end point and mouth at km 0.0	11°07'04" N	84°46'35" W

This freshwater river (salinity 0‰) is a major avenue for traffic between Costa Rica and Nicaragua. Passenger and freight boats pass up and down the river daily. The water is slightly muddy. The lower reaches of the river are lined with farms and ranches. In this section the 2-4 m high banks are covered with pasture grasses. Where the banks are vertical, the bottom 0.5-1 m is bare lateritic clay. Low banks are covered with Maranta-like marsh vegetation. Above the border checkpoint at La Esperanza at km 7.0, the banks support a gallery forest of *Erythrina*, *Cassia*, bromeliad laden ceibas, Raffia palms, and numerous vines. There is little floating camelote grass. The upstream banks are almost like levees separating the river from the surrounding low floodplain.

DISTANCES COVERED

Waterway	km
Río Frio	11.5
Total km surveyed	11.5

A total of 53 *Caiman crocodilus chiapasius* were sighted in the following size classes: 5 (Hatchlings), 20 (2-3'), 4 (3-4'), 1 (4-5'), and 23 (Eyes Only). No *Crocodylus acutus* was detected.

The relative abundance of caimans, despite the heavy boat traffic, might reflect decreased hunting pressure as a result of the presence of military personnel at the border checkpoint. The river is part of the Los Guatuzos Wildlife Refuge.

16. Boca Ancha Creek.

Map sheet San Carlos 3249-III was used for this survey. On the night of 25 February 1993, 4.5 km of this river was surveyed from the upstream starting point to its mouth on Lake Nicaragua, including a small unnamed tributary entering the right bank of Boca Ancha at km 1.8 and extending upstream to the end point.

	Latitude	Longitude
Boca Ancha upstream start point at km 4.0	11°03'20" N	84°45'45" W
Boca Ancha mouth and end point at km 0.0	11°04'30" N	84°47'20" W
Unnamed tributary mouth on Boca Ancha at km 1.8	11°04'17" N	84°46'17" W
Unnamed tributary upstream end point at km 2.3	11°04'16" N	84°46'03" W

This is a short black water creek flowing into Lake Nicaragua from the inundated marshes south of the lake. There are extensive mats of camelote grass and water hyacinths lining the banks and extending into the creek, similar to other rivers in this region.

DISTANCES COVERED

Waterway	km
Boca Ancha creek	4.0
Unnamed tributary	0.5
Total km surveyed	4.5

A total of 50 *Caiman crocodilus chiapasius* were sighted in the following size classes: 15 (Hatchlings), 18 (2-3'), and 17 (Eyes Only). No *Crocodylus acutus* was detected.

This creek is part of the Los Guatuzos Wildlife Refuge.

MANAGUA AND THE PACIFIC COAST AREA

17. Estero Real La Garita.

Map sheet Puerto Sandino 2852-IV was used for this survey. On the night of 1 March 1993, a total of 16.5 km of river and estuary were surveyed, from the upstream starting point on Estero La Gasolina and including all of Estero Real La Garita from an impassable upstream start point to its mouth on the Pacific Ocean.

	Latitude	Longitude
Estero La Gasolina upstream start point at km 12	12°19'00" N	86°56'46" W
Estero La Gasolina confluence with Estero Real la Garita at km 8.7	12°18'09" N	86°55'28" W
Estero Real La Garita upstream start point at km 13.2	12°19'19" N	86°56'09" W
Estero Real La Garita mouth and end point at km 0.0	12°16'11" N	86°52'38" W

This is a meandering saltwater mangrove (*Rhizophora*) estuary. Salt pans for the production of salt have been dredged out of a good bit of the higher mangrove. In 1992, Salinas Grandes, the beach front village just southeast of the mouth of Estero Real La Garita, was swept away by a tidal wave. The massive number of dead and broken mangroves on the banks and blocking the waterways is a stark reminder of that event.

DISTANCES COVERED

Waterway	km
Estero La Gasolina	3.3
Estero Real La Garita	13.2
Total km surveyed	16.5

During the afternoon of 1 March 1993, as we reconnoitered the survey route we saw 7 crocodiles basking on the creek banks or in the water. These were all seen clearly and were in the following size classes: 3 (2-3'), 1 (5-6'), 1 (6-7'), 1 (7-8'), and 1 (8-10'). Clear photographs were obtained of the two largest animals. These crocodiles were all in the section of Estero La Garita km-9-12 and most of the animals were seen again during the night survey four hours later. In addition, fresh tracks and slides of an additional 5 different crocodiles were noted. These informal daytime sightings are not included in the quantitative survey results or analysis. We also inspected the site of a crocodile nest from the previous (1992) nesting season near km 11 on Estero Gasolina.

During the night spotlight survey a total of 18 *Crocodylus acutus* were sighted in the following size classes: 2 (Hatchlings), 2 (2-3'), 2 (4-5'), and 12 (Eyes Only). No *Caiman crocodilus chiapasius* was detected.

18. Estero Ciego, Estero Cangura, and the Izapa and Los Arcos rivers.

Map sheet Puerto Sandino 2852-IV was used for this survey. On the night of 2 March 1993, a total of 22.3 km of mangrove estuaries and rivers were surveyed, from an upstream starting point on the Estero Ciego to Estero El Tamarindo (they are different parts of the same continuous estuary) and the dry dock in Puerto Sandino, including Estero Cangura from an impassable upstream starting point to its confluence with Estero Ciego, and the Los Arcos river from an impassable upstream start point to its confluence with the Izapa river and hence downriver to the Estero Ciego. The upstream terminus of Estero Ciego was chosen because beyond that point much of the habitat has been converted to salt pans.

	Latitude	Longitude
Estero Ciego upstream start point at km 12.5	12°14'34" N	86°49'36" W
Estero La Cangura upstream start point at km 8.5	12°15'08" N	86°47'52" W
Estero La Cangura confluence with Estero Ciego at km 4.5	12°13'42" N	86°47'39" W
Los Arcos river upstream start point at km 6.8	12°14'15" N	86°45'53" W
Los Arcos river confluence with Izapa river at km 6.25	12°14'12" N	86°45'38" W
Izapa river confluence with Estero Ciego at km 1.5	12°12'49" N	86°46'17" W
Estero El Tamarindo end point at the Puerto Sandino dry dock at km 0.0	12°12'03" N	86°45'50" W

This is a saltwater and hypersaline waterway. The salinity in the El Tamarindo estuary at Puerto Sandino is 34‰, and at the upstream starting point on the Ciego estuary it is 44‰. The dominant vegetation evident along all these waterways is *Rhizophora* mangroves. The mangrove peat banks are 1 m high. Lower banks are composed of mud and offer limited basking sites for crocodilians.

DISTANCES COVERED

Waterway	km
Estero Ciego-El Tamarindo	12.5
Estero Cangura	4.5
Los Arcos river	0.6
Izapa river	4.7
Total km surveyed	22.3

A total of 6 *Crocodylus acutus* were sighted in the following size classes: 1 (3-4'), 1 (6-7'), and 4 (Eyes Only). No *Caiman crocodilus chiapasius* was detected.

19. Estero Real upstream of Puerto Morazan.

Map sheets Puerto Morazan 2754-I and 2755-II, Villanueva 2854-V, Tonala 2754-II, and Villa 15 de Julio 2854-III were used for this survey. On the night of 12 March 1993, the upper Estero Real river was surveyed starting at the village of Rigoberto López Pérez and continuing downstream for 33 km to the confluence of Estero Real and the Estero El Tempisque. The first 12 km was above the coastal tidal mangrove, and the remaining 21 km was in the mangrove zone. No salinity refractometer was available, but this section of the river above the mangrove zone is assumed to be fresh. Even in the mangrove zone there probably is a lens of fresh water on the surface during low tides and following rains.

	Latitude	Longitude
Rigoberto López Pérez upstream start point at km 0.0	12°48'40" N	86°56'30" W
Beginning of mangrove zone at km 12	12°49'45" N	87°00'14" W
End point at Estero El Tempisque at km 33	12°49'38" N	87°07'25" W

This survey was conducted by IRENA personnel after the CITES coordinators had returned to the U.S.A. This are is similar to Estero Real La Garita/Estero Ciego coastal mangroves near Puerto Sandino. Extensive tidal mangrove thickets surround salinas and are bisected by tidal creeks. The total habitat area lying in this region on the south side of the Gulf of Fonseca (Golfo de Fonseca) is greater than 450 square kilometers.

DISTANCES COVERED

Waterway	km
Upper Estero Real (riverine) to mangrove zone	12.0
Estero Real mangrove zone to Estero Tempisque	21.0
Total km surveyed	33.0

Three crocodilians, all confidently assigned to *Crocodylus acutus,* were sighted in the first 12 km section above the mangroves: 1 (5-6') and 2 (Eyes Only). In the 21 km mangrove section a total of 16 (Eyes Only) were sighted. No *Caiman crocodilus* was detected.

20. Estero Real, Estero El Chorro and tributaries.

Map sheet Estero Real 2754-IV was used for this survey near the mouth of the Estero Real on the Gulf of Fonseca. On the night of 13 March 1993, spotlight surveys were conducted downstream from an upstream end point at Estero El Embudo to the confluence of Estero El Chorro (which is continuous with Estero El Embudo) and including the tributaries Estero Trompa De Chancho and Estero Cervantes.

	Latitude	Longitude
Estero El Embudo upstream start point at km 10.0	12°51'33" N	87°23'05" W
Mouth of Estero Tromba De Chancho at km 7.0	12°52'00" N	87°22'15" W
Mouth of Estero Cervantes at km 4.9	12°52'22" N	87°21'40" W
Upstream end of Estero Cervantes at km 10.5	12°52'35" N	87°19'42" W
Mouth of Estero El Chorro end point at km 0.0	12°54'42" N	87°22'00" W

This are is part of an extensive, 3-5 km wide, mangrove fringe lying along the southern shore of the Gulf of Fonseca. This survey was conducted by IRENA personnel after the CITES coordinators had returned to the U.S.A.

Distances Covered	
Waterway	km
Estero Embudo and Estero El Chorro	10.0
Estero Trompa Del Chancho	1.3
Estero Cervantes	5.7
Total km surveyed	17.0

A total of 2 (Eyes Only) sightings were made, both of which are assumed to be *Crocodylus acutus*. One was located in the small Estero Trompa Del Chancho and the other at the upper end of Estero Cervantes. Thus both crocodiles in this survey were at more remote and inaccessible locations. No *Caiman crocodilus* was detected.

21. Estero Real, Estero Marota.

Map sheet Estero Real 2754-IV was used for this survey. The survey route lies approximately 4 km upstream and east of Estero El Chorro (survey 20). On the night of 13 March 1993, from a start point at the upper limit of navigation at km 12.5 on Estero Marota, a spotlight survey was conducted downstream to its confluence with Estero Real.

	Latitude	Longitude
Upstream start point at km 12.5 on Estero Marota	12°51'31" N	87°16'26" W
End point at km 0.0 at the mouth of Estero Marota	12°55'03" N	87°19'45" W

This survey was conducted by IRENA personnel after the CITES coordinators had returned to the U.S.A. The habitat is similar to that at Estero El Chorro (see survey 20 above).

Distances Covered	
Waterway	km
Estero Marota	12.5
Total km surveyed	12.5

A total of 3 crocodilians were sighted, all *Crocodylus acutus*: 1 (5-6') and 2 (Eyes Only). The tidal saline mangrove habitat of this area makes the assumption that the 'Eyes Only' were *C. acutus* almost certain. The three crocodiles were seen in a 600 m section of the creek 3 km from the confluence with Estero Real. No *Caiman crocodilus* was detected.

22. Lake Nicaragua, Isla de Ometepe.

Map sheet San Jose Del Sur 3050-II was used for this survey. On the night of 21 April 1993, a spotlight survey was conducted along 8 km of the southern shore of the Island of Ometepe near the narrow Istmo (Isthmus) de Istián which connects the two sections of the island. Ometepe is a large island consisting of two volcanic cones lying about 20 km from the western shore of Lake Nicaragua (= Lake Cocibolca) in the vicinity of Rivas. This is the only locality in Lago Nicaragua where crocodiles are consistently reported. This survey was conducted by IRENA personnel after the CITES coordinators had returned to the U.S.A.

	Latitude	Longitude
Start point at km 0.0 near Punta Coyolmi	11°29'00" N	85°36'50" W
End point at km 8.0 south of Ensenada El Istián	11°28'02" N	25°33'44" W

No physical description of this location was provided by the survey team.

DISTANCES COVERED

Waterway	km
Lake Nicaragua, Ometepe Island	8.0
Total km surveyed	8.0

Two crocodilians were sighted on this survey in the vicinity of the mouth of El Istián, a small stream that almost bisects the Isthmus of Istián. Both were tentatively ascribed to *Crocodylus acutus*: 2 (Eyes Only).

23. Lagunas Monte Galan.

Map sheet La Paz Centro 2853-II was used for this survey. On the night of 4 May 1993, this locality was surveyed on foot around the shores of two adjacent lakes. These lakes are located on the northwest flánk of Volcan Momotombo, 30 km northeast of Managua and 1 km from the shore of Lake Managua. The night time spotlight survey of the two lakes was conducted from shore, the lakes were circumambulated on foot. This survey was conducted by IRENA personnel after the CITES coordinators had returned to the U.S.A.

	Latitude	Longitude
Start point at km 0.0, Monte Galan east lagoon	12°26'20" N	86°34'14" W
Start point at km 0.0, Monte Galan west lagoon	12°26'36" N	85°34'50" W

This locality consists of a pair of small adjacent lakes approximately 300 m greatest width located with a protected government reserve operated by the national electrical company. Access is restricted and requires a permit from the government. The lakes are located just over a kilometer from Lake Managua at a point where a small population of *Crocodylus acutus* is said to remain although greatly reduced by interactions with net fishermen. It is presumed that the crocodiles of Laguna Monte Galan originated from Lake Managua or represent a remnant of that population persisting in a protected refugium. A 10-15 m band of vegetation and shrubs extends around the shore. The lake levels were low at the time of the survey with a band of exposed mud 5-10 m wide between the water and the vegetation.

DISTANCES COVERED

Waterway	km
Laguna Monte Galan, east	3.3
Laguna Monte Galan, west	2.5
Total km of survey	5.8

A total of 19 *Crocodylus acutus* were sighted during the survey (14 in the east lagoon and 5 in the west lagoon) in the following size classes: 3 (2-3'), 1 (3-4'), 15 (Eyes Only). Caiman are not reported from these lagoons.

RESULTS AND DISCUSSION.

Sample distribution and intensity. General localities of surveys are shown in Figure 1. The distribution of surveys generally overlaps with the known and suspected distribution of crocodilians in Nicaragua, and covers most of the areas where harvest of crocodilians is practiced. A significant omission is the central Atlantic coastal region of the middle Río Grande de Matagalpa and the extensive associated lagoons and watersheds. Logistic constraints prevented us from surveying this area and this deficiency should be rectified at the earliest opportunity. We also suspect that some of the more remote rivers of the southern area, e.g., Río Indio, Río Maiz and the extensive wetlands associated with Bismuna lagoon, would be useful to survey.

The total distance surveyed is approximately 11% of the total length of rivers in Nicaragua (estimated at 4,500 km by Peralta-Williams 1991). The quantity of additional crocodilian habitat in Nicaragua (lagoons, marshes, mangrove creeks, lakes) is immense. The survey sample therefore is a representative sample of crocodilian habitats in Nicaragua. Additional sampling in new locations and repetitive surveys in some of our survey locations would greatly refine the precision and accuracy of the results. No attempt was made to structure or randomize the sample distribution. Our surveys probably over-represent open navigable rivers and lagoons and under-represent more inaccessible wetlands where crocodilians, and particularly *Caiman*, are often found. Therefore, extrapolation to non-sampled areas or the calculation of estimated total populations involves significant uncertainty.

We do not have sufficient data to quantitatively evaluate the precision of our survey results. The basic question to be addressed is, "If we count a given number of crocodilians in a section of river, how many are really there?" The minimum number present can be no less than the number sighted. Therefore, uncorrected survey data represent conservative estimates of the population. When the survey technique and location is kept constant these surveys provide relative data that are quite adequate to evaluate population trends and allow comparisons with other areas where similar techniques were used. Messel *et al* 1981, provide a theoretical basis and formulae to evaluate survey precision of spotlight surveys when multiple samples of the same rivers are made. We do not have such samples and in any case they are of limited applicability when the variation between samples is large or the mean density very low. In an attempt to informally address the precision of our surveys we have compared the calculated densities of four locations that were surveyed twice each, i.e., Wark Wark River to Lamlaya, lower Bambana River. These indicate that the difference from one survey to the next, in the same river, on subsequent nights, ranged between 0% and 50% of the higher estimate. Additional sampling to estimate the precision of caiman surveys under the conditions encountered in Nicaragua is urgently needed. In the meantime, we use uncorrected values of estimated density throughout this report.

Not withstanding these caveats, the survey represents a valuable baseline on which to base future monitoring and compares favorably in intensity and distribution, with other similar surveys that have proved adequate for the evaluation and management of crocodilian populations. The use of a strictly standardized technique allows comparison of the results generated with other similar surveys and facilitates the interpretation of the results and the generation of recommendations.

CAIMAN CROCODILUS

Results of surveys of *Caiman crocodilus* are summarized in Table 2 (surveys grouped by region), and Table 3 (surveys grouped by density of caiman). Caiman were found in nearly every suitable freshwater body examined confirming the wide distribution and general adaptability of this species. In many of the localities surveyed (72% of the kilometers surveyed) the density of caiman is low (less than 1 caiman seen per km). These low densities are similar to those seen elsewhere in heavily exploited populations of caiman (Table 6).

We do not believe the low densities are the result of inadequate observations, water conditions, or surveying in the wrong sites. All the surveys were conducted under favorable conditions of low wind speed (less than 10m/sec) and warm air and water temperatures (range 24°–31°C.) see Figure 2. No other physical conditions would lead us to doubt that the low densities observed represent real, low density *Caiman* populations. The fact that we were, under identical conditions, able to observe much higher densities at other localities (Table 3) confirms the reality of these observations. Some observers, including caiman hunters in the field, suggested that caiman could be found in high density in remote unsurveyed locations that could not be easily reached by outboard motor boat. This may be true. We noted that these same caiman hunters were eager to use our maps to locate unexploited water bodies where they could hunt caiman. We interpret the observed low density of caiman in many localities as a direct response to harvesting in the recent past which suggests that harvest pressure is at, or possibly above, sustainable levels in much of the accessible habitat in Atlantic Nicaragua.

In the remainder of our sample the densities of caiman were higher (an average of 2.3 caiman sighted per km in 10% of the km surveyed), and very high (greater than 10 caiman sighted per km in 18% of the km surveyed). These densities are comparable to healthy, unexploited populations of *Caiman* elsewhere (Table 6). These reassuring data give us confidence that our surveys are reasonably accurate estimations of caiman populations and it is clear that in a significant portion of the available habitat healthy populations persist. Management actions and harvest controls need to be developed that maintain these healthy populations and optimize the long term sustainable harvest that can be extracted from this resource.

Caiman Size. The size distribution of the caiman we approached sufficiently close to estimate their length is shown in Figure 3. Overall the size distribution is that expected from a hunted population with a paucity of large individuals (greater than 6 feet). The presence of abundant hatchlings and animals in the 2-3' size class suggests that reproduction and recruitment remains healthy. A total of 9% of the sample falls into size classes at and above the legal minimum size for harvest, which represents the bulk of the larger adult male population.

Figure 4 represents the data on size distribution presented by region. Some distortion of the situation is caused by the different sample sizes from each region and the data are not sufficiently robust to merit statistical analysis. However, inspection of these data suggest that hatchlings are under represented in the Bluefields/Pearl Lagoon area, i.e., Kukra River, Ñari River, Wawashang River and Black Water Creek). We noted that water levels in this region appeared higher, relative to the river banks, with extensive flooded vegetation at the river margins in most areas. We cannot say whether this water level difference represents a real difference (and delay) in the recession of wet season floods in this area. However, if this is so it is possible that the surveys of this region under represent caiman, and hatchlings, that are still dispersed in the flooded forest. Additional surveys re needed to address this possibility. It also is possible that the breeding season of caiman in this area is different from elsewhere in Nicaragua, perhaps timed by flood water levels. Again, additional sampling is needed. Finally, as noted in the Black Water Creek survey above, this area was devastated by a hurricane in 1988 and widespread evidence of forest alteration remains visible. While regrowth of the forest is occurring rapidly, it is evident that the structure, and possibly the ecological balance and productivity, of the riverine forest in the Bluefields area is still reflecting hurricane induced changes and this in turn may have affected caiman reproduction.

Discussion of *Caiman*. We were unable to identify any causal relationship between the localities with high caiman density and natural or human factors. Some of the dense populations were found in open rivers, e.g., Río San Juan. Others were in marshy lagoons, e.g., Kukalaya lagoon. No difference in the distance from commercial centers or the density of human inhabitants was evident. High density populations were located in all the regions surveyed except around Bluefields/Pearl Lagoon. There was a higher incidence of dense populations in the San Carlos region. The one low density survey in this region was the Río Sabalos which has a recent history of timber extraction, de-forestation, dense human settlement and visible siltation of the river. We suspect habitat modification has had a negative effect on caiman in this river.

The assignment of causal relationships to the observed caiman densities will have to await more detailed surveys and analysis. Data provided by IRENA on year to year changes in which areas produce most caiman skins suggest a basis for speculation about the structure and effect of caiman hunting. The IRENA data are assembled from reports of skin buyers and provide a fairly coarse-grained analysis of where the skins are harvested each year. Data for 1990-92 indicate that in 1990 and 1991 most skins came from the northern part of the Atlantic coastal area and were traded through Puerto Cabezas. In more recent years the bulk of skins have originated in the central, Río Grande de Matagalpa area. We speculate that the caiman hunters respond to harvest-caused reductions in caiman density by re-directing their hunting efforts to other areas (mobile, non-resident hunters), or by suspending hunting until they perceive the caimans again are numerous (resident hunters). Caiman hunters in the field explained to us that the fundamental equation for the economic success was whether they could catch enough in one night to justify the cost of the flashlight batteries used that night. At the present batteries cost approximately 5 Cordobas each (C 6.00 = U.S. $1.00) and fresh *Caiman* skins bring 5-12 Cordobas each; so for it to be worthwhile, each night's hunt must produce the skins of at least 3 caiman.

In large areas of the northern and central Atlantic coast, land and resource use is still allocated to traditional Miskito Indian communities. Each community has a well-recognized area within which it has nearly exclusive use of natural resources. This traditional system has great potential for assisting the structuring and regulation of the caiman harvest to ensure that sustainable levels of harvest are not exceeded. Unfortunately, traditional land use is increasingly being undermined. Non-Miskito colonists are penetrating down the river valleys from the central uplands, forest clearing and semi-permanent agriculture is spreading, and there is strong pressure from entrepreneurs to rapidly sell off natural resources of all kinds. Development of a system to regulate the caiman harvest would benefit if it remains supportive of traditional land use. It may be significant that the region where we found no dense caiman populations, around Bluefields, has the longest history of non-traditional resource extraction (e.g., mahogany logging dates from the 1860's) and has significant numbers of non-Miskito communities (i.e., Creole, Carib/Garifuna Indian and Mestizo) who do not use the same community allocation of resources. Also, we should caution that traditional use does not automatically lead to wise and sustainable resource use. We found low densities in the Kukra river in apparently ideal habitat. We were told this river system is hunted almost exclusively by Rama Indians who live on Rama Key, a small traditional community at the mouth of the Kukra river. The observed low densities of caiman suggest this resource has already been overexploited and is not currently capable of providing useful income to this community. A program of reduced harvesting to allow population recovery would be advisable.

Caiman Management. The CITES Management Authority, IRENA, is doing a fine job of regulating export of *Caiman* skins from Nicaragua. It was very roughly estimated that approximately 400 individuals are regularly involved in hunting caiman and others may participate on an occasional basis. Skins from the field are purchased by about 19 field buyers (Table 4). Prices of caiman skins at different levels in trade are shown in Table 5. Skins are then forwarded to a single licensed export tannery which purchases, tans, tags, and ships all the export quota under CITES permit from IRENA. As a safety factor to ensure that all the skins remain above the legal size even after shrinkage during tanning, the tannery only accepts skins greater than 4.5 feet total length. Once the skins reach the tannery, record keeping and inspections are exemplary and compliance with national and CITES regulation is very tight. A well designed system of inventory monitoring allows the Management Authority to close the season as the export quota target is reached and overruns have been insignificant or absent for the last three years.

The need to implement the CITES Universal Tagging Requirement in Nicaragua was discussed at length with IRENA officials. Some practical difficulties will be experienced because during the tanning process a skin from an individual caiman often is divided into different parts (flanks, tails, throat, girdles), which are shipped to different buyers. It may be necessary to apply additional tags to different parts. Discussions on a solution to this problem are ongoing and we will look with interest to solutions developed by other CITES Parties.

Regulation of internal processing and manufacture of caiman products is less well-regulated and requires improvement. During our surveys we identified a significant problem involving the harvest of undersized (i.e., juvenile male and adult female) caiman. The legal minimum size limit is designed to focus exploitation upon the large male component of the population which can more easily sustain harvest. The size limit is supposed to protect breeding adult females which are smaller than the minimum size limit so that production and recruitment is maintained. We noted widespread capture of caiman below the legal limit. We were able to inspect 75 skins in the field from five different sources. Of these, 55 were legal size and 20 (26%) were undersized. All our sources (hunters and traders) were very casual and unconcerned about taking and trading undersized caiman. We must stress that our direct personal inspection, IRENA data, and CITES export data, all confirm that none of these small skins enter formal international trade. The undersized skins are sold directly to small, unregulated artesanal tanneries and manufactured into low quality goods for local sale. The Managua market, the airport and other retail outlets offer a large volume of poorly constructed, small leather items for sale. For example, on 1 February 1993, we conducted an informal count of items for sale at the Managua International Airport. Approximately 223 belts, 32 handbags, 25 headbands and hatbands, 16 stuffed caiman, and 87 wallets, keychains and other small leathergoods items were counted. All of these items are presented as being crocodile although more than 90% of the items were caiman. A small number of items, particularly belts, were made from crocodile. A larger volume of similar material is displayed at the Managua open market and some of these items, allegedly from Nicaragua, are reported to be available for purchase in Honduras (P. Ross pers. observation).

While this local artesanal outlet for tanning and marketing illegal undersized caiman and crocodile skins and products exists, control of this trade will be difficult. Nevertheless, this illegal trade undermines regulation, endangers the sustainable use of the resource, and imperils CITES control of regulated trade, so it must be brought under control. It would be a relatively simple matter to bring the artesanal tanneries under the same level of licensing, control and inspection as the export tannery. Apparently, IRENA used to have jurisdiction over these tanneries, but this inadvertently was removed during legislative changes a few years ago. A significant component to this problem is that all the hunters we talked to were aware of the minimum size limit but were completely ignorant of the reason for it. When we explained the size relationships to sex and reproduction many hunters expressed some surprise, immediate understanding, and approval of such a sensible idea. A program of public education that explains the biological basis for the size limit would be valuable.

CROCODYLUS ACUTUS

Survey results for crocodiles are shown in Table 6 and survey conditions in Figure 5. Our surveys indicate that in Nicaragua, crocodiles are much less widely distributed and less abundant than caiman. We were directed to four locations on the Pacific slope and central highlands where crocodiles were said to persist (Salinas Grandes, Estero Real, Lagunas Monte Galan, and Ometepe) and at each of these sites we confirmed that small populations remain. The density of these populations is in every case low, even when only small areas of habitat were surveyed. We suspect that the number of individuals sighted may be close to the actual number present, i.e., about 70 crocodiles. We were told that a small population of crocodiles persists near Momotombo in Lake Managua and is suffering from the impacts of a local gill net fishery in the area. We were unable to confirm this.

We did not positively identify crocodiles in any of our extensive surveys on the Atlantic coast. However, we are confident, as are many of our informants, that crocodiles occur there. One of us (JPR) has seen a photograph of a fresh *Crocodylus acutus* skin collected near Sandy Bay in 1992. The provenance and identity of this specimen is completely verified. On several occasions during our Atlantic surveys we noted eyeshines of apparent large crocodilians that behaved in a distinctive surreptitious and wary manner, which we suspect were crocodiles, e.g., Laguna Narlaya, Kukalaya Lagoon, and Big Lagoon on the Ñari River. Unfortunately, we could not approach them and they were recorded as 'Eyes Only' in the surveys.

In independent surveys conducted by Dr. A. Valenzuela and Mr. Mario Espinal during November and December 1992, crocodiles were noted in seven localities (Appendix 1), some of which we also surveyed (i.e., Bambana River/Narlaya Lagoon, Prinzipolka River, Kukalaya Lagoon). Mr. Espinal is an experienced crocodile surveyor and we have no reason to doubt his observations. Unfortunately, the data provided to us from the Valenzuela/Espinal surveys did not reflect standard survey methods and as a consequence cannot be used to generate quantitative or comparative data. We conclude that the presence of *C. acutus* at several localities in the Atlantic drainage can be considered 'confirmed' but that the exact extent and quantitative assessment of these populations requires additional standardized surveying. In this regard, the Waspuk River, a remote tributary of the Río Coco that divides Nicaragua and Honduras and runs through the BOSAWAS reserve, a significant area of protected forest, should be surveyed.

Except for the population in Laguna Monte Galan, which is a special case of an isolated population and completely protected location, the observed densities of crocodiles in the Pacific drainage were low in every case.

Crocodile size. Insufficient data were collected to allow meaningful analysis of the size distribution of crocodiles. For future comparison with data from later surveys, the sizes of 14 individuals that were noted are given in Figure 6. They indicate only that some breeding and recruitment (hatchlings and smaller size classes) seems evident. One individual estimated at 8-10' was seen during the day at Estero Garita and is not shown in Figure 6. All other sighted crocodiles were at the lower size range of adult *C. acutus*.

Crocodile Management. Based on current information, *Crocodylus acutus* in Nicaragua would qualify as an endangered species under the Mace-Lande criteria (1991). While it is possible that additional populations remain to be discovered or that the Atlantic populations are larger than we suspect, the current quantitative data indicate that this species requires special management to allow population recovery and to ensure its survival. The primary threats to survival of the crocodile in Nicaragua are uncontrolled hunting, habitat loss, and limited funds for management. Crocodile farming and ranching has been proposed as a mechanism to provide economic incentives for crocodile conservation in Nicaragua. Several commercial groups have expressed interest in this possibility and one company, Nueva Era, S.A., has made significant investments in background information including the Valenzuela/Espinal preliminary survey. The IUCN/SSC Crocodile Specialist Group has strongly recommended that open cycle ranching programs that obtain eggs from wild populations should be promoted for their conservation benefits in preference to closed cycle captive breeding and farming operations that are relatively independent of wild populations.

The development of crocodile ranching in Nicaragua can only proceed if there is a clear conservation benefit to wild crocodiles and is contingent upon three necessary conditions:

1) The wild *Crocodylus acutus* population must be large enough to sustain harvest of eggs or hatchlings for stocking ranches.

2) The CITES Management Authority (IRENA) must have the capacity to manage and regulate harvesting and ranching.

3) CITES must approve changes in the present Appendix I listing of *Crocodylus acutus* to allow international trade in ranched crocodile products.

The current survey data indicate that crocodiles are fragmented into several isolated populations and the number of breeding adults may be very small. If our evaluation of sighting precision of about 50% is correct, then the total number of crocodiles in all the surveyed populations is of the order of 140-150 individuals and only a handful of these, possibly as few as 50, are adult breeding females. A key factor in evaluating the potential for crocodile ranching is the location and abundance of crocodile populations in the Atlantic drainage. Quantitative surveys to assess this resource are urgently needed and should be undertaken prior to further development of ranches.

The relative success achieved with the caiman export program demonstrates that the CITES Management Authority (IRENA) has the capacity to regulate crocodilian trade. However, resolving the problems of illegal use of caiman and crocodile skins in the artesanal trade must be addressed immediately to ensure that opening a trade in ranched crocodiles does not endanger wild crocodile populations by increased poaching.

A change in the CITES listing of *C. acutus* from Appendix I to Appendix II 'Trade in Ranched Specimens' could be achieved by several routes. Of these, submission of a proposal to trade a restricted quota of ranched animals under Conf. Res. 7.14 is the most conservative and follows the model established in eastern Africa for the progressive development of crocodile management programs and regulated trade in ranched specimens. Discussions have been held with the representatives of the management authority and an interested private company, suggesting this option.

The most immediate conservation benefit that could be associated with a ranching program in Nicaragua would be the involvement of the private sector directly and financially in the conservation of wild crocodiles and their habitat. One group of entrepreneurs have suggested that by virtue of their business leases of surrounding areas for shrimp farms and salt production they already control access to an important crocodile population. They have indicated that in return for being allowed to remove a regulated quantity of crocodile eggs for a ranch, they would undertake to preserve key mangrove habitat, employ and equip wardens, and conduct regular population monitoring (in conjunction with IRENA). This interesting proposal deserves careful attention. The obvious drawbacks are that the crocodile populations in question at Salinas Grandes may not be sufficiently large to immediately support an economically viable ranch and such a proposal does not address crocodile conservation needs elsewhere in the country. We recommend that this idea be examined with a flexible and pragmatic mind set, and that models be considered from other countries where private sector and government support have combined to conserve crocodiles. We particularly note the American alligator management program in Florida, U.S.A., where eggs for ranches are provided by the state from state lands as well as from private sources and captive breeding. The example of Papua New Guinea where the commercial crocodile ranch provides major funding support for the crocodile monitoring program is also useful.

RECOMMENDATIONS.

General Scientific Recommendations.

1) A regular program should be established to census and monitor the status of populations at key representative locations. These sites should be censused at least once a year. However, pre- and post-hunt censuses would be ideal, possibly in November and again in April. Data from these repetitive surveys would also provide calibration of the survey data. Recommended sites in the Puerto Cabezas area are Río Wark Wark and Kukalaya Lagoon; in the Bluefield area, Río Kukra and Black Water Creek; in the San Carlos area, the Río Zapote, Guacalito Viejo, Río Frio, and Río San Juan km 10-40.

2) A special study of growth rates and maturity of caiman to provide scientific data for determining the size limits that protect breeding females. One such study has been initiated by the Vida Silvestre staff of IRENA.

3) Special additional surveys of suspected important systems that were not included in the series of surveys reported here: Río Grande de Matagalpa and associated lagoons, Bismuna lagoon, Narlaya lagoon (for crocodiles), Río Coco and Río Waspuk (including participation of bi-national personnel with Honduras), Estero Real.

Recommendations for Management of *Caiman crocodilus*.

1) Domestic artesanal trade in illegal undersized caiman skins must be controlled.

- i) IRENA must be empowered to inspect, monitor, and regulate all tanneries processing wildlife hides and pelts.
- ii) IRENA must monitor outlets for artesanal leathergoods production at Masaya, Managua, and the International Airport.
- iii) IRENA must confiscate illegal skins and products, including artesanal leathergoods.

2) Management of the caiman trade by universal tagging of all hides and significant pieces of hide.

- i) IRENA must license all hide buyers and tanners.

ii) IRENA must purchase locking hide tags from the CITES Secretariat and sell these tags to hunters, skins buyers, and tanners at the lowest possible price.
iii) All whole skins (cueros entero) and frames (chalecos) should have a CITES tag attached to them at the time the animal is killed.
iv) If whole skins subsequently are divided into flanks (flancos), tails (colas), throats (gargantas), and bellies (panzas), additional uniquely numbered locking tags should be attached at least to the significant pieces (i.e., flanks and tails).
v) Prior to the hunting season which is centered on the November to May dry season, tags should be sold or issued to the hunters in the field (possibly in October).
vi) Unused tags should be returned to IRENA by June for a refund or for credit toward the purchase of the next year's tags.
vii) Once a CITES tag is affixed to a skin, that skin may be exported under permit from IRENA at any subsequent date.
viii) IRENA must maintain a computer database on the distribution and use of the crocodilian hide tags.

3) The current export quota of 10,000 *Caiman crocodilus* should remain unchanged pending new data from the monitoring program showing population recovery and a reduction in the domestic artesanal trade in undersized skins.

4) An education program should be launched to explain to the public, particularly the hunters and hide dealers, the biological basis for the size limits on hunting, hunting seasons, and the skin tagging program. This education program should include television, newspapers, radio (especially Miskito radio), brochures and posters.

Recommendations for the Management of *Crocodylus acutus*.

6) Wild crocodiles more than 2 feet long must be protected from all hunting.

7) A series of national parks, wildlife reserves, and other protected areas should be declared in which crocodiles are protected from all hunting. One site that is suitable for immediate protection as a crocodile sanctuary is Estero Real La Garita at Salinas Grande. If future surveys indicate a significant crocodile population there, the sanctuaries might be declared at the following sites: Kukalaya Lagoon, Narlaya Lagoon, Río Waspuk, Estero Real.

8) A ranching program should be established to allow the collection of wild crocodile eggs or the capture of wild crocodile hatchlings in areas where the monitoring program indicates the adult population is sufficiently large to withstand collecting pressure. In addition, any such egg collection/hatchling capture program should only be established in areas where the wild adult population and habitat are adequately protected.

9) IRENA should prepare and submit a ranching proposal to CITES for approval of the Parties. That proposal must describe in detail the proposed ranching program, including how the IRENA Management Authority will control the wild harvest, how it will regulate the licensed ranches, and how the program will benefit conservation of the wild crocodile populations. The proposal also should request a quota for limited export of ranch raised skins to provide an economic base for program development and support. In preparing the proposal, IRENA should be assisted by the private sector that will benefit from any ranching program, and by the IUCN/SSC Crocodile Specialist Group. The proposal must include:

- Survey data on the distribution of crocodiles and crocodile populations in Nicaragua.
- An annual program for monitoring (surveying) both protected and utilized crocodile populations, including a program for censusing nests (monitoring reproductive success) in those populations.
- A detailed description of the protection provided crocodile populations at specific sites.
- A detailed description of how the collection of eggs and hatchlings from the wild is controlled.

- Detailed descriptions of the individual licensed ranch operations should be provided, including information including housing, diet and feeding, temperature and water quality, incubation facilities and methods (if eggs are involved), veterinary care, and other aspects of husbandry, as well as slaughter and skin (and meat) processing methods and facilities.
- Annual egg or hatchling harvest quota should not exceed 50% of the annual output of the adult females in the specific harvest population.
- Provisions should be made for release of a portion (possibly 5%) of the ranch-raised yearlings back into the wild population if annual monitoring data indicate that the wild population is not stable or increasing.
- A system for tagging or otherwise marking ranched products and thereby preventing the entry of illegal wild caught skins and products into trade. For example, in addition to tagging the hides, it might be desirable to set size limits that could best be met by the ranches and not by hunters.
- Documented evidence that the domestic use of illegal undersized crocodile skins has been curtailed and that artesanal tanneries are being inspected and regulated.

General Management Recommendations.

10) IRENA's Management Authority should maintain communication with the CITES Secretariat and in shared waterways and wetlands ecosystems should coordinate conservation and management programs with Costa Rica and Honduras.

11) Appropriate authorities in Nicaragua should encourage the development of a professional association of ranchers, skin dealers, tanners, and other interested companies and individuals in the commercial sector, together with non-governmental conservation organizations. The purpose of the association should be to support the conservation and sustainable utilization of the caiman and ranched crocodile resource. This can be accomplished through fund-raising, including assessing the membership, to support surveys, protection of critical populations and habitats. Another function of the association should be to lobby government and to advise IRENA on crocodilian management.

12) The use of taxes currently collected on the export of caiman hides should be revised so the funds are placed in a government trust fund for the exclusive use by IRENA for crocodilian conservation. Fees collected by IRENA from the sale of CITES hide tags and ranching licenses should be placed in the trust fund for the same purpose.

13) IRENA's authority must be expanded to include inspection and regulation of all tanneries that process wildlife hides and pelts.

14) Appropriate legislation should be enacted to provide a legal basis for the crocodilian management program.

15) A regional or tri-national accord should be developed to coordinate crocodilian management in Nicaragua, Costa Rica, and Honduras.

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Table 2. Caiman Surveys Arranged by Location.

Region Locality	Survey Date	Caiman Sighted	Density Caiman/km	Total Km Surveyed
Puerto Cabezas				
Wark Wark River	3 Feb	23	0.74	31.3
Lamlaya Lagoon	3 Feb	0	0	18
Wark Wark River	4 Feb	12	0.38	31.3
Lamlaya Lagoon	4 Feb	0	0	17.3
Bambana River	6 Feb	6	0.18	33.8
Bambana River	7 Feb	0	0	0
Narlaya Lagoon	7 Feb	34	2.05	16.6
Kahru/Kisa Lagoon	8 Feb	13	1.69	7.7
Prinzipolka River	8 Feb	6	0.27	22.3
Kukalaya Lagoon	10 Feb	182	14.22	12.8
Kukalaya River	10 Feb	7	0.49	14.4
Wouhnta Lagoon	10 Feb	0	0	4.7
	Subtotal	283		
Bluefields				
Kukra River	16 Feb	11	0.38	28.6
Ñari River	17 Feb	16	0.52	30.5
Wawashang River	18 Feb	2	0.1	20.0
Black Water Creek	19 Feb	20	0.69	29.1
	Subtotal	49		
San Carlos				
Zapote River	23 Feb	21	2.16	9.7
Guacalito Viejo River	23 Feb	41	10..25	4.0
Lake Nicaragua	23 Feb	2	0.57	3.5
Río Sabalos	24 Feb	2	0.36	5.5
Isla Chica River	24 Feb	9	1.29	7.0
San Juan River	24 Feb	120	26.67	4.5
San Juan River	24 Feb	530	13.25	39.25
Río Frio	25 Feb	53	4.61	11.5
Boca Ancha	25 Feb	50	11.1	4.5
	Subtotal	828		
Totals and Average Density		1160	3.68	413.6
Variance		1	39.58	

Table 3. Caiman Surveys Arranged by Observed Densities.

General Density Location	Observed Density Caiman/km	Mean Density & % of Location Sample
Absent		
Lamlaya Lagoon	0	
Wouhnta Lagoon	0	
Pearl Lagoon	0	Mean density 0 in 5% of sample
Low Density		
Wawashang River	0.1	
Bambana River	0.2	
Prinzipolka River	0.3	
Kukra River	0.4	
Río Sabalos	0.4	
Wark Wark River	0.5	
Kukalaya River	0.5	
Ñari River	0.5	
Black Water Creek	0.7	Mean density 0.4 in 67% of sample (s = 0.18)
Medium Density		
Island Chica River	1.3	
Narlaya Lagoon	2.0	
Zapote River	2.2	
Kahru/Kisa Lagoon	2.5	Mean density 2.3 in 10% of sample (s = 0.75)
High Density		
Guacalito Viejo River	10.25	
Boca Ancha River	11.1	
Kukalaya Lagoon	13.2	
San Juan River	14.8	Mean density12.3 in 18% of sample (s = 2.06)

% of location samples is expressed as kilometers of total surveyed.

Table 4. Buyers of Crocodilian Skins by Region*.

Northern Region (RAAN)	
Rosita	1
Prinzipolka	5
Puerto Cabezas	6
Southern Region (RAAS)	
Bluefields	2
La Cruz de Río Grande de Matagalpa	2
Punta Gorda	1
Río San Juan Region	
Boca de Sabalos	2
Total Field Buyers	19

* Information provided to IRENA by Mr. Juan Sequiera, General Manager, Reptiles de Nicaragua, S.A. (Reptinic), Granada. These buyers purchase crocodilian skins from the hunters and sell them to the Reptinic tannery in Granada and other tanneries.

Table 5. Prices Paid for Caiman Skins in Nicaragua in 1993*.

Point of Sale Location / Source of Information	Price Information
Puerto Cabezas	
Narlaya Lagoon hunters	7 C's for a 4-foot long skin; 5 C's / foot total length for skins above 4 feet.
Prinzipolka River	
Kahru/Kisa Lagoon/Mango Village hunter	3 C's / foot of length for small individuals (2-4'); 8 C's / foot for skins over 4 feet.
Bluefields	
Ñari River/La Fe Village hunters	10 C's / foot length.
Bluefields	
Wawashang River hunter	10 C's / foot for skins 4 feet long or larger.
Granada	
Reptinic Tannery general manager	30 C's / foot for skins 4.5 feet or over.

* Information gathered from interviews with hunters, buyers, and tanners. Prices are listed in Nicaraguan Cordobas (C 6.00 = U.S. $1.00). Lengths are measured to the nearest whole foot.

Table 6. Abundance (individuals/km of shoreline) of caimans in several regions of South America.

Species	Abundance	Region/Habitat	Source
C. crocodilus	6.6–9.02	Perú / Rivers	Gorzula and Seijas 1989
C. crocodilus	8.51	Perú / Rivers	Verdi *et al* 1980
C. crocodilus	0.7–19	Suriname / Rivers	Glastra 1983
C. crocodilus	19.8–86.5	Suriname / Rivers	Outboter and Nanihoe 1989
C. crocodilus	1.61–155.71	Venezuela / Lagoons	Gorzula and Woolford 1990
C. crocodilus	5.5	Venezuela / Lagoons	Espinoza 1992
C. crocodilus	2.52	Guyana / Rivers	Gorzula and Seijas 1989
C. yacare & *C. latirostris*	0.4–29.8	Argentina	Waller and Micucci 1993
C. yacare	0.01–1.5	Bolivia / Rivers	King and Videz-Roca 1989
C. yacare	0.2–70	Bolivia / Lagoons	King and Videz-Roca 1989
C. yacare	3.0	Bolivia / Lagoons	Ergueta and Pacheco 1990
C. yacare	5.6	Bolivia / Rivers	Ergueta and Pacheco 1990
C. yacare	0.3–8.4	Bolivia / Rivers	Pacheco 1993
C. yacare	0.15–3.8	Bolivia / Lagoons	Pacheco 1993

Many of the lower limits of abundance indicated above represent exploited populations or observations made during the wet season when the caimans are dispersed, while unexploited populations or dry season concentrations may account for some of the upper limits. Adapted from Pacheco 1993.

Table 7. Crocodile Surveys Arranged by Location.

Region Locality	Survey Date	Crocodiles Sighted	Density Crocodiles/km	Total Km Surveyed
Managua and Pacific Coast				
Estero Real La Garita	1 Mar	18	1.09	16.5
Estero Ciego	2 Mar	6	0.27	22.3
Estero Real (Pto Morazon)	12 Mar	19	0.58	33.0
Estero El Chrro	13 Mar	2	0.12	17.1
Estero Marota	13 Mar	3	0.24	12.5
Isla de Ometepe	21 Apr	2	0.25	8.0
Lagunas Monte Galan	4 May	19	3.28	5.8
Totals and Average Density		69	0.60	115.2

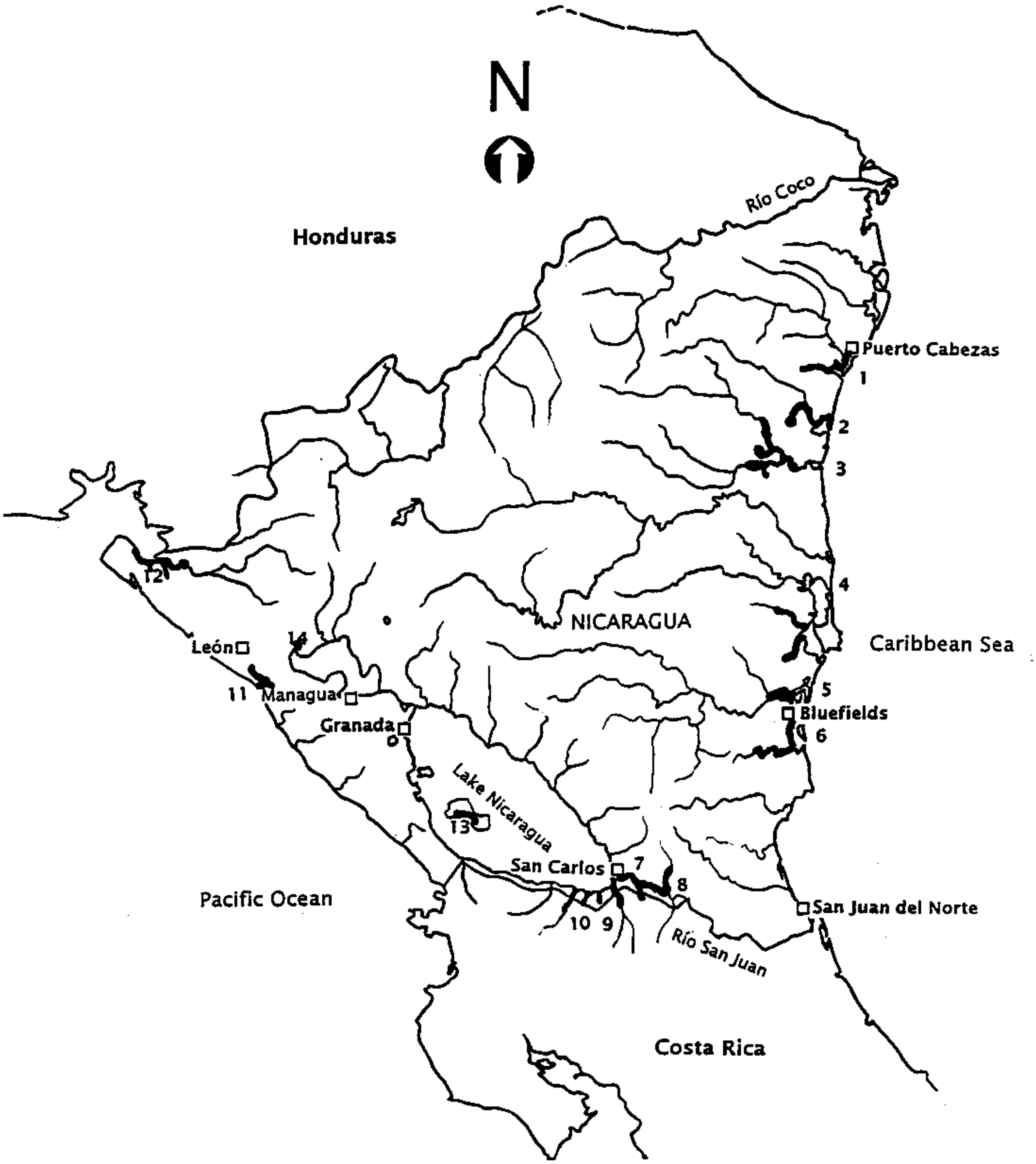

Figure 1. Map of Nicaragua showing general locations of surveys. 1) Wark Wark River, Laguna Karata and Lamlaya. 2) Wouhnta Lagoon, Kukalaya River, Kayubila Tingni (Creek), Kukalaya Lagoon, and Pusalaya Tingni (Creek). 3) Prinzipolka River, Bambana River, Lagunas Narlaya, Narlaya Bila River, Kusaia River, and Lagunas Kahru and Kisa. 4) Ñari River, Big Lagoon, and Wawashang River. 5) Black Water Creek and Escondido River. 6) Río Kukra River, Caño Negro, and Las Pavas Creeks. 7) Río San Juan, Río Frio, Boca Ancha Creek, and Río Isla Chica. 8) Río San Juan and Río Sabalos. 9) Río Zapote and Lake Nicaragua. 10) Río Guacalito Viejo and Lake Nicaragua. 11) Estero Real La Garita, Estero Ciego, Estero Cangura, and the Izapa and Los Arcos rivers. 12) Estero Real, Estero Chorro and Estero Marota. 13) Lake Nicaragua, Isla de Ometepe. 14) Lagunas Monte Galan.

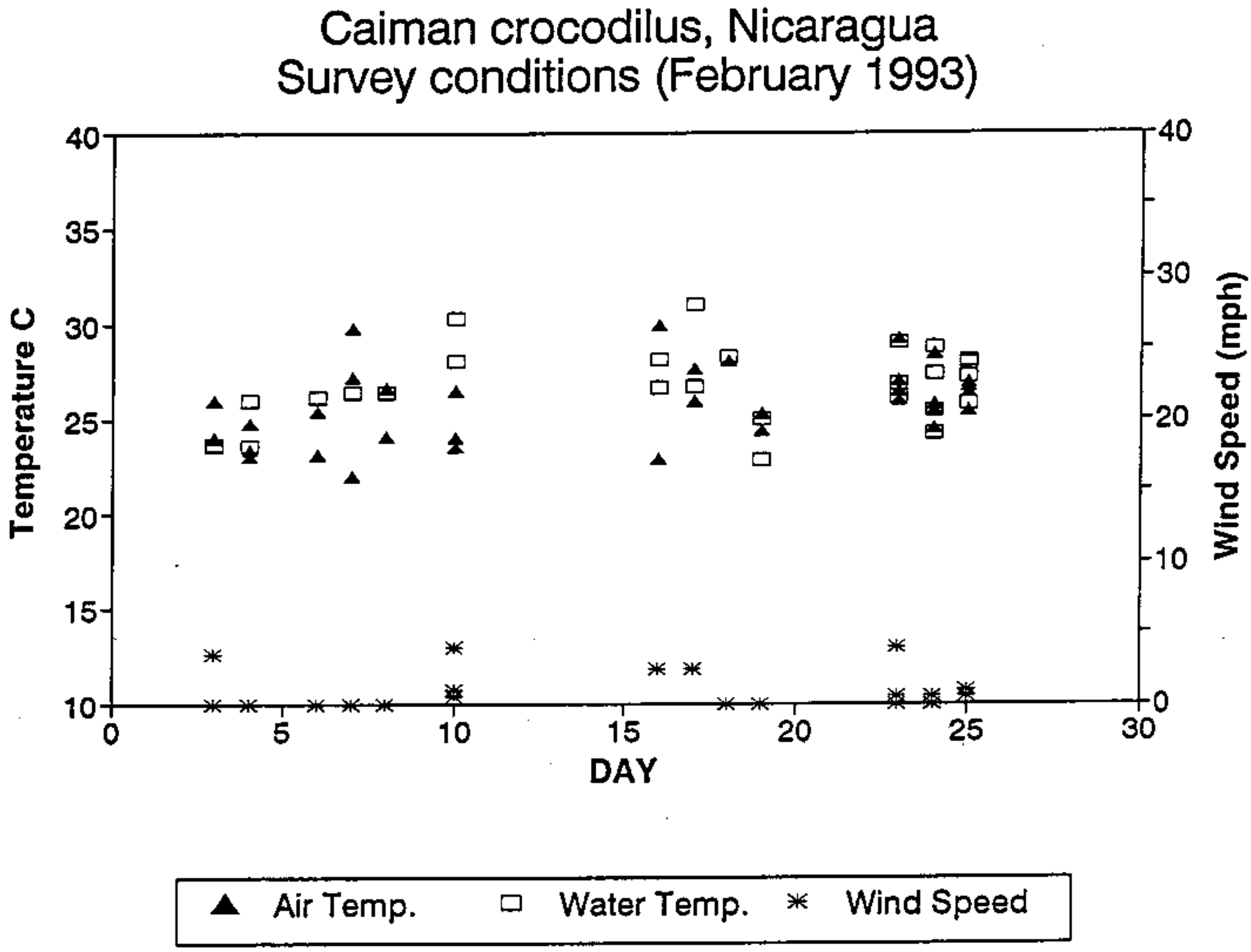

Figure 2. Caiman survey physical conditions.

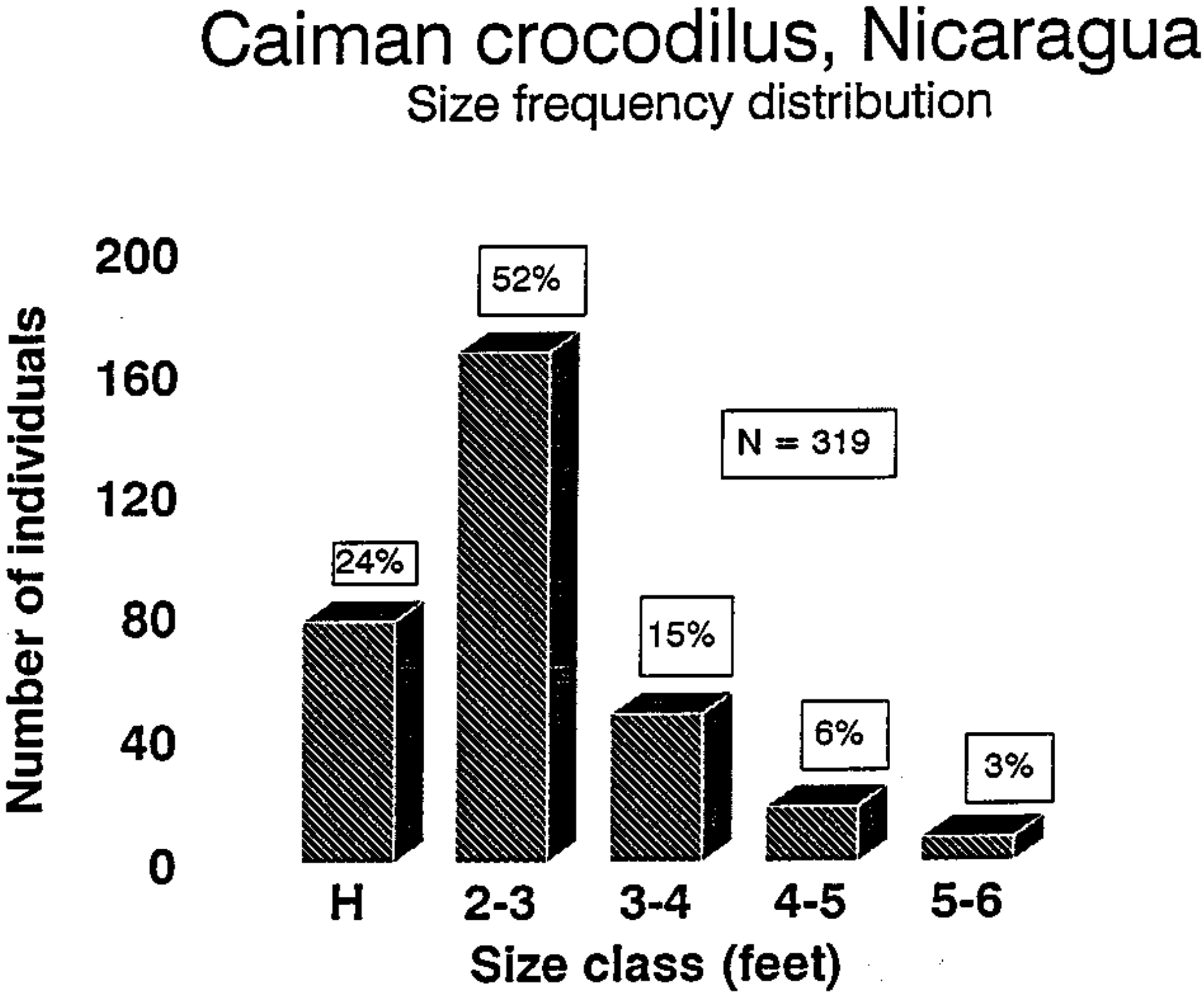

Figure 3. Caiman size distribution.

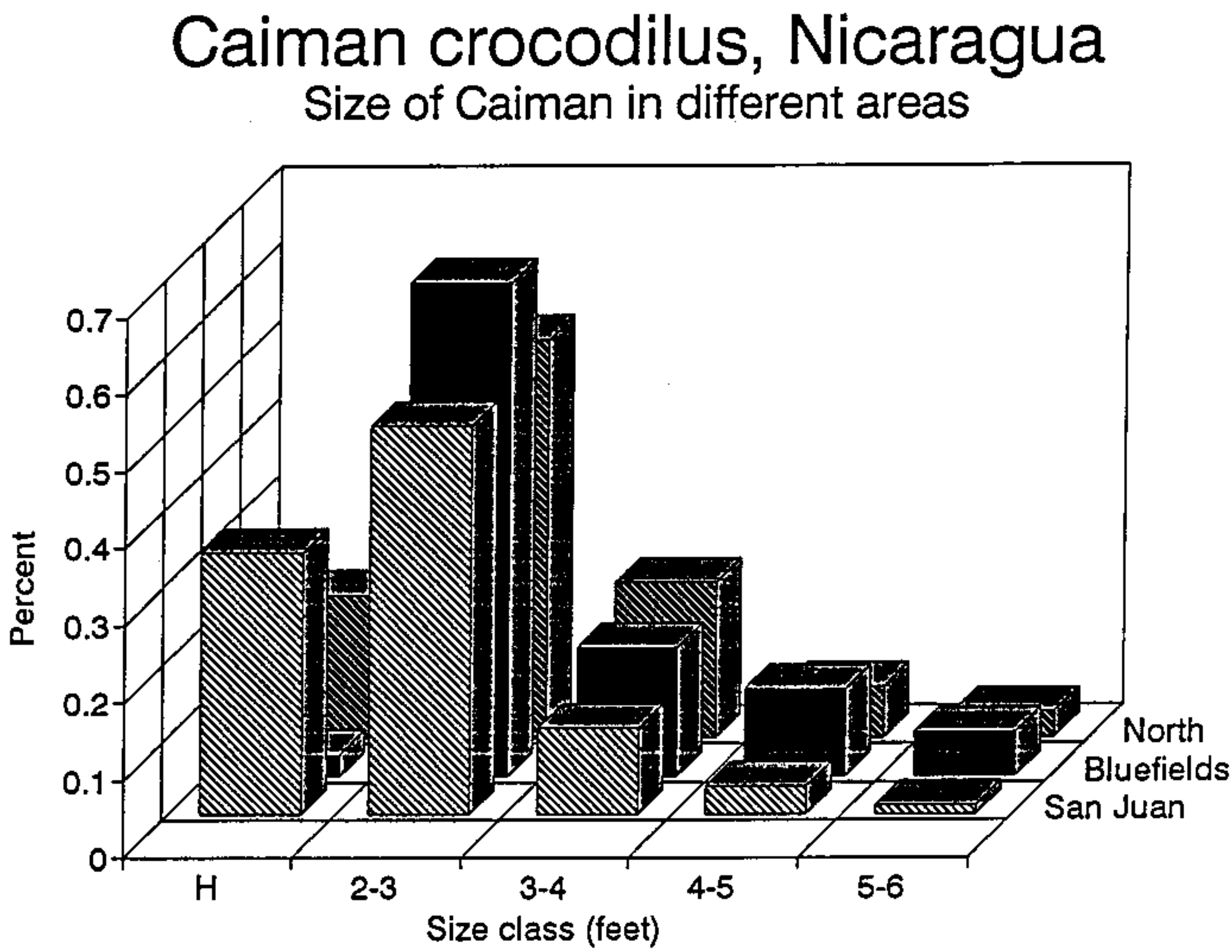

Figure 4. Caiman size distribution by region.

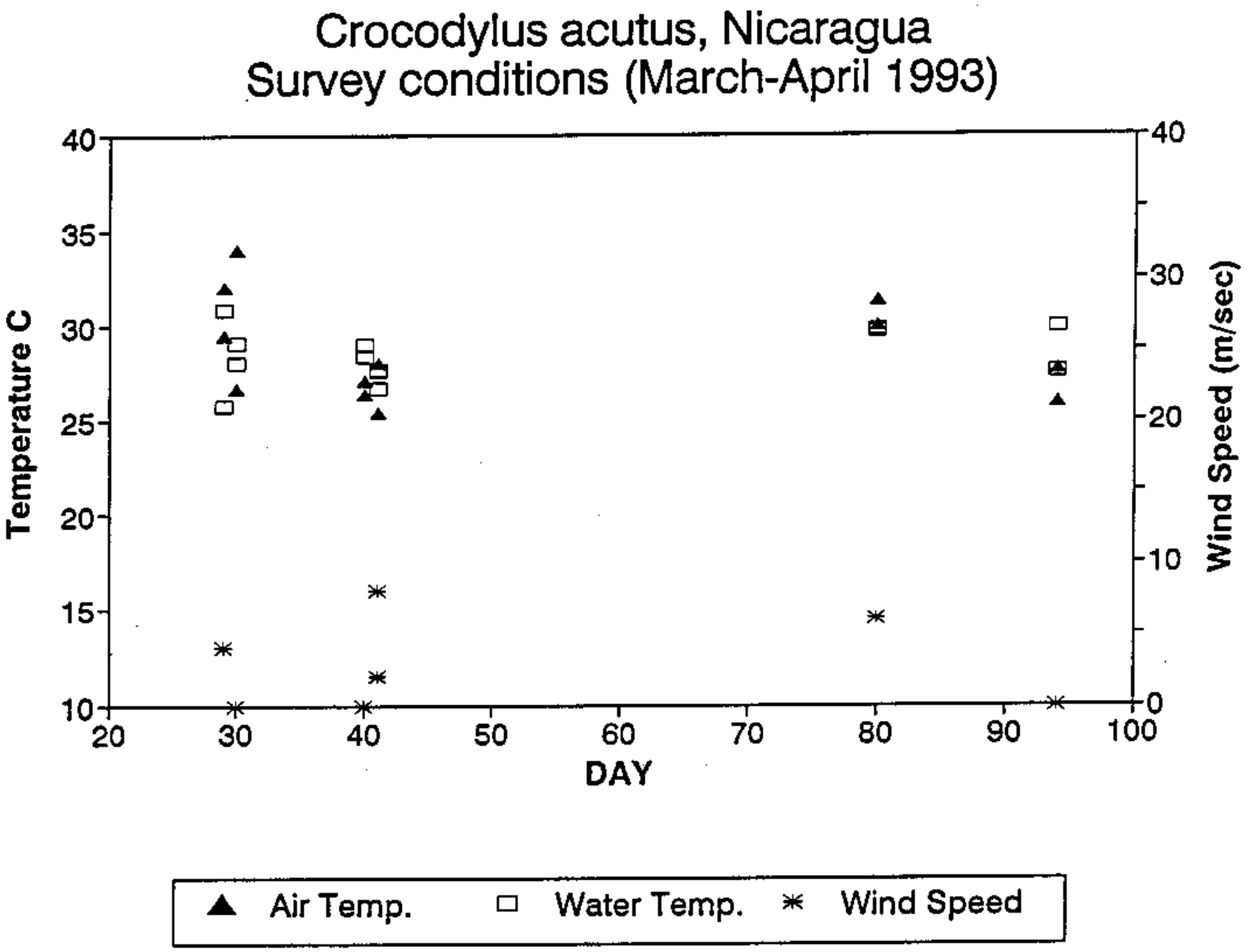

Figure 5. Crocodile survey physical conditions.

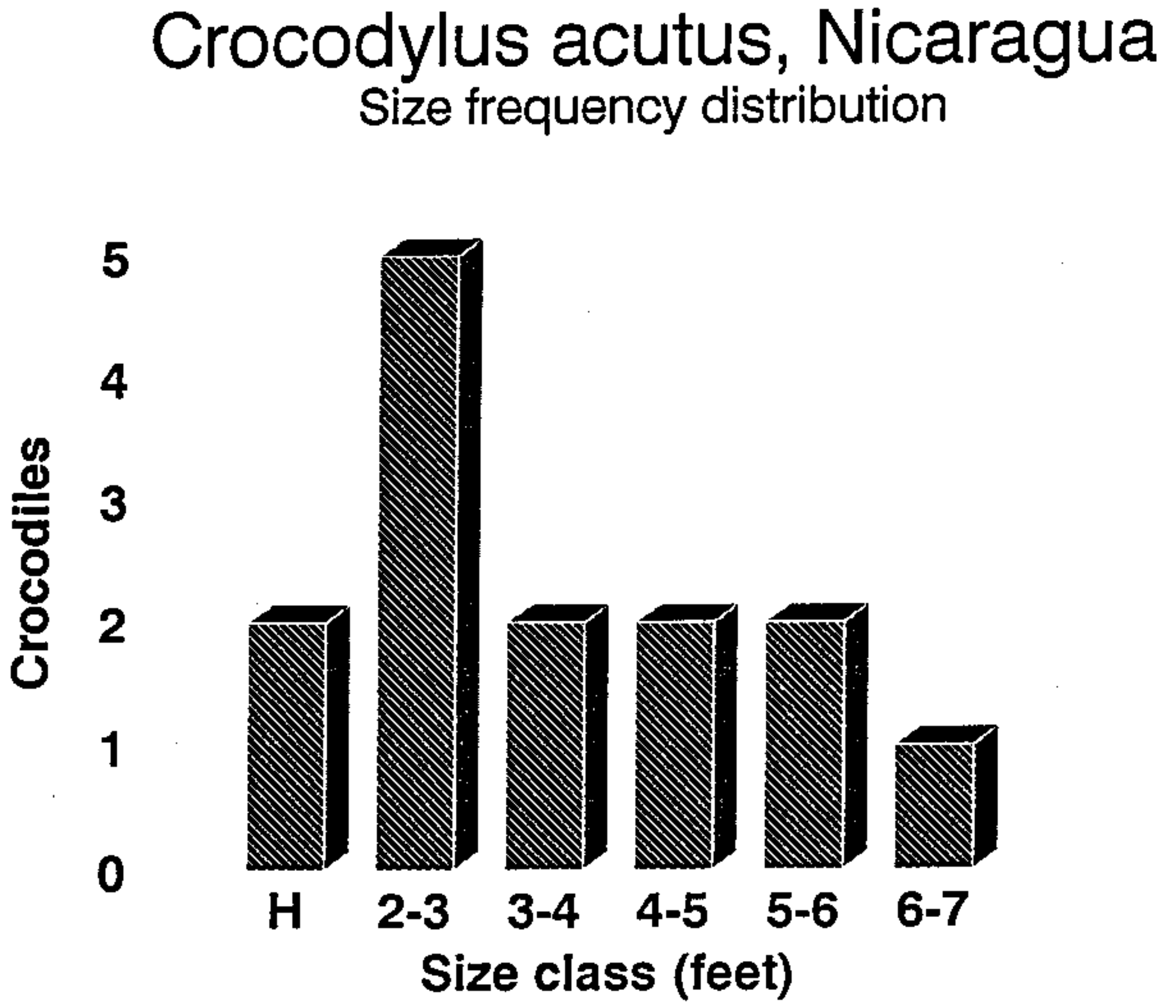

Figure 6. Crocodile size distribution.

STATUS OF THE CROCODILIANS OF PARAGUAY: RESULTS OF THE 1993 MONITORING SURVEYS

A REPORT FROM

BIODIVERSITY SERVICES, INC.,

TO

PARAGUAY'S MINISTERIO DE AGRICULTURA Y GANADERIA

AND THE

SECRETARIAT OF THE CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES

OF WILD FAUNA AND FLORA

By

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INTRODUCTION. Paraguay's crocodilians have been the subject of scientific studies for hundreds of years. Dobrizhoffer (1783-84) referred to two species of caiman found in Paraguay. Azara (1801) visited Paraguay and made observations on the characteristics and natural history of a black yacaré, and was told of a second species, a red caiman. Daudin (1802) described *Crocodilus yacare* (*Caiman yacare*) based on Azara's description of the black caiman. Schenkel (1902) reported *Caiman latirostris* from Villarca in southcentral Paraguay. Winkelried-Bertoni (1913) described general distribution of the caimans of Paraguay. Krieg (1928) observed yacaré caiman in the upper Paraguay River and near the mouth of the Pilcomayo River. Schmidt (1928) reported on his 1926-27 observations on *Caiman yacare* in the Paraguay River and *Caiman latirostris* in the Paraná River and lower Pilcomayo River, and demonstrated that Azara's black caiman was *Caiman yacare* and his red caiman was *Caiman latirostris.* Müller and Hellmich (1936) treated *yacare* as a subspecies of *Caiman crocodilus* and recorded it from a number of localities along the Paraguay River. Mertens (1943), Wermuth (1953), and Wermuth and Mertens (1961, 1977) also treated *yacare* as a subspecies of *Caiman crocodilus.* Fuchs (1971) described two new subspecies of caiman, *Caiman crocodilus matogrossoiensis* and *Caiman crocodilus paraguayiensis* (later spelled *matogrossiensis* and *paraquaiensis* by Fuchs 1974) from Paraguay and adjacent Bolivia and southern Brazil. These two subspecies were shown to be invalid by Medem (1983), King and Burke (1989), and Scott, Aquino and Fitzgerald (1990).

In 1973, Federico Medem traveled throughout southern South America to determine the conservation status of caimans in the region. His anecdotal observations on Paraguay's caimans were reported in Medem, 1983, LOS CROCODYLIA DE SUR AMERICA, Vol. II. Scott and Lovett (1975) recorded *Caiman yacare* from the Paraguayan chaco. Aquino (1988) reported on food habits of yacaré caiman in Paraguay.

Despite all these studies, surprisingly little is known about the conservation status of Paraguay's crocodilians. Throughout southern South America there is a long history of exploiting the caimans for their valuable skins. Past exploitation was not based on the biological needs of the species, their habitat, or level of exploitation that the populations can sustain. Considerable efforts are now being made to put utilization of caimans on a sustainable basis. This will be difficult or impossible to accomplish without repeatedly surveying the conservation status of the caiman populations. In the late 1980's surveys were initiated to collect the data needed.

From October 1986 through January 1987, under the sponsorship of the Inventario Biológico Nacional, Museo Nacional de Historia Natural de Paraguay, Ministerio de Agricultura y Ganaderia, Paraguay, and the CITES Secretariat, a survey of caimans in Paraguay was initiated and completed. That survey covered the entire country and documented the distribution of the various crocodilian taxa in Paraguay, the habitats they occupy, and general observations on their conservation (Scott, Aquino and Fitzgerald 1990). It demonstrated that *Caiman yacare* exists in good numbers throughout its historical range in Paraguay; despite much illegal hunting of the species in the last 30 years. Data from this crucial survey provides the basis for later long-term monitoring programs.

With funding from the Japan Leather & Leather-Goods Industries Association (JLIA), in October 1991, CITES–Paraguay, Ministerio de Agricultura y Ganaderia (MAG), and the CITES Secretariat initiated a survey of caiman populations to establish long-term monitoring sites. This survey covered the entire country and was under the supervision of Aida Luz Aquino, Scientific Authority, Oficina CITES–Paraguay, and Dr. Norman J. Scott, U.S. Fish and Wildlife Service. A total of 25 localities and more than 65 sites were visited in order to select permanent monitoring sites and sites for long-term studies on *Caiman yacare* and *Caiman latirostris* biology. When the selection is complete, MAG personnel will return annually to monitor the population at the sites.

In October 1992, brief preliminary nighttime spotlight surveys were made of the Río Apa and Laguna General Díaz, and daytime aerial surveys of the habitat around Laguna Inmakata, Laguna Riari, Laguna Morocha, Estancia Cerrito Jara and much of the upper Río Paraguay and Río Negro (Messel and

King 1992). This brief survey effort yielded a series of recommendations to the Government of Paraguay for the effective management of the wild caiman resource for the conservation and economic benefit of Paraguay. Included in those recommendations was the establishment, as soon as possible, of a program for repeatable censusing of the wild populations; that the results of these repeated surveys would provide the basis for determining the status of the populations (increasing, decreasing or remaining stable) and for developing a comprehensive management plan for the caiman in Paraguay.

With continued funding from the Japan Leather & Leather-Goods Industries Association (JLIA), in October 1993, the first of the repeatable systematic surveys were conducted in 87 sites scattered through most of Paraguay's western, central, and northern caiman producing regions. Most of these locations will serve as permanent sites for monitoring population trends. The results of those surveys are the subject of this report.

ACKNOWLEDGMENTS. This survey would not have been possible without the support of Akira Saikyo of the Japan Leather and Leather Goods Industries Association (JLIA), which funded this survey, and especially JLIA's CITES Promotion Committee and the committee chairman, Mr. Yoichi Takahara, who actively promotes conservation through implementation of programs for the sustainable utilization of wildlife resources.

The Paraguay office of the United Nations Development Programme (UNDP) provided crucial funding for equipment and personnel. Of equal importance is the continuing support of Paraguay's Government and particularly of the Minister of Agricultura y Ganadería, Raúl Torres Segovia, and the Autoridad Administrativa de CITES, Ing. Oscar Ferreiro.

The fieldwork would not have been possible without the hospitality and logistical support provided to the survey team by many estancia owners, managers and staffs. We cannot emphasize enough how difficult the fieldwork would have been if estancia hosts had not welcomed the survey team and taken the time to answer questions or show the team the best caiman habitats in the region. Of particularly note were the following: Estancia Palo Santo and its owner François Martel; Estancia Juan de Zalazar and its owner, Robert Eaton, its agent in charge of arrivals, Anibal Aldama, its administrator, Dr. Roque Quevedo, and Miguel Fernandez; Estancia La Golondrina and its administrator, Ing. José Sánchez, and our contact with La Golondrina, the Fundación Moises Bertoni; Estancia Laguna General Díaz and its operator, Yasushi Kobuchi; Estancia Loma Porá and its owner, Dr. Heriberto Roedel, its administrator, Don Mario Ortíz, and our contact for Loma Porá, Dr. Emilio Escobar Faela; Estancia La Josephina and its owner Don Chiquitin Nuñez, our contact for Josephina, Juan Nuñez, and ranchhand, Pablo Acosta; and Estancia 26 de Agosto and its foreman, Eduardo Justiniano, and administrator, Jorge Dacack. In addition, Eliodoro Silva, and his son, Aldo Silva, opened their house to the survey team in Bahia Negra. Yasushi Kobuchi not only hosted the survey team on Estancia Laguna Gral. Díaz, he also provided all logistical support for the team in Puerto Valle Mí and Bahia Negra and for surveys of the Río Apa, upper Río Paraguay, and Río Negro.

In addition, of special note is the support of the staff of the Office of CITES–Paraguay, especially Hector Caballero, Margarita Mieres, Silvia Frutos, Luís Garcia, Carmen Vitale, and Carlos Vasquez, whose hardwork and dedication freed the survey team to chase after caimans and caiman habitats. Hector Caballero, Margarita Mieres, and Cristina Morales accompanied the team on some of the surveys.

Finally, encouragement and logistical support was received from the Camara de Industriales de Pieles Silvestres de Paraguay and from the staff of the Museo Naciónal de Historia Natural del Paraguay; from Emeritus Professor Harry Messel and the IUCN/SSC Crocodile Specialist Group; from Dr. Obdulio Menghi and the CITES Secretariat; and from Juan Villalba-Macias and TRAFFIC-SUDAMERICA.

METHODS. The survey methods for systematic and repeatable night spotlight censusing of crocodile populations are described in Messel *et al* 1981, and summarized and discussed in Bayliss 1987 and Graham 1987. In addition, they are outlined in the Crocodile Specialist Group's (1993) 'GUIDELINES ON MONITORING CROCODILIAN POPULATIONS'. Refer to these publications for details of the survey methods.

An estimation of the density of crocodilian populations was obtained by traveling representative sample sections of waterways at night and counting the crocodilians sighted with a spotlight. Where possible, an estimate was made of the size of the individuals sighted from which a size distribution of the population can be estimated. Such brief sample surveys do not sight and count all the crocodilians in an area. However, extensive repetitive sampling by Professor Messel and colleagues in Australia (involving thousands of such surveys over a period of 11 years) has established a very sound statistical basis from which the results of single night spotlight counts can be interpreted with confidence. By following a strict protocol of procedures to conduct such surveys, developed by Professor Messel, the results can be compared with similar survey results in other places and interpreted with confidence. Comparisons between locations and between different sample periods can also be made.

This technique has been used in crocodilian surveys in numerous countries involving several different species. In several studies additional repetitive sampling, and population estimation by other techniques such as mark and recapture studies, confirm the validity of the results of single night spotlight surveys. The technique has been widely applied to the quantitative survey of crocodilian populations in Latin America, e.g., Honduras (King *et al* 1990), Venezuela (Gorzula and Seijas 1989, Thorbjarnarson 1991), Guyana (Gorzula and Woolford 1990), Argentina (Waller and Micucci 1993), Bolivia (Erqueta and Pacheco 1989; Pacheco 1993), Costa Rica (Mahmood and Chaves 1992), Haiti (Thorbjarnarson 1988), Nicaragua (King and Ross 1993), and elsewhere in the world (see Bayliss 1987).

The essential elements of the procedure are that the exact position of start and end points of each survey are carefully noted as is the distance or area surveyed, and these are reported in subsequent publications so the surveys can be duplicated by independent researchers. In the surveys reported here, a Magellan GPS NAV 1000 PRO was used to accurately determine the latitude and longitude in degrees, minutes and seconds of all start and end points. In one instance, indicated below, the Magellan GPS instrument was used in combination with a KVH DataScope digital compass and rangefinder to project (calculate) the location of an alternate endpoint that was in sight but could not be reached because of shallow water. Physical variables are recorded such as wind strength, tide or water level, vegetation, water and air temperature, and water salinity, which are known to affect the proportion of crocodilians sighted. Preferably, surveys are conducted at high speed to cover distances of 20-50 km in a night after preliminary reconnaissance has been made of the waterway in daylight to identify hazards and verify positions and distances.

In Paraguay it was not always possible to survey caiman populations using the standard nighttime spotlight survey protocol in which every individual crocodilian sighted is approached sufficiently close to record what species it is, and to estimate its size, and record its location. Caimans in some Paraguay populations were so abundant and so close together that it was not possible to write fast enough to record the usual data before several nearby caimans had submerged or moved to new positions, making it impracticable to keep track of which individuals had been recorded and which had not. This is particularly true in dense populations that contain numerous dominant, territorial males more than 2 m in length. Many of these males actively swim toward the spotlight only to submerge with a great swirling splash when they are within 3–6 m of the boat. This may be part of a territorial display, a challenge to the boat invading their territory, and finally submission when the boat does not flee. Some of the dominant males swim not toward the boat but diagonally away from it. In either instance, movement of the large males causes smaller caimans to flee from their path or to submerge. This combination of a large, dense population of moving, submerging and reappearing caimans in a relatively small body of water prevents the spotter from doing more than make a fast count of the total number of caimans present before they moved or submerged. A number of populations were sufficiently abundant to force a simple count of the total number of caimans present. These total counts were conducted from a boat moving through the population or from shore. Simple total counts do not contribute information on the size classes of the caimans in the population. To overcome this shortcoming, where possible, sizes were recorded of the caimans sighted from a boat transect through the population. Data from these transects are presented below as the percentage of the population in each size class encountered.

Occasionally a count from shore would be hampered by vegetation that partially blocked a clear view of the total population. One such occasion occurred when the dense population in Arroyo Syry at Laguna General Díaz was surveyed. The population was so dense, 1,017.3 caimans/km, that it was impossible to conduct the normal standard survey. Two separate spotlight total counts were taken of Arroyo Syry, one from a tractor on shore that counted 2,050 caiman, and one from a boat moving down the middle of the stream that counted 2,238 caiman. The total count from the tractor moving along the shore was easier because it disturbed the animals less so they moved less. However, thick stands of cattails, *Typha*, in two locations blocked the view of the stream, making it difficult to sight caimans along the near shore. The count from the boat provided an unrestricted view of the caimans, but clearly disturbed many, prompting them to move toward or away from the boat, adding to the difficulty of trying to keep track of which ones had been counted and which had not. To help overcome this difficulty, one spotter (W. King) counted the caiman on the right side of the boat, while a second spotter (L. Aquino) counted the caimans on the left side of the boat. Considering the difficulty imposed by the cattails, *Typha*, the difference in the two Arroyo Syry counts was surprisingly small (8.5%). This suggests that in other localities where local conditions forced total counts from shore, a small error was introduced if the view of the total population was partially blocked by vegetation. When that occurred, it is noted in the survey results presented below and the count is considered a record of the minimum number of caimans present.

A few Spanish terms are used throughout this report both because they appear prominently on maps of Paraguay and in other publications and because they are terms widely used in Paraguay. These few terms are defined here for the reader who is not fluent in Spanish:

- *arroyo* = stream
- *cañada* = gully, ravine
- *estancia* = ranch, usually a cattle ranch
- *lago* = lake
- *laguna* = lagoon, a shallow lake
- *represa* = a dam, or the impounded lake or pool behind the dam
- *retiro* = retreat, usually a small ranch or secondary ranch headquarters
- *riacho* = stream, frequently an intermittent stream that flows only during the rainy season, or the permanent pools found along the stream course during the dry season
- *rio* = river
- *tajamar* = man-made waterhole, dug cattle tank, livestock waterhole, or highway borrow pit. In many tajamars the water is supplied from a well, so the waterlevel fluctuates little during the year. Special reference is made to the '*tajamar Australiano*', a waterhole in which the earth removed by the bulldozer during construction is formed into a tall mound adjacent to the waterhole. A depression is dug into the top of the raised earth mound and a windmill used to fill it with water from the waterhole. Gravity flow through PVC pipes disperses water from the raised earth pool to other parts of the ranch.

Original field data records of the surveys are retained in the offices of CITES–Paraguay in Asunción, Paraguay, and the Crocodile Specialist Group and Biodiversity Services, Inc., in Gainesville, Florida, USA.

RESULTS. In the presentation of the survey results that follow, the sites of the individual surveys are grouped together primarily under the general region, Central Chaco, Eastern Chaco, Río Pilcomayo, Alto Paraguay, and Oriental localities, and secondarily under the name of the estancia or waterway where the surveys occurred.

CENTRAL CHACO AREA

ESTANCIA PALO SANTO. For the survey sites on this ranch, map Loma Plata HOJA SF-21-9 in the 1:250,000 Mapa Nacional series, was used in combination with a partly hand-drawn map provided by the ranch. Only *Caiman yacare* is known to occur on the ranch.

1. LAGUNA CORONEL MARTINEZ. On the night of 28 October 1993, this entire 1 km long lagoon was surveyed. The exact size and shape of the lagoon varies with the waterlevel between dry and rainy seasons. On the map it is shown as a 'V'-shaped lake with the arms extending NNW and SW from an east pointing apex. Each arm is approximately 0.5 km long so the midline length of the lagoon is 1 km. The surrounding habitat is intermediate between the dry chaco and the inundated chaco. The shore of the lagoon was a 1–30 m wide stretch of essentially bare sand and clay with scattered logs. In the past the lagoon has been covered with water lettuce, *Pistia* sp., but at the time of the survey was free of floating or emergent vegetation. The water was less than 2 m deep.

	Latitude	Longitude
Laguna Coronel Martinez starting point at eastern apex the lagoon	22°14'20" S	59°09'45" W

This is good caiman habitat. The lake is freshwater (0‰ salinity) and supports a variety of fish and waterfowl. The caimans were so abundant that the standard survey could not be conducted, so a total count was made from shore and combined with a size-class sample made from a boat transect through the population. Hunting is not allowed on Estancia Palo Santo so the caimans are not shy. Nevertheless, many submerged before the boat was within 30 m of them.

A total of 487 *Caiman yacare* were sighted, and the transect sample indicates the following percentage size classes were present: 2.4% (Hatchlings), 46.3% (2–3'), 4.8% (3–4'), 4.8% (4–5'), 24.4% (5–6'), 15.5% (6–7'), and 1.6% (7–8'). No true hatchlings were sighted. The 'Hatchlings' recorded are based on animals less than 2' in length sighted during the transect. However, at least two pods of these near yearlings were sighted, one of 11 individuals at the end of the SW arm of the lake and one of 39 individuals near the apex of the 'V'.

Waterway	Caiman sighted	km surveyed	Caiman/km
Laguna Coronel Martinez	487	1.0	487
Totals	487	1.0	

2. CASADO TAJAMAR. On the night of 28 October 1993, this 1.0 hectare tajamar (bulldozed cattle waterhole) was surveyed. This is one of a series of three similar tajamars constructed at the downstream end of the Riacho Mosquito, a seasonal stream that carries salty water (12‰ salinity) from the upstream drainage. The waterhole has become an artificial evaporating basin that further concentrates the salt in the water (27‰ salinity in the tajamar), with the result that the cattails and other emergent aquatic vegetation, the fish, and the mollusks have all died. The waterhole now is a dead sump that smells of hydrogen sulfide. The surrounding area is a seasonally flooded grassy savanna on heavily salinized soils.

	Latitude	Longitude
Casado Tajamar	22°12'19" S	59°11'26" W

No caimans were sighted.

Waterway	Caiman sighted	ha surveyed	Caiman/ha
Casado Tajamar	0	1.0	0
Totals	0	1.0	

3. Riacho and Represa Mosquito. On the afternoon of 29 October 1993, the Riacho Mosquito and that portion of it impounded as a large lake north of Estancia Palo Santo's main east-west road were surveyed. The Riacho Mosquito is a salty stream (12‰ salinity) that supports little apparent wildlife at this time; although it becomes sufficiently fresh to support a freshwater flora and fauna (including caiman) in the rainy season. The shore is littered with dead rooted vegetation (what appeared to be the roots and stems of cattails) and dead mollusks. A thin white line of dried salt encrusted the soil and flotsam just above the waterline.

The lake was constructed by building an earth dam across the course of the stream for the purpose of retaining water through the dry season. It accomplishes that but as an evaporating basin that further concentrates the salt (73‰ salinity). Dead trees line part of its shore. No aquatic vegetation is present apart from a reddish-brown algal fringe at the water's edge. Fish skeletons and mollusk shells litter the shore.

	Latitude	Longitude
Riacho Mosquito at the bridge on the Estancia Palo Santo east-west road	22°11'46" S	59°14'03" W

No caiman were sighted and no sign of caiman was detected. This was not a standard survey and the results are offered here to show the variety of habitats encountered in Paraguay.

Waterway	Caiman sighted	km surveyed	Caiman/km
Riacho and Represa Mosquito	0	2.0	0
Totals	0	2.0	

Estancia Juan de Zalazar. For the survey sites on this ranch, maps Loma Plata HOJA SF-21-9 and Pozo Colorado HOJA SF-21-13 in the 1:250,000 Mapa Nacional series, were used in combination with a partly hand-drawn map provided by the ranch. Only *Caiman yacare* is known to occur on the ranch, but the known range of *Caiman latirostris* is sufficiently close that it is possible the species might occur here.

4. Laguna Benítez Cué. On the night of 30 October 1993, this 3 km long lagoon was surveyed. It is a 'C'-shaped, freshwater (0‰ salinity) lagoon with the opening of the 'C' oriented to the NW. The waterlevel was sufficiently low to provide a 10–30 m wide flat shoreline free of vegetation other than sparse grass on the upper slopes. Near the water's edge the shore consisted of dried mud-cracked cakes of what appeared to be dehydrated *Pistia* peat. In the wave lap zone there was a slurry of dead algae and mud. Mud extended offshore some distance. The northwestern end of the lagoon is only a few inches deep, sufficiently shallow for wading birds to walk across its middle. The lagoon supports a good population of spoonbills, stilts, cormorants, screamers, and tapirs. The combination of wide muddy shore and shallow water discouraged the use of a boat. Instead, the lagoon was surveyed by spotlight from the back of a pickup truck on the shore.

	Latitude	Longitude
Laguna Benítez Cué start point at the tip of the SW arm	23°02'03" S	59°13'01" W
Laguna Benítez Cué end point at the tip of the NW arm	23°01'46" S	59°12'28" W

A total of 63 *Caiman yacare* were sighted in the following size classes: 4 (4–5'), 1 (5–6'), and 58 'Eyes Only'. The majority of the caiman were on the opposite side of the lagoon and many were light shy, submerging as soon as the spotlight beam hit them. Hunting is prohibited on Estancia Juan de Zalazar, but the ranch's many large lagoons are popular camping and fishing spots for local citizens, many of whom surreptitiously hunt despite the wishes of the owners. During our daytime reconnaissance of the lagoon, two tapirs were spotted and only our presence and discouraging shouts prevented hunters in a passing pickup truck from shooting them. The shyness of the caiman may well result from this 'holiday' hunting pressure.

Waterway	Caiman sighted	km surveyed	Caiman/km
Laguna Benítez Cué	63	3.0	21.0
Totals	63	3.0	

5. LAGUNA HE-É. On the night of 30 October 1993, this 1.8 km long freshwater (0‰ salinity) lagoon was surveyed. Its name is sometimes spelled Laguna Jhe-É. It is a 'C'-shaped lagoon with the opening of the 'C' pointing south. The road passes between the mouth of the 'C' and marshes lying to the south. The lagoon is a popular camping and fishing site for local citizens. Several groups were camped across the lake on the NW shore the night of the survey. The lagoon could easily have been surveyed by boat, but the narrowness of the lake and the extreme shyness of the caimans (most submerged as soon as the spotlight beam hit them) and the presence of a wide grassy shore made surveying from a truck on shore possible.

	Latitude	Longitude
Laguna He-É starting point at the end of the SW arm	22°58'50" S	59°07'08" W
Laguna He-É end point at the end of the SE arm	22°58'40" S	59°07'01" W

A total of 38 *Caiman yacare* were sighted in the following size classes: 2 (4–5'), 1 (5–6'), and 35 'Eyes Only'. The majority of caiman were located on the far shore, opposite from the road. The only caiman on the near shore were in the part of the lake where campers occupied the opposite shore. The shyness of the caiman undoubtedly comes from hunters and from harassment by campers and fishermen.

Waterway	Caiman sighted	km surveyed	Caiman/km
Laguna He-É	38	1.8	21.1
Totals	38	1.8	

6. LAGUNA TAPA CUÉ. On the night of 31 October 1993, this 1.8 km long lagoon was surveyed. It is a slightly salty (5‰ salinity) 'C'-shaped lagoon with the ends of the 'C' pointing west. It supports a good fauna of fish and mollusks. A low swale of seasonally flooded wetland extends south from Tapa Cué lagoon to Romualdo Cué lagoon. As the dry season progresses, Tapa Cué shrinks in size, finally occupying only the eastern end of its shallow basin. At the time of the survey, the waterlevel in the lagoon was relatively low. The exposed, hard sandy shore varied from 20–30 m wide. A soft ooze of muck and algal debris extended from the water's edge inland for several meters. The lagoon was shallow (much of it less than 1 m deep) and drying. Although it was the rainy season, the rains had not yet started in earnest. The general area is a mosaic of dry chaco and inundated chaco.

	Latitude	Longitude
Laguna Tapa Cué starting point at the end of the SW arm	23°01'08" S	59°11'39" w
Laguna Tapa Cué end point at the end of the NW arm	23°00'54" S	59°11'27" W

A livestock fence prevented us from approaching Tapa Cué closer than 500 m by pickup truck or boat, so a 12-volt battery and spotlight were hand-carried and the shoreline was surveyed by foot. The survey was done by spotlight from the shore. A total of 33 *Caiman yacare* were sighted in the following size classes: 1 (6–7'), 1 (7–8') and 31 'Eyes Only'. The 6–7' and 7–8' specimens were at the northern end of the lagoon, encountered on land, leaving the water and heading toward the surrounding dry chaco forest. Fresh tracks in the mud at that location recorded the movement of dozens of caiman into the surrounding forest, where they apparently will wait the late arrival of the rains and renewed expansion of the lagoon. The caiman were light shy, many submerging when the spotlight beam hit them.

Waterway	Caiman sighted	km surveyed	Caiman/km
Laguna Tapa Cué	33	1.8	18.3
Totals	33	1.8	

7. LAGUNA ROMUALDO CUÉ. On the night of 31 October 1993, this 2.6 km long lagoon was surveyed. It is a 'C'-shaped lagoon with the ends of the 'C' pointing northwest. A low swale extends from the northern end of Romualdo Cué to Tapa Cué to the north. The slightly salty (5‰ salinity) water was sufficiently low to provide a 3–70 m wide hard baked clay, sand , and muck shore between the water's edge and the surrounding forest. The ends of the arms were shallow and drying. Cattle walked across the ends without getting much more than their ankles wet. The lagoon was surveyed by spotlight from the back of a pickup truck that drove the western shore on the inner curve of the crescent. The surrounding habitat is a mosaic of dry and inundated chaco.

	Latitude	Longitude
Laguna Romualdo Cué starting point at the end of the north arm	23°01'33" S	59°11'28" W
Laguna Romualdo Cué end point at the end of the south arm	23°01'46" S	59°11'41" W

A total of 46 *Caiman yacare* were sighted, all in the 'Eyes Only' category. Romualdo Cué is a favorite camping and fishing site used by local citizens. As a consequence, the caimans probably are harassed more here than in many other populations. The caimans were light shy.

Waterway	Caiman sighted	km surveyed	Caiman/km
Laguna Romualdo Cué	46	2.6	17.7
Totals	46	2.6	

8. CAÑADA LUCI-Í. On the night of 31 October 1993, this 0.9 km long meandering waterway was surveyed. Although it looks like a natural waterway, it is an artificial impoundment in a fossil oxbow of the Riacho San Carlos behind an earth dam formed by the ranch road. The water is essentially fresh (3‰ salinity). Large stands of cattail, *Typha*, line the shore and partly obscure the view of the water. The waterlevel was relatively low making the impoundment shallow. The bottom was mucky. Caimans were leaving the water for the surrounding forest. We discovered three caiman that were intercepted on their way to the woods by Indians, who harvested the meat. The shore was 30 to 100 m wide and consisted of grass-covered, hardbaked clay and peat. The surrounding habitat is dry chaco thorn forest. The waterway was surveyed by spotlight from the back of a pickup truck and on foot.

	Latitude	Longitude
Cañada Luci-Í starting point at the western end	23°04'21" S	59°13'29" W
Cañada Luci-Í end point at the roadway dam at the east end	23°04'29" S	59°13'02" W

A total of 71 *Caiman yacare* were sighted all but one in the 'Eyes Only' category. The only exception was a 3–4' caiman caught on shore.

Waterway	Caiman sighted	km surveyed	Caiman/km
Cañada Luci-Í	71	0.87	81.6
Totals	71	0.87	

9. LAGUNA ZALAZAR TUYÁ. On the night of 1 November 1993, this 0.5 km long, relatively straight, natural lagoon was surveyed. This is an extremely rich freshwater (2‰ salinity) lagoon. There are large stands of cattail, *Typha*, on its perimeter, and between the tangle of cattail the shore is covered with extensive beds of *Hydrocotyle* and rooted *Eichhornia*. The vegetation has produced a thick bed of peat that is exposed when the water is low. The lagoon is visited by large flocks of black-billed treeducks, white-faced treeducks, muscovy ducks, screamers, spoonbills, egrets, herons, and jabiru storks. *Caiman yacare* heads are readily visible during the day scattered across the surface. The lagoon was about 1 m deep at the time of the survey. The surrounding habitat is dry chaco. The lagoon was spotlight surveyed from the back of a pickup truck on shore.

	Latitude	Longitude
Laguna Zalazar Tuyá starting point at the S end	23°05'10" S	59°16'45" W
Laguna Zalazar Tuyá end point at the N end*	23°04'54" S	59°16'47" W

A total of 345 *Caiman yacare* were sighted, all in the 'Eyes Only' category. Judging from the close clumping of eyes in a cove at the southern end, at least one pod of yearlings was present.

Waterway	Caiman sighted	km surveyed	Caiman/km
Laguna Zalazar Tuyá	345	0.5	690
Totals	345	0.5	

10. REPRESA GALPÓN. On the afternoon of 31 October 1993, and the night of 1 November 1993 this impoundment was visited. Galpón is a cattle waterhole behind an earth dam on a tributary of the Riacho San Carlos. The afternoon reconnaissance made it apparent that the pool was unlikely to contain any caimans. The end-of-the-dry season water was almost gone, only a shallow muddy remnant remained. What was once submerged bottom was now a bare muddy clay shore with no vegetation. Much of the mud was dried and cracked into large cakes that lay loose on the surface. Local fishermen were busy catching the fish, mostly symbranchid eels, trapped in the drying pool. It rained the night of 31 October, and the water rose slightly, but the nighttime survey revealed no caiman present in the Represa Galpón remnant pool. A previous survey on 16 November 1991 found a 0.64 hectare pool occupied by 16 *Caiman yacare*. Since Represa Galpón is not large enough or deep enough to provide a permanent water source, it is mentioned here not as a standard survey, but solely for future reference on the habitat.

11. REPRESA VICENTE. On the night of 1 November 1993, 1.0 km of this stream-like impoundment was surveyed. This is a slightly salty (8‰ salinity), meandering waterway that supports a rich flora and fauna. Extensive groves of cattail line its shore and floating algal mats cover the shallow water overlying the peaty bottom. There were flocks of treeducks and screamers and a few cormorants on the water and shore. The spotlight survey was conducted from an aluminum skiff. The caiman were light shy. The water was too shallow for an outboard motor, but the center of the waterway was sufficiently deep to allow the boat

* This end point may be less accurate than others as it was calculated from the map and not by use of the Magellan GPS instrument.

to be poled. However, poling was awkward and slow because the poles kept getting caught in the muck bottom, so a total count was taken in combination with a size class transect.

	Latitude	Longitude
Represa Vicente starting point at the southern end of the waterway at the earth dam	23°04'39" S	59°15'43" W
Represa Vicente end point at the northern end of the waterway	23°04'18" S	59°15'54" W

A total of 203 *Caiman yacare* were sighted, and the transect sample indicates the following percentage size classes were present: 13% (2–3'), 30% (3–4'), 35% (4–5'), and 22% (5–6'). No really big mature males (>7') were sighted.

Waterway	Caiman sighted	km surveyed	Caiman/km
Represa Vicente	203	1.0	203
Totals	203	1.0	

EASTERN CHACO AREA

ESTANCIA LA GOLONDRINA. For the survey sites on this ranch, maps Asunción HOJA SG-21-6 in the 1:250,000 Mapa Nacional series, and Benjamin Aceval HOJA 5371-II, Río Confuso HOJA 5371-III, Puerto Galileo HOJA 5370-IX, and Villa Hayes HOJA 5370-I in the 1:50,000 Carta Nacional Paraguay series, were used in combination with a hand-drawn map provided by the ranch. The general area is inundated chaco with occasional islands of dry chaco. Both *Caiman latirostris* and *Caiman yacare* are known from the area.

12. REPRESA LA GOLONDRINA. On the night of 4 November 1993, this 4.0 ha freshwater (0‰ salinity) impoundment was surveyed. The impoundment is relatively shallow with cover in the form of emergent, woody shrubs scattered across its surface. Stream-like channels run through the shrubs, but there is no large open water in the center of the impoundment. This is a clear, blackwater system that carries no sediment load, and may be energy poor. Recent rains had soaked the ground between the road and the represa, turning the soil into a soft muddy ooze and forcing us to leave the truck 500 m away. The spotlight survey was conducted on foot from the top of the earth dam. Below the dam the water spread through the woods and eventually joined a fast-flowing blackwater stream. The path from the road south of the represa passes near a small tajamar, which was surrounded by bunch grasses. Tracks of raccoon and ocelot were present in the muddy path, and numerous frogs were calling.

	Latitude	Longitude
Represa La Golondrina starting point at the north end of the dam	24°57'40" S	57°42'29" W
Represa La Golondrina end point at the south end of the dam	24°57'47"S	57°42'28" W
Small tajamar immediately south of the represa	24°57'56" S	57°42'30" W

A single 'Eyes Only' category caiman was sighted in the represa, but it was extremely shy so we were unable to get sufficiently close to determine what species it was. No caimans were sighted in the water below the dam or in the nearby tajamar.

Waterway	Caiman sighted	ha surveyed	Caiman/ha
Represa La Golondrina	1	4.0	0.25
Small tajamar	0	0.05	0.0
Totals	1	4.05	

Although hunting is prohibited on La Golondrina, it is believed that in the recent past local Indians did invade the ranch to take skins for commercial sale and subsistence hunting probably still occurs on the ranch. That does not account for the present paucity of caiman. Enforcement of Paraguay's current ban on caiman exports, seizures of illegal skins, and the international economic recession since 1990, has resulted in closing down the caiman skin market in Paraguay. Virtually no one is hunting, buying or selling caiman skins.

13. TAJAMAR AUSTRALIANO PUNTA PORÁ. On the night of 4 November 1993, this 0.8 hectare man-made waterhole was surveyed. It is a freshwater (0‰ salinity) pool surrounded by bunch grasses and weedy shrubs. The water is murky with algae and nutrients. In addition, there is a 0.2 ha raised-earth tank immediately beside the tajamar from which gravity-fed water is piped away to water the cattle. A fence keeps cattle out of both the tajamar and the raised tank pool. The tank pool contains some emergent grasses and sedges.

	Latitude	Longitude
Tajamar Punta Porá	24°58'27" S	57°43'45" W

No caiman were sighted in the tajamar. A single 3–4' *Caiman yacare* was sighted in the raised tank. No *Caiman latirostris* was detected.

Waterway	Caiman sighted	ha surveyed	Caiman/ha
Tajamar Punta Porá	0	0.8	0.0
Tajamar Punta Porá raised-earth tank	1	0.2	5.0
Totals	1	1.0	

14. TAJAMAR AUSTRALIANO SANTA LUISA 2. On the night of 4 November 1993, this 0.8 hectare man-made waterhole was surveyed. It is surrounded by bunch grasses, vines and shrubs. Immediately next to the pool is a 0.2 ha raised-earth tank from which water is piped to the cattle. Both the tajamar and the raised tank are freshwater (0‰ salinity). A narrow fringe of what looked like dry season dwarfed *Pistia* ringed the edge of the tajamar pool. The raised-earth tank pool had emergent grasses and sedges along its edge.

	Latitude	Longitude
Tajamar Santa Luisa 2	24°59'23" S	57°43'47" W

A total of 12 *Caiman yacare* were sighted in the following size classes: 11 'Hatchlings' and 1 'Eyes Only'. The 'Hatchlings' are called that solely because they were approximately 12 inches (30.5 cm) long; they were hatched last nesting season and now are nearly a year old. One of the hatchlings was in the raised tank and the remainder were in the tajamar pool. The 'Eyes Only' in the tajamar pool could have been a *Caiman latirostris*, but most probably was the *Caiman yacare* mother of the hatchling pod.

Waterway	Caiman sighted	ha surveyed	Caiman/ha
Tajamar Santa Luisa 2	11	0.8	13.75
Tajamar Santa Luisa 2 raised-earth tank	1	0.2	5.0
Totals	12	1.0	

15. TAJAMAR AUSTRALIANO SANTA LUISA 4. On the night of 4 November 1993, this 0.8 hectare man-made waterhole was surveyed. Immediately adjacent to the tajamar pool is a 0.2 ha raised-earth tank from which water is piped to the cattle. The pool and tank are freshwater (0‰ salinity). The waterhole is surrounded by bunch grasses and woody shrubs.

	Latitude	Longitude
Tajamar Santa Luisa 4	25°00'34" S	57°41'58" W

No caiman were sighted in either the waterhole or in the raised tank.

Waterway	Caiman sighted	ha surveyed	Caiman/ha
Tajamar Santa Luisa 4	0	0.8	0
Tajamar Santa Luisa 4 raised-earth tank	0	0.2	0
Totals	0	1.0	

16. DOÑA CYNTHIA ROAD. On the night of 4 November 1993, 0.4 km of the ditches alongside the road to Doña Cynthia Represa were surveyed. The road passes through inundated grassy fields and marshy palmare (palm savanna). This is the road to the Represa Doña Cynthia and it was our original intention to survey this large impoundment, but recent rains had raised the water so high that a culvert no longer could handle the flow and the road was completely washed out. The impassable, washed-out, watery crevasse was the end point of our survey. The ditches contained many submerged, floating, and emergent aquatic plants. Rails, cranes, caracaras, and hawks were abundant in the area.

	Latitude	Longitude
Doña Cynthia Road start point	25°01'14" S	57°41'50" W
Doña Cynthia Road end point	25°01'26" S	57°41'53" W

A total of 17 *Caiman yacare* were sighted in the following size classes: 15 (2–3') and 2 'Eyes Only'. The 2–3' animals were so remarkably similar that we are convinced they represent a pod of young from last year or, more probably, the year before. The two 'Eyes Only' might have been *Caiman latirostris*, but more probably were more members of the *Caiman yacare* pod or their parents.

Waterway	Caiman sighted	km surveyed	Caiman/km
Doña Cynthia roadside ditches	17	0.4	42.5
Totals	17	0.4	

17. 'NEW' AUSTRALIANO TAJAMAR. On the night of 4 November 1993 this 0.8 ha man-made waterhole was surveyed. Immediately adjacent to the waterhole is a 0.2 ha raised-earth tank from which water is piped to the cattle. The banks of the pool are covered with bunch grasses and shrubs.

	Latitude	Longitude
'New' Tajamar	24°59'39" S	57°41'03" W

No caiman were sighted in either the waterhole pool or the raised tank.

Waterway	Caiman sighted	ha surveyed	Caiman/ha
'New' Tajamar	0	0.8	0
'New' Tajamar raised-earth tank	0	0.2	0
Totals	0	1.0	

RÍO CONFUSO. For the survey of this river, map Asunción HOJA SG-21-6 in the 1:250,000 Mapa Nacional series was used. The general area is inundated chaco. The river is fringed with a gallery forest that includes not only the ubiquitous mesquite, but also with some broadleaf evergreen trees and scattered *Copernicia alba* palms. Both *Caiman latirostris* and *Caiman yacare* are known from the area.

18. RÍO CONFUSO. On the night of 6 November 1993, 23 km of this river west of the Trans-Chaco highway bridge was surveyed. The Río Confuso is a murky black, freshwater (0‰ salinity) river more than 2 meters deep. The name reflects the large looping, 'confused,' meanders that characterize its course (while the river distance surveyed is 23 km, the straight-line distance between the upstream start and downstream end points is only 9 km). The banks are a sandy clay, frequently with the lower 1–4 m bare. The tops of the banks are covered with gallery forest. A fine matted tangle of vines covers many of the trees and frequently drapes into the river. Apart from the vines and occasional floating grass mats, there is little cover available. The river has remarkably few logs, floating limbs, or other obstructions.

	Latitude	Longitude
Río Confuso upstream starting point	25°01'31" S	57°35'36" W
Río Confuso downstream end point at the Trans-Chaco Highway bridge	25°06'26" S	57°32'47" W

A total of 5 *Caiman yacare* were sighted in the following size classes: 1 'Hatchling' and 4 (3–4'). No *Caiman latirostris* were detected. However, 4 'Eyes Only' were sighted, and while it seems probable that these were *Caiman yacare* as well, they could have been *Caiman latirostris*. In addition, during the daylight reconnaissance of the survey route, two belly slide marks of a large adult caiman were discovered in the soft mud of the river bank. The impressions left by the belly scales suggest the slides were made by a caiman 6' (1.8 m) long or longer. The slides were facing each other on opposite sides of the river and presumably represent a single adult, which was not sighted during the nighttime survey.

Waterway	Caiman sighted	km surveyed	Caiman/km
Río Confuso	9	23.0	0.39
Totals	9	23.0	

The Río Confuso is a popular site frequented by fishermen from Asunción. The night of the survey, though they were more frequent within 5–10 km of the Trans-Chaco highway, fishermen were found throughout the entire survey route. The absence of caiman probably is the result of little available cover and harassment from fishermen and boaters.

ESTANCIA LOMA PORÁ. For surveys in this area, map Concepción HOJA SF-21-14, in the 1:250,000 Américas series, was used. The area is primarily inundated chaco with scattered patches of dry chaco. Both *Caiman latirostris* and *Caiman yacare* are known from the area. Hunting is not allowed in the ranch, though some undoubtedly occurs without the knowledge of the management. Nevertheless, hunting is not believed to be intensive here.

19. REPRESA CAÑADA. On the night of 17 November 1993, this 3 km long series of in-line, freshwater (0‰ salinity) pools impounded behind this earth dam and roadway were surveyed. The pools vary in elevation, the lowest and first surveyed being farthest west and progressively climbing a gentle slope toward the east and the last pool surveyed. Many of these pools dry out during the dry season and as a consequence have vegetation only around the edges. However, a few contain water nearly year-round as evidenced by more floating (*Pistia* and the red waterfern, *Azolla*) and emergent (*Cyperus*) aquatic vegetation. The pools are nearly devoid of fish and mollusks. The represa was constructed approximately 2-years ago and might develop into permanent waterbodies as the pools mature and the bottoms seal. Despite the lack of year-round water, the area supports a varied associated terrestrial fauna of muscovy ducks, white-faced treeducks, jacanas, various herons, rails, and peccary.

	Latitude	Longitude
Represa Cañada starting point	23°31'45" S	57°33'22" W
Represa Cañada end point	23°30'05" S	57°32'54" W

A total of 2 *Caiman latirostris* were sighted in the following size classes: 1 (3–4') and 1 (4–5'); and 1 (3–4') *Caiman yacare* also was sighted. In addition, 1 'Eyes Only' caiman timidly sank out of sight before it could be determined to species. The intermittent nature of water in this series of impoundments undoubtedly accounts for the scarcity of caiman.

Waterway	Caiman sighted	km surveyed	Caiman/km
Represa Cañada – *latirostris*	2	3	0.6
Represa Cañada – *yacare*	1	3	0.3
Represa Cañada – 'Eyes Only'	1	3	0.3
Totals	4	3	

20. REPRESA BARRARITO NORTE. On the night of 18 November 1993, this 8 km long series of freshwater (0‰ salinity) pools along the raised entrance road from the Pozo Colorado-Concepción (Ramal Puerto Militar) highway to the ranch headquarters of Estancia Loma Porá was surveyed. The majority of the pools parallel the road but some near the highway end are perpendicular to the road. Many of these pools dry out during the year, but several are permanent bodies of water that support a rich growth of *Pistia, Eichhornia, Typha*, a papyrus-like *Cyperus*, *Cleome*, and floating mats of camelote grass.

	Latitude	Longitude
Represa Barrarito Norte starting point	23°29'59" S	57°33'06" W
Represa Barrarito Norte end point at the village of Dieciseís on the Pozo Colorado-Concepción highway	23°27'58" S	57°36'20" W

A total of 4 *Caiman latirostris* were sighted in the following size classes: 3 (3–4') and 1 (4–5'); and 3 *Caiman yacare* were sighted in the following size classes: 1 (2–3') and 2 (3–4'). In addition, 16 caiman could not be approached sufficiently close to identify as to species and were recorded only as 'Eyes Only'. Most of the caiman were sighted in two different pools, both of which supported an extensive growth of floating and emergent aquatic vegetation. Most of the 'Eyes Only' probably were *Caiman yacare* as they appeared to be members of a pod of last year's hatchlings scattered through the *Pistia* of one pool that contained adult *Caiman yacare*.

Waterway	Caiman sighted	km surveyed	Caiman/km
Represa Barrarito Norte – *latirostris*	4	8	0.5
Represa Barrarito Norte – *yacare*	3	8	0.38
Represa Barrarito Norte – 'Eyes Only'	16	8	2.0
Totals	23	8	

21. RIACHO NEGRO AND REPRESA ALEGRIA. On the night of 18 November 1993, 0.5 km of the small lagoon in the Riacho Negro near the ranchhouse on Retiro Alegria and the series of pools along the 6 km represa and entrance road from the Pozo Colorado-Concepción highway (on the map this highway is indicated as Ramal Puerto Militar) were surveyed. The Riacho Negro lagoon is excellent caiman habitat. It is a permanent body of water in a seasonally flowing stream. It supports a rich flora of floating and emergent aquatic vegetation that provides habitat for both prey species and young caiman. Camelote grass mats and *Eichhornia* blocked passage of the boat so only the pools near the ranchhouse could be spotlight surveyed. Muscovy ducks, jacanas, stilts, various frogs, mollusks, and foxes abound. Along the raised-earth entrance road to the Retiro Alegria ranchhouse is a series of borrow pits (tajamars), most of which are seasonally flooded, but some of which are permanent or semi-permanent. Both the lagoon and represa pools are freshwater (0‰ salinity).

	Latitude	Longitude
Riacho Negro lagoon starting point	23°27'32" S	57°46'53" W
Represa Alegria end point at the Pozo Colorado-Concepción highway	23°30'51" S	57°44'30" W

A total of 26 *Caiman yacare* were sighted in the following size classes: 2 (2–3'), 4 (3–4'), 5 (4–5'), 1 (6–7'), and 14 'Eyes Only'. No *Caiman latirostris* were detected, and the Retiro Alegria staff informed the survey team that only *Caiman yacare* was found in the lagoon and represa. All but 7 of the caimans were sighted in the riacho lagoon. The single 6–7' caiman spotted was found walking along the shore of one of the shallow represa pools.

Waterway	Caiman sighted	km surveyed	Caiman/km
Riacho Negro lagoon	19	0.5	38.0
Represa Alegria	7	6.0	1.17
Totals	26	6.5	

22. LAGUNA CORRALITO NORTE AND RIACHO CHE RAY. On the night of 19 November 1993, 2.45 km this large lagoon and two smaller pools along the Riacho Che Ray were surveyed. None of these permanent bodies of freshwater (0‰ salinity) are indicated on the Concepción map sheet, though seemingly every ranchhand in the area and their families have visited the lagoon at some time. No roads lead to the riacho so the waterways normally are reached on horseback or by tractor. The lagoon and pools occur in the middle of the wide, seasonally flooded, course of the Riacho Corralito Norte. The floodplain consists of emergent aquatic vegetation, papyrus-like *Cyperus*, and various grasses on a peaty soil, with *Copernicia alba* palms and mesquite on floodplain islands and on the higher streambanks. The Corralito Norte stream was shallow at the time of the survey (less than 1 m deep in most places) and the lagoon even more shallow. The stream was spotlight surveyed from a boat brought in by tractor-towed trailer, but the lagoon was too shallow to traverse by boat so a total count of caimans was made from the open water of the lagoon at the mouth of the stream near the boat launch site. As a possible aid to future survey teams that may find sufficient water to survey the lagoon perimeter by boat, and in order to determine the distance covered by the total count of caimans, the latitude-longitude location of the survey end point on the far shore of the lagoon was projected (calculated) using the Magellan GPS NAV 1000 PRO and a KVH DataScope. The two smaller Riacho Che Ray pools were spotlight surveyed for total caiman from a tractor-towed trailer on the shore. Caiman heads were plainly visible during the day in all these waterways. Screamers and treeducks were abundant.

	Latitude	Longitude
Laguna Corralito Norte starting point at NW end of stream	23°25'06" S	57°41'14" W
Laguna Corralito Norte boat launch site	23°25'26" S	57°41'26" W
Laguna Corralito Norte projected end point on SW shore of lagoon	23°25'54" S	57°41'44" W

A total of 123 *Caiman yacare* were sighted in the following size classes: 1 'Hatchling', 16 2–3'), 24 (3–4'), 13 (4–5'), 10 (5–6'), and 59 'Eyes Only'. No *Caiman latirostris* were detected. Though hunting is not permitted in the area, the discarded bony belly cut out and thrown away from a chaleco skinned from a caiman was found on the shore near the boat launch site. It clearly was from an animal killed this year. This might be suggestive of the reason large caimans are missing from the Corralito Norte stream population.

Waterway	Caiman sighted	km surveyed	Caiman/km
Laguna Corralito Norte and stream	113	1.7	66.5
Riacho Che Ray pool 1	6	0.5	12.0
Riacho Che Ray pool 1	4	0.25	16.6
Totals	123	2.45	

23. Tajamars along East End of Pozo Colorado-Concepción Highway. On the night of 19 November 1993, 54 roadside tajamars along the 16 km portion of the highway between the village of Dieciseís and the bridge to Concepción over the Río Paraguay was surveyed. The extreme eastern and western ends of this highway (indicated on the map as Ramal Puerto Militar) are graded and paved with asphalt, but the middle half to two-thirds is unpaved and poorly graded. Earth used to raise the finished road above the surrounding seasonally flooded chaco was taken from tajamars (borrow pits) dug along the north and south sides of the graded and paved portions. The size of these freshwater (0‰ salinity) pools varies considerably, from 1 to 3 hectares, and probably average about 2 hectares. The exact size of individual tajamars could not be determined precisely because access to most of the pools was denied by cattle fences without gates. Most of the tajamars are deep enough to provide permanent water, but a few are shallow pools that dry out seasonally. Many of these shallow pools appear as little more than luxurious patches of flooded savanna. Newly dug tajamars lacking aquatic vegetation and an invertebrate and fish fauna are relatively sterile pools. However, once they have been invaded by local flora and fauna, they provide good caiman habitat. That 16 km portion of the highway between the village of Dieciseís and the bridge to Concepción over the Río Paraguay to the east is bordered by tajamars which, for the most part, can be easily seen and spotlight surveyed from the highway. Eventually, the trees and shrubs on the shore become sufficiently large to block the view of the pools from the highway, as is the case for the tajamars along the paved highway west of the village of Dieciseís.

The following listing shows consecutively numbered locations along the highway and whether at that location a tajamar is located on the north, the south, or on both sides of the highway:

	N or S of Highway	Latitude	Longitude
1	N	23°27'21" S	57°27'23" W
2	N & S	23°27'19" S	57°27'35" W
3	N & S	23°27'12" S	57°28'10" W
4	S	23°27'10" S	57°28'18" W
5	N	23°27'06" S	57°28'41" W
6	N	23°27'05" S	57°28'41" W
7	S	23°27'05" S	57°28'47" W
8	S	23°27'05" S	57°29'14" W

9	N	23°27'05" S	57°29'26" W
10	S	23°27'05" S	57°29'38" W
11	S	23°27'05" S	57°29'45" W
12	S	23°27'04" S	57°29'54" W
13	N	23°27'04" S	57°29'59" W
14	N	23°27'04" S	57°30'04" W
15	N	23°27'03" S	57°30'17" W
16	N	23°27'03" S	57°30'27" W
17	N	23°27'04" S	57°30'34" W
18	N & S	23°27'04" S	57°30'48" W
19	N & S	23°27'03" S	57°30'57" W
20	S	23°27'03" S	57°31'24" W
21	N & S	23°27'02" S	57°31'30" W
22	N	23°27'02" S	57°31'37" W
23	N & S	23°27'02" S	57°31'43" W
24	S	23°27'02" S	57°31'57" W
25	S	23°27'02" S	57°32'12" W
26	N & S	23°27'02" S	57°32'28" W
27	S	23°27'01" S	57°33'01" W
28	N & S	23°27'01" S	57°33'15" W
29	N & S	23°27'01" S	57°33'23" W
30	N & S	23°27'02" S	57°33'29" W
31	N & S	23°27'02" S	57°33'49" W
32	N	23°27'02" S	57°33'56" W
33	N & S	23°27'02" S	57°34'07" W
34	N & S	23°27'03" S	57°34'26" W
35	N & S	23°27'03" S	57°34'38" W
36	S	23°27'11" S	57°35'04" W
37	N	23°27'22" S	57°35'20" W
38	N & S	23°27'46" S	57°36'04" W
39	N	23°27'49" S	57°36'10" W

A total of 73 caiman were sighted in these roadside pools, all in the 'Eyes Only' category. Because the views of the tajamars at locations 16, 17, 24, 25, 26S, and 36 were partially blocked by trees and shrubs, this must be considered a minimum count. Nevertheless, waterways along major highways always are subject to hunting, so monitoring the numbers of caimans in these tajamars should give some indication of hunting pressure on caiman populations in the area.

Waterway	Caiman sighted	highway km surveyed	Caiman / hwy km
54 tajamars along the E end of the Pozo Colorado-Concepción highway	73	16	4.6
Totals	73	16	

RÍO PILCOMAYO AREA

ESTANCIA JOSEPHINA AND ESTANCIA 26 DE AGOSTO. For the surveys on these ranches, map Fortín Gral. Díaz HOJA SF-20-16 in the 1:250,000 Mapa Nacional series was used. Estancia 26 de Agosto is identified on the map by its former name, Retiro Yulupi. The area is characterized by typical dry chaco forest interspersed with wide expanses of inundated savanna in the Río Pilcomayo floodplain. Many of these savannas are characterized by deep peaty soils produced by extensive stands of cattails. Few *Copernicia* palms are found in the area. Both *Caiman latirostris* and *Caiman yacare* are known from the area. Currently, organized caiman hunting does not occur on these ranches, though it was allowed in the past.

24. RIACHO MONTE LINDO. On the night of 24 November 1993, 1.5 km of this stream was surveyed. The riacho is an intermittent stream that feeds the Pilcomayo. During much of the year it is little more than a series of interconnected 1–5 m wide, freshwater (0‰ salinity), pools scattered along a meandering course through thorny chaco woodland. The survey began at an earth dam constructed across the stream and extended upstream to a point where the stream was little more than a trickle less than 1 m wide. There is little vegetative cover on the 2 to 3 m high banks apart from grass and an occasional young mesquite. A submerged aquatic plant, probably *Elodea*, filled much of the pool immediately above the earth dam. By February, the seasonal rains have raised the water above the banks and the entire surrounding area is flooded. The spotlight survey was conducted by walking the east bank of the stream.

	Latitude	Longitude
Riacho Monte Lindo starting point at earth dam	23°36'24" S	60°13'48" W
Riacho Monte Lindo upstream end point	23°35'55" S	60°14'27" W

A total of 15 *Caiman yacare* were sighted in the following size classes: 4 (3–4'), 3 (4–5'),and 8 'Eyes Only'. No *Caiman latirostris* was detected. All the caiman were found in the 2 or 3 deeper pools immediately above the dam.

Waterway	Caiman sighted	km surveyed	Caiman/km
Riacho Monte Lindo	15	1.5	10.0
Totals	15	1.5	

This is not great caiman habitat. There is little vegetative cover to provide a nursery for young caiman. It is sufficiently remote that it does not suffer from daily or weekly harassment from hunters and the stream is too shallow to attract fishermen.

25. ESTANCIA JOSEPHINA TAJAMAR 1. On the night of 24 November 1993, this 0.25 ha freshwater (0‰ salinity) tajamar was surveyed. It sets like a thorn tree surrounded island on the edge of a peaty floodplain dominated by cattail. At the time of the survey, the cattails had been burned down to their rootstock. The thorn trees are separated from the water by a bare, sandy clay, shore. The tajamar has a sizable population of fish in it. Buff-necked ibis were common. When the tajamar was first approached during the day, caimans were basking on shore and heads remained visible once the animals fled into the water. The spotlight survey was conducted from the shore.

	Latitude	Longitude
Estancia Josephina Tajamar 1	23°36'04" S	60°19'47" W

A total of 31 *Caiman yacare* were sighted in the following size classes: 15 (2–3'), 3 (3–4'), 1 (4–5'), 1 (7–8'), and 11 'Eyes Only'. No *Caiman latirostris* were detected. Though some of the 'Eyes Only' might have been *Caiman latirostris*, but this seems unlikely. This tajamar provides dry season habitat for the caiman that will disperse into the surrounding marsh during the wet season.

Waterway	Caiman sighted	ha surveyed	Caiman/ha
Estancia Josephina Tajamar 1	31	0.25	124.0
Totals	31	0.25	

26. ESTANCIA JOSEPHINA TAJAMAR 2. On the night of 24 November 1993, this 0.25 ha freshwater (0‰ salinity) tajamar was surveyed. It is dug in sandy clay soil and has a thorn tree fringe around it. The shore is bare and there is no aquatic vegetation in the water. A small dry stream course enters one side of the tajamar, but a log barrier had been constructed across it. Many caimans were basking on shore when the survey team first approached the tajamar during the daytime reconnaissance. The spotlight survey was conducted by walking the perimeter shore.

	Latitude	Longitude
Estancia Josephina Tajamar 2	23°35'55" S	60°18'49" W

A total of 19 *Caiman yacare* were sighted in the following size classes: 11 (2–3'), 3 (4–5'), 2 (7–8'), and 3 'Eyes Only'. No *Caiman latirostris* were detected. Some of the 'Eyes Only' might have been *C. latirostris*, but this seems unlikely since none were seen either during the day reconnaissance or the nighttime survey.

Waterway	Caiman sighted	ha surveyed	Caiman/ha
Estancia Josephina Tajamar 2	19	0.25	76
Totals	19	0.25	

At the time of the survey, hundreds of dried and fresh piranha and armored catfish covered the shore and attracted a goodly number of vultures. One of the ranch's gauchos informed the survey team that the fish started jumping out of the water 3 days earlier when the seasonal heat raised the temperature of the water. Armored catfish were gulping air at the surface during the daytime visit of the survey team, but by the time the team returned for the nighttime survey there was a new layer of armored catfish on the shore and few fish breaking the surface. Surprisingly, the caiman seemed to be scavenging few, if any, of the live or newly dead fish on shore.

27. ESTANCIA JOSEPHINA TAJAMAR 3. On the night of 25 November 1993, this 0.5 ha freshwater (0‰ salinity) tajamar was surveyed. This tajamar sits in the midst of a cattail floodplain. At the time of the survey the cattails had been burned down to their root stock. The soil is a deep peat. Mesquite trees grow atop the earth mounds at each end of the pool. The shore is bare marl-like clay, pockmarked by the hooves of the many cattle that drink here. The spotlight survey was conducted by walking around the perimeter shore.

	Latitude	Longitude
Estancia Josephina Tajamar 3	23°35'40" S	60°16'27" W

A total of 120 caiman were sighted. During the daytime reconnaissance of the tajamar, a total of 4 *Caiman latirostris* were sighted in the following size classes: 3 (5–6') and 1 (7–8'). During the nighttime survey, the adult *C. latirostris* were not sighted, but 3 (2–3') were sighted. Virtually all the other caiman sighted were *Caiman yacare*. Undoubtedly, a few other *Caiman latirostris* might have been present but were unidentifiable because they were submerged or because they faced away from the spotlight so the shape of the snout could not be determined.

Waterway	Caiman sighted	ha surveyed	Caiman/ha
Estancia Josephina Tajamar 3	120	0.5	240
Totals	120	0.5	

The survey team was informed that this tajamar has been in existence for 25 years, and has always supported a large population of caiman. Considering the number of cattle that drink here, it is surprising that the caiman population has survived in good numbers. The dehydrated skeletal remains of two adult *Caiman yacare*, one estimated to be 2.5 m in length, were found under the mesquite trees on shore.

28. ESTANCIA 26 DE AGOSTO, RIO PILCOMAYO 1. On the night of 25 November 1993, two freshwater (0‰ salinity) pools, with a combined area of approximately 2 ha, behind (upstream of) an earth dam near the ranch headquarters was surveyed. The 2–4 m high banks are bare clay. The main pool, nearest the estancia, has little vegetative cover; however, the side pool contains a number of aquatic plants. The Río Pilcomayo in this area breaks up into a series of pools during the dry season. The represa was constructed to provide a year-round water source for the ranch. At the time of the survey, work was underway to raise the height of the represa. The spotlight survey was conducted from the shore.

	Latitude	Longitude
Río Pilcomayo 1	23°43'31" S	60°14'19" W

A total of 86 *Caiman yacare* were sighted, all in the 'Eyes Only' category. No *Caiman latirostris* was detected, though the species occurs in the area. Because of the proximity to the ranchhouse and the lack of vegetative cover, this is not prime caiman habitat.

Waterway	Caiman sighted	ha surveyed	Caiman/ha
Río Pilcomayo 1	86	2.0	43
Totals	120	0.5	

The ranch staff reported that piranha were abundant in the pools; one 7–8' *Caiman yacare* seen on shore during the daytime reconnaissance had a fresh wound with a large portion of its tail tip missing and seemed reluctant to enter the water after all the other caimans had fled from the survey team.

29. ESTANCIA 26 DE AGOSTO, RÍO PILCOMAYO 2. On the night of 25 November 1993, this 1 km long, 10–25 m wide, 0.1–2 m deep, pool of the Río Pilcomayo was surveyed. It is a drying freshwater (0‰ salinity) pool in a separate river channel isolated from the rest of the Río Pilcomayo quite some distance from the ranch headquarters. The pool contains a large population of mollusks and fish (reported by the ranchhands to be piranha). The bottom 1–2 m of the banks are bare muddy clay while the tops of the banks are covered with thorny trees and shrubs. The surrounding area is seasonally flooded savanna. Because major parts of the pool were to shallow for a boat, the spotlight survey was conducted by walking along the shore, except in two places where vegetation blocked views of the pool. A transect by boat through one of the deep pools provided data on size class distribution.

	Latitude	Longitude
Río Pilcomayo 2	23°43'29" S	60°18'55" W

A total of 868 *Caiman yacare* were sighted in the following size categories: 2.2% (2–3'), 1.1% (3–4'), 10% (4–5'), 22.2% (5–6'), 42.2% (6–7'), and 22.2% (7–8'). No *Caiman latirostris* was detected, though the species occurs in the area. The proportion of large adults in the population was unduly large, probably reflecting a dry season concentration drawn from the surrounding area.

Waterway	Caiman sighted	km surveyed	Caiman/km
Río Pilcomayo 2	868	1.0	868
Totals	868	1.0	

ALTO PARAGUAY AREA

LAGUNA GENERAL DÍAZ. For the survey of this lagoon, the 1:1,000,000 scale map sheet of Paraguay issued under 'Direccion del Servicio Geografico Militar, 5th Edition, 1988', was used in combination with a 1:2,500 scale map of Laguna Gral. Díaz, apparently prepared as part of a boundary survey of this property by the operator of the 2,000 hectare Estancia Gral. Díaz, Mr. Yasushi Kobuchi.

30. LAGUNA GENERAL DÍAZ. On the night of 10 November 1993, we surveyed the lagoon and 2.2 km of Arroyo Syry, the stream that flows into the west end of the lagoon. During the 1992 survey, the lake was 80 cm above normal and the perimeter of the fully flooded lagoon was 13.0 km in length. By contrast, during this year's survey the lake was 100-150 cm lower and the shore exposed as a 60 to 100 m wide, bare, sandy clay beach. The lagoon perimeter clearly was shortened, but was there was no easy way to determine the difference, so 13.0 km was also used as the perimeter length in the 1993 survey calculations. In 1992, the entire system was freshwater (0‰ salinity); however, this year's lack of rain has lowered the waterlevel and decreased the inflow from Arroyo Syry to the point that the stream and the western end of the lagoon remain fresh (0‰ salinity), but has allowed the salinity to increase (2‰ salinity) in the middle and eastern end of the lagoon.

	Latitude	Longitude
Arroyo Syry upstream starting point	21°09'05" S	58°36'29" W
Laguna General Díaz start and end point	22°07'28" S	57°55'35" W

A total of 3,294 *Caiman yacare* were sighted in Arroyo Syry and Laguna Gral. Díaz in the following size classes: 1% 'Hatchlings', 21.9% (2–3'), 14.6% (3–4'), 18.8% (4–5'), 28% (5–6'), 11.5% (6–7'), and 4.2% (7–8'). Most (68%) of the caiman were in the arroyo. That population was so dense that only a total count was possible, coupled with a transect through the population to gather data on size class distribution. Two separate spotlight counts were taken, one from a tractor on shore and one from a boat moving down the middle of the stream (see discussion in Methods section above). The results of the boat survey are presented here. The size class transect was made on caiman encountered randomly while moving up the stream prior to surveying back downstream.

Waterway	Caiman sighted	km surveyed	Caiman/km
Arroyo Syry	2,238	2.2	1,017.3
Laguna Gral. Díaz	1,035	13.0	76.7
Totals	3,294	15.2	

The low water Arroyo Syry/Laguna General Díaz caiman population, with its many 2 m or longer territorial males, is sufficiently large that it could withstand a managed harvest and still provide a wildlife spectacle many eco-tourists would be interested in viewing. The same is true of the large waterfowl and fish populations found there.

NORTHERN RÍO PARAGUAY AND RÍO NEGRO AREA. For the surveys in this area, the 1:1,000,000 scale map sheet of Paraguay issued under 'Direccion del Servicio Geografico Militar, 5th Edition, 1988' was used. Bahia Negra is the largest town in northeastern Alto Paraguay. It was built on trade in caiman skins from the region and from the Brazilian pantanal and adjacent Bolivia. As recently as 6-8 years ago, business was brisk and the local warehouses were filled with skins. Today, as dramatic evidence of the effectiveness of the Government of Paraguay's efforts to curtail illegal wildlife trade, Bahia Negra is a dying town. The warehouses are empty and their owners have moved to Asunción. Local people are trying to develop a fishing industry but are currently thwarted by a lack of markets. However, Bahia Negra could become the center of a thriving ecotourism industry (see 32. Río Negro and Río Paraguay North of Bahia Negra below).

31. Río Paraguay and Riacho Esperanza from the Mouth of Riacho Nueva to Bahia Negra. On the night of 11 November 1993, 27 km of the Paraguay River and one of its alternate channels south of Bahia Negra was surveyed. Both the river and the channel are freshwater (0‰ salinity). The night of the survey, a strong east wind carried thick smoke across the river from burning ranges on Brazilian cattle ranches on the opposite bank of the river. The smoke made spotlight surveying difficult along the southern-most 20% of the survey route. The survey began from an aluminum skiff in the Riacho Esperanza channel and ran north to the Indian village at Puerto Esperanza where the surveyors moved aboard a 50' steel-hulled river freight boat and continued north to Bahia Negra. Caimans were spotlighted on both shores while the freight boat navigated up the middle of the river.

	Latitude	Longitude
Ríacho Esperanza starting point at the mouth of the channel leading to Riacho Nueva	20°30'03" S	58°01'23" W
Puerto Esperanza village	20°23'43" S	58°03'26" W
Bahia Negra end point at the docking area in front of the public square	20°13'38" S	58°09'59" W

A total of 384 *Caiman yacare* were sighted in the following size classes: 1 (2–3'), 2 (3–4'), 5 (4–5'), 3 (5–6'), and 376 'Eyes Only'. This must be considered a minimum count because of the smoke that obscured much of the river. Even so, this is a surprisingly large number of caiman considering the heavy boat traffic that moves up and down the Río Paraguay everyday. Much of the river bank is bare clay, but there are numerous entrances to oxbow lakes, small streams and embayments with vegetation that would provide cover for caiman.

Waterway	Caiman sighted	km surveyed	Caiman/km
Riacho Esperanza channel	161+	5.0	32+
Río Paraguay from Punta Esperanza to Bahia Negra	226+	22.0	10+
Totals	387+	27.0	

32. Río Negro and Río Paraguay North of Bahia Negra. On the night of 12 November 1993, 31.9 km of the Río Negro and Río Paraguay were surveyed north of Bahia Negra. The Río Negro is a major freshwater (0‰ salinity) tributary of the Río Paraguay that forms the border between northeastern Paraguay and extreme southeastern Bolivia. As implied by its name, in contrast to the silty, buff-colored Río Paraguay, the Río Negro is a muddy, black water system. The surrounding area is seasonally flooded savanna, much of which has been encompassed in cattle ranches. It supports one of the largest waterfowl populations the survey team had ever seen; flocks of thousands of woodstorks, jabiru storks, Maguari storks, whitefaced treeducks, black-bellied treeducks, muscovy ducks, coscoroba swans, roseate spoonbills, cormorants, plumbeous ibis, buff-necked ibis, southern screamers, limpkins, rails, seriemas, jacanas, black skimmers, and numerous egrets and herons abound in the shallow embayments of the Río Negro. The river also supports thriving mollusk and fish populations, including one of the largest and most aggressive piranha populations in all of Paraguay. The river banks are covered by a narrow strip of gallery forest in places and groves of *Copernicia* palms in others. In many places a narrow fringe of rooted water hyacinth (*Eichhornia* sp.) and camelotte grass lined the water's edge. Clearly this is good caiman habitat. The survey from a shallow-draft aluminum skiff began upstream in the Río Negro and ran downriver for 12 km to where a deeper draft, 50' steel-hulled, river freight boat was tied up waiting the return of the survey team. The team then moved aboard the freight boat and continued down the middle of the river spotlighting both banks all the way to Bahia Negra.

	Latitude	Longitude
Río Negro upstream starting point	19°55'29" S	58°11'49" W
Río Negro confluence with the Río Paraguay	20°09'41" S	58°10'12" W
Bahia Negra end point at the docking area in front of the public square	20°13'38" S	58°09'59" W

A total of 2,100 *Caiman yacare* were sighted in the following size classes: 192 (2–3'), 108 (3–4'), 97 (4–5'), 90 (5–6') 16 (6–7'), and 1,597 'Eyes Only'. The upper stretches of the Río Negro contained embayments that were too shallow to be entered by the survey skiff, even by poling. The area was heavily hunted when Bahia Negra was the buying center for skins illegally smuggled out of Bolivia and Brazil. However, curtailment of the hunting has allowed the population to recover. A majority (82%) of the caimans sighted were on the Río Negro. The Río Paraguay between the mouth of the Río Negro and Bahia Negra is heavily traveled by boats and fishermen, which undoubtedly accounts for the relative paucity of caimans along that stretch of river.

Waterway	Caiman sighted	km surveyed	Caiman/km
Río Negro	1,724	25.0	68.9
Río Paraguay from confluence with the Río Negro to Bahia Negra	376	6.9	54.5
Totals	2,100	31.9	

ORIENTAL AREA

RÍO APA. For the survey of this river, the Puerto Valle-Mí HOJA SF-21-10 map in the 1:250,000 Mapa Nacional series was used. The Río Apa flows into the Río Paraguay just north of Puerto Valle Mí and forms the border between northeastern Paraguay and Brazil. The continuing dry season had lowered the waterlevel significantly. Many shoal areas prevented close approach to the shore by the survey boat. The banks are alternately cut-away, high, rocky faces and gently rising sandy or grassy slopes. Gallery forest tops the banks.

33. RÍO APA.

During the night of 9 November 1993, we resurveyed the same 55 km of this freshwater (0‰ salinity) river that were surveyed by Messel and King in 1992. Unlike 1992, when the Rio Apa had just returned to within its banks following a wet year, in 1993 the Río Apa was shallow and travel was impeded by many sandbars. More of the sandbar that formed the upstream start point was exposed which slightly changed the start point between the 1992 and 1993 surveys.

	Latitude	Longitude
Río Apa upstream starting point	22°06'13" S	57°40'24" W
Río Apa downstream end point	22°07'28" S	57°55'35" W

A total of 550 *Caiman yacare* were sighted in the following size classes: 12 'Hatchlings', 39 (2–3'), 32 (3–4'), 45 (4–5'), 52 (5–6'), 15 (6–7'), 2 (7–8'), and 353 'Eyes Only'. This is a significant increase over the 158 caiman sighted in the 1992 survey. The difference probably is, at least in part, the result of the animals being concentrated by the lower water. *Paleosuchus palpebrosus* is recorded from the upper Río Apa, and special attention was paid so that species would not be misidentified. Nevertheless, no *Paleosuchus* and no *Caiman latirostris* were detected.

Waterway	Caiman sighted	km surveyed	Caiman/km
Río Apa	550	55.0	10.0
Totals	550	55.0	

The Río Apa is heavily traveled by both Paraguayan and Brazilian boats. The caiman were more frequent in the upper portion of the river and dropped dramatically in the last 5 km before reaching Puerto Valle Mí. That alone indicates the impact of river traffic on the caiman population.

LAGO YPACARAI. For the survey of this large natural lake and the Río Salado that flows out of it, map Asunción HOJA SG-21-6 in the 1:250,000 Américas series was used. The Río Salado flows through an extensive marsh that borders the northern end of the lake and joins the Río Paraguay near the town of Piquete Cué. The marsh appears to be near ideal caiman habitat. The river is bordered by floating camelote grass mats and *Eichhornia*, and behind that there are thick stands of a papyrus-like *Cyperus*.

34. LAGO YPACARAI AND RÍO SALADO. On the night of 14 November 1993, 16.5 km of this river and lakeshore was surveyed. Lago Ypacarai is a large freshwater (0‰ salinity) lake, and despite its name, the Río Salado also is fresh (0‰ salinity). The central eastern shore of the lake is heavily settled by residents of San Bernardino with the consequence that all caiman habitat in that area has been replaced by boat docks and seawalls. However, the northern end of the lake, and much of the western side of the lake remains undeveloped.

	Latitude	Longitude
Río Salado downstream starting point at the San Bernardino to Luque bridge	25°12'24" S	57°22'27" W
Lago Ypacarai shore at the mouth of the Río Salado	25°14'53" S	57°19'37" W
Lago Ypacarai end point at the public beach	25°18'54" S	57°17'46" W

A total of 2 caiman were sighted, both 'Eyes Only'. Both were in the marsh immediately downstream (north of) the San Bernardino-Luque bridge. It is believed that both were *Caiman yacare*, though *Caiman latirostris* is known from the area. Waterskiers, pleasure boaters, and fishermen use the lake heavily.

Waterway	Caiman sighted	km surveyed	Caiman/km
Río Salado	2	6.5	0.3
Lago Ypacarai	0	10.0	0.0
Totals	2	16.5	

DISCUSSION. As shown in Figure 1, the 34 survey sites generally cover the known ranges of distribution of *Caiman yacare* and *Caiman latirostris* in Paraguay. The only major exception is the Río Paraná drainage in eastern Paraguay, which is occupied primarily by *Caiman latirostris* (see Scott, Aquino, and Fitzgerald 1990). Eastern Paraguay has not been an important source of caiman hides in recent years, and *Caiman latirostris* populations remain too depleted to support any hunting, much less a program of sustainable utilization, so this area was excluded from the present round of surveys. It should be included in future surveys in order to document any recovery.

It is difficult to determine what percentage of the total waterways in Paraguay was sampled in these surveys. Many of the rivers, streams, and shallow lagoons marked on maps of Paraguay's chaco and pantanal flow during the rainy season (October to March) but break up into a series of pools or dry out completely during the dry season (April to September). Should the estimate of the area surveyed be based on the high water systems or on the low water remnants, not all of which are indicated on maps? In addition, the expansion of cattle ranching and the concurrent construction of permanent water sources for the cattle is increasing the dry season freshwater habitat available to caiman in some areas and decreasing habitat in other areas through salinization of waterways. How is that to be measured? Certainly less than 10% of the dry season waterways were surveyed, so the survey of additional locations and repetitive surveying of the present sites is desirable to improve the accuracy of the results. Of particular interest as additional survey sites are Estancia Cerrito Jara in northeastern Alto Paraguay on the border with Bolivia, Riacho Yacaré in eastern Chaco, and a series of the oxbow lakes and lagoons scattered along the western bank of the middle Río Paraguay.

We do not have sufficient data to quantitatively evaluate the precision of our survey results. Clearly the minimum number of caimans present can be no less than the number sighted. Therefore, uncorrected survey data represent conservative estimates of the population. When the locations are surveyed using standard techniques, these surveys provide relative data that are adequate to document population trends and allow comparisons with other areas where similar techniques were used. Messel *et al*, 1981, presents standard survey techniques as well as formulae that can be used to evaluate the precision of spotlight surveys when the same waterways are surveyed repetitively. Thorbjarnarson (1991) used the Messel *et al* survey technique to repetitively survey *Caiman crocodilus crocodilus* in waterways in the llanos of Venezuela and demonstrated a high sighting fraction, mean = 80%. Lower numbers were encountered when the animals were dispersed during the wet season, high water, and when their presence was obscured by aquatic vegetation. Ideal sighting conditions occurred when dry season, low water, conditions concentrated the caimans in waterways that lacked vegetative cover (Thorbjarnarson 1991).

No waterways in Paraguay have been repetitively surveyed dozens of times much less hundreds of times. A number of sites have been surveyed previously, but are not included here because of the uncertainty of where the survey started and where it stopped. Thirteen well-delineated sites have been surveyed 2 or 3 times, i.e., this survey and a previous survey of the population at the exact same site—the Río Apa, lagunas Coronel Martinez and General Díaz, and lagoons and represas on estancias Juan de Zalazar and La Golondrina (Table 1). The variation between individual surveys of each of these 13 waterways is large, except in the case of tajamars Punta Porá and Sta. Luisa 4 which had very low population densities. One cause of this variation is the difference in waterlevel (i.e., wet versus dry season) at the time of the individual surveys. More surveys are needed before clear trends of population stability, increase, or decrease will become evident, and since the start and end of the wet and dry seasons have varied greatly in recent years, surveys also need to be conducted during the dry season as determined by water levels and not solely by the calendar.

Despite the lack of data on population trends from repetitive surveys, the current surveys clearly show that in Paraguay, while *Caiman latirostris* and *Paleosuchus palpebrosus* remain scarce, large populations of *Caiman yacare* can be found in suitable habitat. The surveys of lagunas Cnel. Martinez, Zalazar Tuyá, and Gral. Díaz documented some of the densest caiman populations ever recorded (see survey results above and Table 2). However, many of the populations surveyed lack significant numbers of large caimans in excess of 5 ft. (1.5 m.) length (Figure 2), which probably is evidence that the population is still recovering from past hunting.

Even with volumes of data on population numbers, establishing a sustainable utilization program is an experiment to the extent that monitoring is required to determine the impact the harvest has on the population. For example, a conservative quota that easily can be tolerated during normal years can become excessive if a natural catastrophe occurs, e.g., an abnormal wet season floods most nests or a lengthy drought dries habitats. By monitoring the impact the harvest is having, population trends can be documented in time to modify the program and correct any problem that arises. The recommendations that follow are conservative but depend on monitoring and future adjustment—effective wildlife management programs require monitoring and periodic adjustment.

As a result of the government's effort to stamp out illegal trade, coupled with a worldwide economic recession that has dramatically reduced the market for all caiman hides, traffic in the skins of *Caiman yacare* currently is virtually non-existent in Paraguay. The warehouses in Asunción and Bahia Negra that once were filled with skins illegally obtained from Brazil and Bolivia are empty, and the tanners are busy tanning *Tupinambis*, not caiman skins. Discussions with businessmen indicates that they understand the necessity of supplanting illegal trade with a rigorously regulated sustainable harvest, and a number have demonstrated that willingness by supporting the survey program and by constructively discussing ways in which the wildlife officials can improve the program.

Of critical importance to the ultimate success of the program for sustainable utilization of *Caiman yacare* is patience on the part of the people interested in participating in the program. No wildlife conservation management program can be instantly implemented. The program has to be initiated; it has to be monitored during implementation; and in response to problems that are discovered the program must be adjusted in later seasons. This is the course that must be followed by Paraguay's wildlife officials in implementing a caiman harvest program. The details of the program must be agreed by the appropriate officials, the public must be informed, staff must be trained, equipment and supplies purchased, companies must be licensed, and hunters must be contacted and taught the new regulations. Once this is done, the program must be implemented, and during implementation the program must be evaluated so that is can be revised and improved before the next year's program commences. Lastly, notices must be sent to CITES and other international bodies to inform them about Paraguay's program. Successful programs of wildlife conservation through sustainable utilization are dynamic processes that require frequent adjustment and modification. This takes time and requires patience, but the reward is a program that can continue to produce economic and cultural benefits far into the future.

RECOMMENDATIONS FOR THE MANAGEMENT OF *CAIMAN YACARE*. Wild caimans can be conserved through sustainable utilization if no more of the animals are being harvested than will be replaced by the normal reproductive rate of the wild populations before the next harvest. By focusing the harvest on large adult males and minimizing the killing of the smaller females and males, a program of sustainable utilization has been established for the harvest of *Caiman crocodilus* in Venezuela. A similar program for the sustainable utilization of wild *Caiman yacare* in Paraguay would contain the following functional elements:

- a program of annual surveys to monitor the status of the wild populations—to determine whether the populations are stable, increasing, or decreasing,
- hunting should be restricted to the dry season—15 March to 30 September,
- hunting initially should be restricted to Alto Paraguay—hunting should be expanded to other regions in future years,
- the quota for the first year (1994) hunting season should be 5,000 *Caiman yacare*—initially quotas for the number of *Caiman yacare* that may be killed each year should be established for each region, and later possibly for individual estancias,
- to protect most females and smaller males, a minimum size limit of 180 cm total length should be established for the harvest of *Caiman yacare*—this size caiman yields a belly hide of 180 cm total length or a flank of 90 cm.
- all *Caiman yacare* hides harvested during the hunting season should be tagged with government issued locking, non-reusable tags—untagged skins should be considered *prima facie* evidence of illegality,
- no later than 30 October, all *Caiman yacare* skins should be brought to centralized government warehouses where they can be validated,
- only tanners that are authorized by the government should be allowed to purchase, tan, and export *Caiman yacare* skins—the licensed tanners should show their active support for the program by refusing to purchase undersized skins or skins smuggled into Paraguay from neighboring countries,
- caiman populations scattered throughout Paraguay should be conserved in national parks and protected areas—particularly worthy of national park or biosphere reserve protection are the populations in the Río Negro in extreme northeastern Paraguay and in Laguna General Díaz, and
- the government of Paraguay should implement and vigorously enforce the provisions of the program.

An annual survey/monitoring program. To ensure that the harvest of *Caiman yacare* is truly sustainable and does not deplete the wild populations by decreasing their normal reproductive rate, the status of the wild populations must be monitored (repeatedly censused) in a manner that will reveal whether or not they are remaining stable, are increasing or are decreasing. A program of systematic, repeatable, annual surveys will yield such data on both hunted and non-hunted populations. Surveys and monitoring programs that cannot be repeated by independent researchers are not scientific. To be repeatable, each survey must include the following minimal data: 1) a description of the survey method; 2) the exact start point and exact end points, both preferably recorded as latitude and longitude degrees, minutes, and seconds; 3) the distance and route, or area, surveyed between the start and end points; 4) the date and time of the survey; 5) the season, wet or dry, if appropriate; 6) the number of crocodilians sighted; the water level or tide level; 7) water temperature and air temperature; 8) wind strength; and 9) salinity of the water (Crocodile Specialist Group 1993). Where possible, it also is desirable to record in standard units of measure (feet or half-meters) the size-classes of the crocodilians sighted; and the location along the survey route of each crocodilian sighted.

The restricted hunting season. When they are guarding their nests, female crocodilians are especially vulnerable to hunters. In populations that are hunted during nesting season, females usually do not guard their nests; females that do not abandon their nests are killed. Whether the females are killed or simply abandon their nests, unguarded nests suffer increased losses to egg predators. That reduces the population's reproductive rate. In Paraguay, *Caiman yacare* nests during the October–April wet season, so to minimize the threat to nesting females, the hunting season should extend from 15 March through 30 September.

The restricted hunting area. There is insufficient time for the government of Paraguay to promulgate all the necessary regulations, to train the necessary staff, and to implement a country-wide program for the sustainable harvest of *Caiman yacare* if the 1994 hunting season is to start on 15 March. Therefore, 1994 is recognized as an experimental season and hunting of *Caiman yacare* will be allowed in Alto Paraguay only. During and following the season the government authorities will evaluate the program and make whatever adjustments are needed to correct problems and to expand the program to other regions in coming years.

The hunting/export quota. Sustainability is a goal, a direction, not a fixed end point (Lee 1993), and as a consequence management for sustainable utilization must be adaptive, not deterministic (Salwasser 1993). The scientific data may suggest an optimum level of sustainable exploitation, but applying that level as a quota still requires trial and error (Ludwig, Hilborn and Walters 1993). For this reason, initial management must be conservative. Monitoring then reveals how the population responds to the management program. This allows the management to be adjusted as needed. The results of the current survey suggest that it may be possible to sustainably harvest tens of thousands of *Caiman yacare* annually. However, to be conservative, a first year hunting and export quota of 5,000 *Caiman yacare* skins should be established for 1994. This is in keeping with the recommendations of Messel and King (1992) and will allow the Paraguay wildlife authorities to correct any problems that arise during the experimental first year of the program. The quota should be expanded during the second season to 10,000 as the hunt is extended to other regions and as the annual population surveys monitor the impact of hunting on the wild populations. If everything goes well, by the third season the quota could be raised to an annual harvest of 15,000 or 20,000 caiman.

The minimum size limit. Male *Caiman yacare* mature at about 156 cm total length or 90 cm snout-vent length (Crawshaw 1987) and reach a maximum total length of approximately 300 cm or snout-vent length of 174 cm (Medem 1983). Female *Caiman yacare* attain sexual maturity at 130 cm total length or 76 cm snout-vent length (Crawshaw 1987), and reach a maximum total length of about 200 cm or 105 cm snout-vent length (based on Museo Nacional de Historia Natural de Paraguay specimens). However, most females seldom exceed 180 cm total length. Therefore, if the killing of *Caiman yacare* smaller than 180 cm total length or 93 cm snout-vent length in Paraguay were prohibited, this would allow the harvest of large males while protecting most females and smaller breeding males.

A *Caiman yacare* that measures 180 cm total length will yield a 180 cm belly hide (measured from the tip of the chin to the tip of the tail) or a 90 cm flank skin (measured from the tip of the chin to the most posterior end of the skin behind the anal vent).

No licensed hide buyer should purchase skins smaller than the 180 cm minimum size limit for belly skins or 90 cm minimum size for flank skins. However, as there were no limits on the size of caiman killed in Paraguay in the past, it is proposed that during the first year's hunt (1994) allowances be made for up to 10% of the skins being taken by mistake from slightly smaller caiman. Experienced hunters have no difficulty in estimating the size of the caiman before killing them and the inexperienced hunters will rapidly learn, so the minimum size limit should be strictly enforced after the first year.

Tagging the hides. Recognizing that illegal trade in poached or smuggled crocodilian skins will not be controlled until it is possible to distinguish between legal and illegal skins, the Parties to CITES passed a resolution calling for all crocodilian skins in international commerce to be tagged with locking, non-reusable, uniquely numbered, chemically inert tags. Such tags should be supplied to the hide buyers by the Paraguay wildlife authorities and should be attached to all *Caiman yacare* skins as soon as the animals are skinned. The total number of tags issued must equal the hunt and export quota. To comply with the CITES resolution, the tags must stay on the skins through the tanning process. Any untagged skins in the possession of hunters, estancia owners, buyers, tanners or other individuals should be considered *prima facie* evidence of illegality. Broken tags should be reattached with locking plastic cable ties.

Validation of the hides. In order to verify the legality of the harvest, all the tagged *Caiman yacare* skins should be brought to regional validation centers. During the experimental 1994 harvest in Alto Paraguay, validation centers should be established in Bahia Negra and Fuerte Olimpo. Anytime during the hunting season, or for 30 days following the hunting season (i.e., until 30 October), tagged *Caiman yacare* skins may be brought to the centers for validation. Wildlife officials at the centers will verify that the skins were harvested by the individual to whom the tags were issued or by his or her agents, that the skins are properly tagged, are equal to are longer than the minimum size limit, and originated in the authorized hunting region. Once validated, shipment of the skins to a tannery in Asunción or another part of Paraguay will be permitted.

Tanning and export. The export of raw salted caiman skins should be prohibited. Only companies or individuals licensed by the wildlife authorities of Paraguay should be permitted to buy, tan, or export *Caiman yacare* skins. Further, only those companies or individuals who actively support the sustainable utilization program through their refusal to traffic in skins taken prior to or following the authorized, 15 March–30 September, hunting season, or skins smaller than the minimum size limit, or skins that originate outside the authorized region (including skins that are smuggled into Paraguay from neighboring countries) should be allowed to participate in the program. All exports must comply with all CITES requirements.

Protecting caiman populations in national parks and protected areas. The biological diversity of Paraguay's caimans should be conserved by protecting caiman populations in a network of national parks, biosphere reserves, wildlife sanctuaries, or other protected areas scattered throughout the range of distribution of the caiman species in Paraguay.

Particularly worthy of protection—not only for its caiman population, but also for the spectacular waterfowl populations and associated capybara and yellow anaconda populations—is the habitat bordering both sides of the Río Negro running between extreme northeastern Paraguay and extreme southeastern Bolivia. We urge the government of Paraguay to begin negotiations with the governments of Bolivia and Brazil to have this area, and an adjoining portion of the Brazilian pantanal, declared a joint bi-national or tri-national park. A second population particularly worthy of protection are the caimans in Laguna General Díaz and Arroyo Syry. Laguna Gral. Díaz also supports a large cormorant, heron, and egret rookery during the wet season. Both of these areas, Río Negro and Laguna Gral. Díaz, could be major attractions for ecotourism, and ecotourism could provide an important source of legal income to replace the revenue Bahia Negra and Alto Paraguay lost when the illegal trade in smuggled Brazilian caiman skins was shut down.

Implementation and enforcement. The government of Paraguay should implement and vigorously enforce the provisions of the caiman harvest program. This will forestall any international claims that illegal shipments of caiman skins originated in, or were transshipped through, Paraguay.

Figure 1. Map of Paraguay showing location of the numbered survey sites reported in the 'Results'—1–3 are Estancia Palo Santo survey sites; 4–11 are Estancia Juan de Zalazar sites; 12–17 are Estancia La Golondrina survey sites; 18 is the Río Confuso survey site; 19–22 are Estancia Loma Porá sites; 23 is the Pozo Colorado–Concepción highway tajamar survey sites; 24–27 are Estancia Josephina survey sites; 28–29 are Estancia 26 de Agosto survey sites; 30 is the Laguna General Diaz survey site; 31 is the Río Paraguay and Riacho Esperanza survey site; 32 is the Río Negro and Río Paraguay survey site; 33 is the Río Apa survey site; and 34 is the Lago Ypacarai survey site.

FIGURE 2. SIZE DISTRIBUTION OF *CAIMAN YACARE* IN PARAGUAY BASED ON THE 1993 SURVEY DATA FOR NON-'EYES ONLY' CAIMAN.

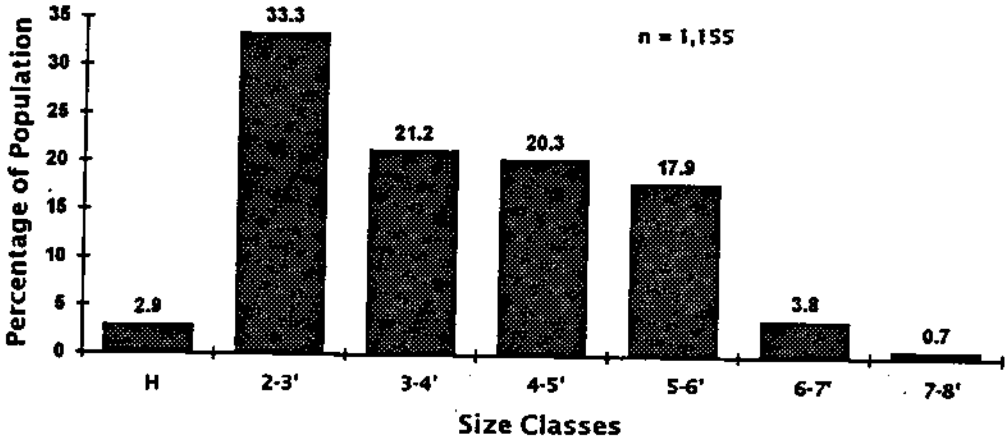

TABLE 1. COMPARISON OF THE RESULTS OF CURRENT AND PREVIOUS SURVEYS AT SELECTED SITES.

Survey Site	Area Surveyed[a]	Survey Date[b] and Surveyors	Caiman Sighted	Caiman Density	Water Level[b]
Laguna Cnel. Martinez	1 km	28 Oct 1993 Current Survey	487	487/km	Low
		14 Apr 1992 Aquino and Scott	21	21/km	High
		12 Nov 1991 Aquino and Scott	48	48/km	High
Laguna Benítez Cué	3 km	30 Oct 1993 Current Survey	63	21.0/km	Low
		15 Nov 1992 Aquino and Scott	94	31.3/km	High
Laguna He-É	1.8 km	30 Oct 1993 Current Survey	38	21.1/km	Low
		15 Nov 1991 Aquino and Scott	59	32.7/km	High
Laguna Tapa Cué	1.8 km	31 Oct 1993 Current Survey	33	18.3/km	Low
		15 Nov 1991 Aquino and Scott	97	53.9/km	High
Laguna Romualdo Cué	2.6 km	31 Oct 1993 Current Survey	46	17.7/km	Low
		14 Nov 1991 Aquino and Scott	20	7.7/km	High
Laguna Zalazar Tuyá	0.5 km	1 Nov 1993 Current Survey	345	690/km	Low
		16 Nov 1991 Aquino and Scott	88	176/km	High
Represa Galpón	0.64 ha	31 Oct 1993 Current Survey	0	0/ha	Low
		16 Nov 1991 Aquino and Scott	16	25/ha	High
Represa Vicente	1.0 km	1 Nov 1993 Current Survey	203	203/km	Low
		15 Nov 1991 Aquino and Scott	11	11/km	High
Tajamar Punta Porá and Earth Tank	1.0 ha	4 Nov 1993 Current Survey	1	1/ha	High[c]
		10 Apr 1992 Aquino and Scott	0	0/ha	High[c]
Tajamar Sta. Luisa 2 and Earth Tank	1.0 ha	4 Nov 1993 Current Survey	12	12/ha	High[c]
		10 Apr 1992 Aquino and Scott	1	1/ha	High[c]
Tajamar Sta. Luisa 4 and Earth Tank	1.0 ha	4 Nov 1993 Current Survey	0	0/ha	High[c]
		10 Apr 1992 Aquino and Scott	0	0/ha	High[c]
Laguna Gral. Díaz and Arroyo Syry	15.2 km	10 Nov 1993 Current Survey	3,294	216.7/km	Low
		16 Oct 1992 Messel and King	103	6.78/km	High
		16-20 Oct 1987 Aquino	3,002	197.5/km	Low
Río Apa	55 km	9 Nov 1993 Current Survey	550	10.0/km	Low
		15 Oct 1992 Messel and King	158	2.87/km	High

[a] The surface area of some bodies of water can change dramatically between wet and dry seasons, while others change little. The area listed here, and used in calculating density, was the area at the time of the 1993 survey. However, as noted in the discussion above, Represa Galpón was nearly dry at the time of the 1993 survey, so its area at the time of the 1991 survey is shown.

[b] Normally, October through March is the wet (high water) season and April through September is the dry (low water) season.

[c] Waterlevels in some tajamars are maintained artificially and fluctuate little.

TABLE 2. ABUNDANCE OF VARIOUS CROCODILIAN SPECIES.

Species	Crocodilians/km	Region	Source
Alligator mississippiensis	2.5 to 7.8	Florida	Wood and Humphrey 1984
Caiman crocodilus	0.17 – 17.1	Brazil	Brazaitis *et al* 1990
"	6.6 – 9.02	Perú	Gorzula and Seijas 1989
"	8.51	Perú	Verdi *et al* 1980
"	0.7 – 19.0	Suriname	Gorzula and Seijas 1989
"	19.8 – 86.5	Suriname	Ouboter and Nanhoe 1989
"	0.29 – 15.12	Venezuela	Seijas 1988
"	2.52 – 23.4	Venezuela	Gorzula and Seijas 1989
"	1.61 – 155.71	Venezuela	Gorzula and Woolford 1990
"	5.5	Venezuela	Espinoza 1992
Caiman yacare & Caiman latirostris	0.4 – 29.8	Argentina	Waller and Micucci 1993
Caiman yacare	0.01 – 70.0	Bolivia	King and Videz 1989
"	3.0 – 5.6	Bolivia	Ergueta and Pacheco 1990
"	0.15 – 8.4	Bolivia	Pacheco 1993
"	– 169.14	Brazil	Schaller and Crawshaw 1982
"	0.0 – 1,017.3	Paraguay	Current 1993 surveys
Crocodylus acutus	0.0 – 3.89	Venezuela	Seijas 1988
"	6.3	Haiti	Thorbjarnarson 1988
Crocodylus porosus	0.1 – 4.0	Australia	Messel and Vorlicek 1986
Melanosuchus niger	7.5 – 11.11	Bolivia	Vaca 1992
"	0.25 – 15.8	Bolivia	Pacheco 1993
"	0.0 – 2.0	Brazil	Brazaitis *et al* 1990
"	0.0 – 14.72	Ecuador	Hines and Rice 1993
"	2.02	Ecuador	Jahoda 1990
"	7.4	Guyana	Gorzula and Woolford 1990
"	0.28	Perú	Verdi *et al* 1980
Paleosuchus palpebrosus	0.15	Bolivia	Pacheco 1993
"	0.29	Guyana	Gorzula and Woolford 1990
"	0.23	Perú	Verdi *et al* 1980

Adapted from Pacheco 1993.

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Interim Results of the IUCN Nepal Crocodile Survey

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ABSTRACT

Since September 1993 IUCN Nepal has been conducting a habitat assessment and survey of the mugger, *C. palustris,* and the gharial, *G. gangeticus,* throughout the Terai. This preliminary survey is an attempt to determine presence of populations and to quantify their numbers. The results include information on habitat, suitable release sites for restocking, and observed and reported crocodile sightings. At present the total number of crocodiles sighted amount to 32 adult, 5 sub-adult, and 2 juvenile *C. palustris,* and 14 adult and 5 juvenile *G. gangeticus*. Reliable local sightings bring the number of adult *G. gangeticus* to 35. We have yet to calibrate sightings with actual population densities. The survey has covered most of the available habitat in Nepal with up to seven surveys at some sites.

1. INTRODUCTION

Nepal has two species of the family Crocodylidae, to which all modern crocodilians belong. The mugger, *Crocodylus palustris,* (subfamily Crocodylinae) is listed as vulnerable and is on Appendix I of CITES. The gharial, *Gavialis gangeticus,* (subfamily Gavialinae) was on the verge of extinction with less than 150 adults surviving throughout its range in 1974. Subsequent breeding and restocking programs in India and Nepal have raised the feral population to more than two thousand. The gharial is listed as endangered and is on Appendix I of CITES.

Both species exist on the Indian subcontinent with large historical ranges from Bangladesh in the east to as far west as Iran for the mugger and Pakistan for the gharial.

1.1. Gharial (*Gavialis gangeticus*).

The gharial once occurred in many river systems in Nepal. The main rivers where populations could be found were the Mahakali, the Karnali, the Babai and Bheri to the west; the Narayani and its tributaries, including the Kali Gandaki, in central Nepal; and the Sapta Kosi Tappu Region to the east.

Currently, they are distributed in isolated populations in the Karnali, Babai, and Narayani systems all of which are in or adjacent to protected reserves. The gharial is nearly extinct in the Mahakali and Sapta Koshi. A survey conducted in 1989 found nine gharials in the Karnali and seven in the Babai, giving rise to an estimated 20 to 40 gharials in that system.

In India their range is restricted to the Ganges River and its main tributaries. Scattered populations exist in Pakistan on the Nara and Indus and may still exist in Bangladesh on the Jamuna and Padma Rivers.

1.2. Mugger (*Crocodylus palustris*).

The mugger was also widely distributed in Nepal. Their habitat ranged throughout the Terai. In the Karnali and Babai they co-existed with the gharial. They occurred along the West and East Rapti, into the Narayani systems, and in the Koshi River.

The mugger has now been reduced to isolated populations in primarily protected habitats. Royal Sukla Phanta Wildlife Reserve, Bardia, and Royal Chitwan National Park contain the only viable populations. A limited number have been reported from the Sapta Koshi area. The Mahakali and Bahuni Rivers adjacent to Sukla Phanta represent excellent habitats and are contiguous with areas in Uttar Pradesh where an effective rehabilitation program is in underway. Large numbers have been reported by locals in this area. However, surveys by this project revealed few.

Habitat loss has been the leading cause for declining crocodile populations in Nepal. This was accelerated in the mid-1950s when an intensive malaria eradication program opened the Terai for habitation. Forty percent (7.6 million) of Nepal's population live in the Terai.

2. SURVEY METHODOLOGY

Important areas for crocodile populations were previously defined based on literature and interviews with local people (Andrews & McEachern, 1994). The survey is being conducted in conjunction with the IUCN Wetlands Reconnaissance Survey so many sites have been assessed for habitat suitability in addition to actual counts.

Shore counts entailed scanning with binoculars the entire shoreline and water surface of lakes and wetlands in one direction to limit recounts. Results were checked by reversing the direction and counting back to zero. In river systems, shore counts were made along the visible banks of known lengths of river channels. Some wetland habitats allowed for complete circumnavigation of the shoreline to search for tracks and scat. However, these were always disturbed sites where grazing reduced reed growth. We recently acquired a tape recording of C *palustris* hatchling chirrups which has greatly increased the effectiveness of shore counts.

Many of the wetland sites in Nepal contain dense macrophyte populations that render boat counts impossible. Boat counts were performed by traversing the site from one end to the other and entering all navigable fingers with a small non-motorized inflatable. Use of a motor was precluded by the density of submerged macrophytes.

For night count we use halogen spotlights with an effective range of 75-100 meters.

We report results in terms of the maximum individuals seen at a site. Results of repeat visits are noted in this paper for comparison. We are attempting to model our approach based on survey methods used elsewhere (Bayliss, 1987; Nichols, 1987) Where possible we have reported relative densities.

3. EASTERN NEPAL

Nepal's eastern Terai consists of seven districts east of the Kamala River. All seven districts were surveyed for crocodile populations and habitat. There are several large rivers, the largest being the Sapta Koshi. The Sapta Koshi drains the eastern and central Himalaya as far west as Langtang, having a catchment area of approximately 60,000 km^2. This river is permanently flooded and the large floodplain, formed as it enters the low laying Terai, is impounded by an irrigation barrage at the Indian border. Nearly all the other rivers in this section become completely dry or are reduced to low volume trickles during the dry season. All permanent waterbodies in this section are heavily impacted by human use. Wild populations of gharial and mugger are restricted to the Koshi system.

3.1. The Sapta Koshi

Construction began on an irrigation barrage in 1958 and was completed in 1965 across the Sapta Koshi River at Bahardaha. Containment berms extend from the barrage to points 40 km northeast with regular spurs extending inward towards the river. A seepage canal lies outside the eastern berms and is permanently flooded.

The river has a number of braided channels with the main channel meandering from the center to the eastern margin of the impounded flood area. Water depths are generally shallow; during our boat surveys the main channel was usually less than 0.5 m deep. The deepest sections, along the eastern berms, are up to three meters deep.

A protected area, the Koshi Tappu Wildlife Reserve (KTWR), was established in 1976. The southern boundary of the protected area is seven kilometers upstream from the barrage and the protected area extends 15 km further upstream. The width of the flood area between the containment berms averages 10 km within the protected area.

Table 1: Summary of Eastern Habitat and Survey Information

Site Name	Date	Survey type	Habitat type	Air Temp	Water Temp	Count/ suitability	Remarks
Biring Khola	02/12/94	HA	PR	-	-	Poor	400 m wide/agr. on both banks
Kankai Khola	02/12/94	HA	PR	-	-	Poor	570 m wide/agr. on both banks
Ratawa Khola	02/12/94	HA	PR	-	-	Poor	300 m wide/agr. on both banks
Bakra Khola	02/12/94	HA	PR	-	-	Poor	300 m wide water shallow
Balan Khola	02/12/94	HA	SR	-	-	Poor	
Sapta Koshi, Koshi Tappu and	04/28/93 02/10-	D, B, S	PR	20-25 18	17 13	2MA(R) 2GA(R)	Rel. density 0.1/km river
Oxbows	13/94		POL	20.1	20.3		2-3 m depth
Chisang Khola	02/12/94	HA	SR	-	-	Poor	275 m wide/no water
Singhiya Khola	02/12/94	HA	PR	-	-	Marginal Disturbed	150 m wide good banks

Survey Types: HA= habitat assessment only, B= boat count, S= shore count, C= chirrup tape used, D= day count, N= night count.

Habitat Type: SR= seasonal river, PR= perennial river, OL= oxbow lake, PL= permanent wetland or lake, SL= seasonal wetland or lake.

Counts: M= mugger, G= gharial, A= adult, SA= sub-adult, J= juvenile, H= hatchling, R= reported.

Nesting habitats in the protected area are of low quality. The berms and spurs which form the principle banks during summer flooding are constructed from wire and stone gabions. Grasslands and islands are regularly flooded during monsoon. In addition to a lack of nesting banks disturbance is high within the protected area. Approximately 15,000 domestic cattle and buffalo range within the protected area (Bhandari & McEachern, 1993). Grass cutting is allowed for two weeks in January. The remaining grasslands are then burned. Despite time allocation restrictions, grass harvesting continues year round.

From local accounts, mugger habitat used to extend throughout the lakes and rivers of the entire area with more frequent sightings during summer months. At present sightings are limited to the Koshi river system. Surveys were conducted on the Sapta Koshi on five occasions. Two of these were boat counts travelling down the main channel from the northern border of the protected area to the park headquarters of the KTWR and from the headquarters to the southern border of the protected area. Three counts were performed by driving along the eastern berms from the northern border to the barrage 25 km south. Using binoculars, driving the berms is more effective than rafting among the shallow braided channels (see *Table 1*).

During our five surveys, no mugger or gharial was spotted. Discussions with the warden for the KTWR indicate that there are only two adult *C. palustris* and one or two adult *G. gangeticus* in the area between the barrage and the protected area's northern boundary. This figure was corroborated by army personnel who patrol the protected area . A local fisherman estimated there were four adult muggers by including two he had seen upstream at the Trijuga confluence.

In 1983, and again in 1986, forty-two *G. gangeticus* sub-adults were released on the KTWR. It is likely these animals have either succumbed to mortality or have migrated down river below the barrage to India.

Despite a dearth of habitat suitable for wild populations, the general low altitude of the area promotes regular and long term inundation resulting in large numbers of permanent fish tanks approximately 0.5 - 1 m deep and 0.5 - 1 ha in surface area. From a commercial utilization stand point for *C. palustris* this area would be viable.

4. CENTRAL NEPAL

Central Nepal consists of a short section of Terai from the Kamala River west to the Narayani River. The area of primary importance in this section is the Chitwan district. It includes the Royal Chitwan National Park (RCNP), which contains and is bordered by the East Rapti River to the north and the Narayani River to the west. Both rivers are excellent habitat for mugger. The Narayani supports the largest population of gharial in the country. Some gharial have been sighted in the smaller East Rapti as well. The two rivers have left a series of oxbows within the park which indicate historic mugger populations in the wetlands of Nepal prior to malaria eradication and the settling of the Terai in the mid-1950s (see *Table 2*).

4.1. Royal Chitwan National Park

The Narayani River offers excellent habitat for both gharial and mugger. It is the primary source for gharial eggs collected each year by the Department of National Parks and Wildlife Conservation (DNPWC) for their Gharial Project in RCNP. Last summer five gharials were released from the project into the Narayani River. Further upstream the Krishna Gandaki River also has a small population of gharial. We have not yet had the opportunity to survey this river, but have travelled the Narayani on one occasion (see *Table 2*). Since 1981 DNPWC has released 180 *G. gangeticus* into the Narayani River and its tributaries.

The East Rapti River is the primary source for mugger eggs collected each year by DNPWC. During the 1993 laying season 12 nests were located of which 11 came from the East Rapti. Nine of these nests, or 264 eggs, were removed and incubated by the DNPWC project. Of these 134 hatched for a success rate of 51 percent. Subsequent to hatching, 35 individuals were released into Tamor Tal (inside RCNP) but records were not supplied. During our visit in October there were 59 surviving mugger hatchlings of the approximate 99 originally kept at the project .

Staff from Tiger Tops, a local resort, travel the lower section of the East Rapti and part of the Narayani on a daily basis. They organize tourist trips regularly down most of the East Rapti and the Narayani. In February, we initiated a joint effort to intensively survey the Narayani and Rapti systems, and instructed their guides to collect survey information using maps and data sheets for the collaborative effort. During their most recent trip in December 1993 (see *Table 2*), which covered the lower East Rapti and the entire length of the Narayani, inside RCNP, 28 gharial were spotted. Sighting locations were noted in this 80 km stretch of river. This corresponds to a relative density of 0.35 gharials per kilometer of river surveyed. Unfortunately, this was prior to our involvement and although many muggers were observed mugger sightings were not recorded.

The wetlands and rivers inside RCNP have been visited on numerous occasions (see *Table 2*) and from these, 23 adult, 5 sub-adult, and 1 juvenile *C. palustris* were observed. We observed 7 adult and 1 juvenile *G. gangeticus* in our visits.

4.2. Beeshajar Tal

In addition to the RCNP, a large forest reserve, the Tikauli, incorporates a seasonally inundated area with 4 permanent water bodies joined by an irrigation canal that flows through the area. The largest of these is Beeshajar Tal.

Beeshajar Tal is IUCN Nepal's proposed location for a demonstration site on wetlands management. The proposal incorporates a *C. palustris* breeding and rearing facility, the long term goal being sustainable utilization of this species to promote its conservation.

We have visited Beeshajar Tal on seven occasions (see *Table 2*) as it is a principle site for our seasonal monitoring of water chemistry. On every occasion we have noted the mugger population and it is the only lake where we now recognize individuals along

with some of their habits. We estimate a *C. palustris* population of 6 adults and 3 sub-adults. We have not seen any evidence of smaller size classes.

We have found a large burrow on this lake with an entrance and an exit hole, actively used by one of the muggers. Both holes become submerged during high water periods. Hatchlings likely disperse *via* the irrigation canal to the other wetlands within the forested area. Mortality to the numerous egrets, Lesser Adjutant Storks, and flushing into agricultural lands is likely high.

4.3. East of Chitwan

East of Chitwan there are seven districts which contain a number of seasonal rivers and wetlands. All of these were assessed as poor habitat for *C. palustris*. Most of the rivers become dry prior to monsoon and the wetlands severely degraded by human use. One such example is Halkhoriya Tal located in the center of a protected forest area. During dry months it is the only water in the area and villagers drive their cattle several miles through the forest to access it. No crocodiles were observed or reported from the Kamala River west to Chitwan.

The Munusmara is an exception to the complete desiccation of smaller rivers in this section. The Munusmara has a large watershed originating in the Terai. However, this river is highly disturbed along its length; otherwise it would serve as an excellent habitat with its deep slow flowing pools and high loam banks.

5. WESTERN NEPAL

The western Terai of Nepal is less densely populated than the east and some of the habitat is subsequently less disturbed. Politically, it is divided into the Western, Mid-western, and Far-western development zones. The Western and Mid-western zones, extending from the Narayani River to the Karnali River, contain 11 Terai districts of which nine have been surveyed. There are three main river systems of interest in these sections: the West Rapti, the Karnali, along with its tributary the Bheri, and the nearby Babai. The Far-western development zone contains four Terai districts and is the most interesting in terms of potential habitat. It contains the Mahakali River, along with numerous smaller rivers draining forested watersheds.

5.1. The Lumbini Area and the West Rapti

The Lumbini area, just west of the Narayani River, is known for its large number of wetlands and high water table. This area, however, is densely populated and is the most disturbed of the Western zone. We visited 27 wetland and river sites in the Western zone with no sign of crocodiles. Local people unanimously agreed that no crocodiles inhabit this area.

The West Rapti River traverses the Mid-western zone from east to west, turning south and entering India near Nepalgunj. It is a large, permanently flooded river with many smaller seasonal tributaries. The river contains moderately good habitat for both gharial and mugger, but again is subjected to human pressures. Both *C. palustris* and *G. gangeticus* have been reported from this system (T.M. Maskey pers. comm.). We have not had the opportunity to survey this river, but anticipate the best time to be in the post-monsoon season. A conservation area must be established in order to ensure this as an appropriate habitat for release.

Table 2: Summary of Central Habitat and Survey Information

Site Name	Date	Survey type	Habitat type	Air Temp	Water Temp	Count/ suitability	Remarks
Kamala Nadi	02/12/94	HA	PR	-	14.4	Poor	640 m wide very low water
Manusmara Khola	02/13/94	HA	PR	-	22.2	Marginal disturbed	Good banks and depth
Bagmati River	02/13/94	HA	PR	-	17.2	Poor	400 m wide low water
Chandi Nadi	02/13/94	HA	SR	-		Poor	
Halkhoriya Tal	03/28/94	D, B, S	PL	33	28	No crocs marginal disturbed	Protection and earth dam at outflow would make it good
Bakaeya Nadi	02/17/94	HA	SR	-	21.1	Poor	Low water
Narayani River	10/04/93 10/05/93	DS DB	PR	-	-	1A,1JG 2AG+6T 2AM+13T	Good hab. low area excel.
East Rapti River	04/01/93 03/24/94	DS	PR	-	-	2AM,1AG	1km section
Beeshajar Tal	07/06/93 07/06/93 10/01/93 10/02/93 02/24/94 03/23/94 03/27/94	DBS NB NB D, S DSBC DSBC DS	PL	32 - - 27.5 19.4 34.3 31.6	34 34 28 28.8 19 28.2 26.7	2AM 7M 3A,3SAM 3AM 5A,3SAM 6AM 2AM	Good habitat, moderately disturbed. Relative density = 0.82/ha
Devi Tal	03/05/94	DSB	PL	22.9	24.3	2SAMT	Good habitat
Dhakare Tal	03/05/94	DSB	OL	23.8	24.9	3AM	Good habitat
Lami Tal	03/31/93 10/03/93 03/05/94 03/24/94	NS NB/DB DS DSC	OL	21 27 27.5 30.6	22 29 24 24.4	5AM 6AM/5AM 1AM 4AM	Good habitat, army fails to keep local cattle from grazing in nesting area. Rel. dens.= 6/ha
Tamor Tal	03/29/94	DSC	PL	-	-	none	none observed in 4 other day visits with boat
Nandan Tal	12/01/92	DS	PL	-	16.6	none	75? Hatchlings released in 1992

Proximate to Royal Bardia National Park (RBNP), the habitat is more interesting and less disturbed. The mid-western zone contains the Babai, Bheri, and Karnali Rivers.

5.2. The Babai River

We surveyed the Babai River, which traverses Royal Bardia Park, by raft on 22 February 1994.

The river was generally shallow, ranging from 0.1 to 0.5 m, but contained deep pools at regular intervals. Adult gharials and adult muggers were not seen in the same locations. The muggers appeared to be concentrated in one section of the river. One pair was observed. A juvenile mugger was seen in the same pool as 2 large adult gharials. The relative density was 0.19 crocodile sightings per km of river.

The warden of Bardia National Park surveyed the same section of the Babai in November 1993, and counted 8 *G. gangeticus* and 2 *C. palustris*.

In 1990, DNPWC released 30 sub-adult *G. gangeticus* into the Babai River.

5.3. The Bheri River

The Bheri River runs west, north of Bardia National Park, and subsequently joins the Karnali River. Crocodiles have been sighted along the lower reaches of the river at its Karnali confluence. Upstream, near Birendranagar, the river is small and highly disturbed If crocodile populations exist in the upstream locations, they are likely a temporary result of post-hatching dispersion and move back downstream during the dry season.

5.4. The Karnali River

The Karnali is Nepal's second largest river. It is a single channel from the Bheri confluence south to the East-West Highway bridge, but below the bridge it diverges into multiple channels. The upper section of this river, from the Bheri to the bridge, is thought to have the richest crocodile population. It is also habitat for the ganges dolphin. Crocodiles are rarely seen along the lower channels. We surveyed the river on two occasions, once from the Bheri confluence down to the new bridge, and from the bridge to the southern end of the protected area along the eastern channel.

During our trip from the Bheri to the bridge, no crocodiles or their spoor were observed, despite intensive searching along the banks. A new road to Jumla is being constructed along the western bank, so the dearth of sightings maybe attributed to blasting which had been ongoing for several days. Local people claimed they regularly sight 4-10 crocodiles a day basking on the eastern banks during the warm months of June to September. In addition to disturbances from blasting, several

Table 3: Summary of Western and Mid-western Habitat and Survey Information

Site Name	Date	Survey type	Habitat type	Air Temp	Water Temp	Count/ suitability	Remarks
Amlahawa Tal	11/23/93	HA	PL	-	-	Poor	High disturb.
Bakulla ghat	11/22/93	HA	PL	-	-	Poor	High disturb.
Dande Khola	11/22/93	HA	PR	-	-	Marginal	Large, slow
Dano River	11/22/93	HA	PR	-	-	Poor	High disturb.
Gaindahawa Tal	11/22/93	HA	PL	21	22.4	Marginal	Large, disturb.
Gulariya Tal	11/22/93	HA	PL	-	-	Poor	High Disturb.
Materia Tal	11/22/93	HA	PL	-	-	Marginal	Large, disturb.
Padrahawa Tal	11/22/93	HA	PL	-	-	Marginal	Large, disturb.
Sagrahawa Tal	11/22/93	HA	PL	-	-	Poor	Small, disturb.
Telar River	11/22/93	HA	PR	-	-	Marginal	Disturb.
Tinau River	11/22/93	HA	PR	-	-	Marginal	Disturb.
Gajedia Tal	11/23/93	HA	PL	-	-	Marginal	Large, disturb.
Karbalah Tal	11/23/93	HA	PL	-	-	Poor	High disturb.
Lausako Tal	03/23/93	HA	PL	27.9	22.5	Fair	Forested
Siktihawa Tal	11/23/93	HA	PL	21.4	19	Marginal	Large, disturb.
Ajigara Tal	11/24/93	HA	PL	-	-	Poor	Small, disturb.
Bahadur Ganja P.	11/24/93	HA	PL	-	-	Poor	Small, disturb.
Ban Ganga Reservoir	11/24/93	HA	PL	-	-	Fair	Large, protected
Buddi Tal	11/24/93	HA	PL	-	-	Poor	
Jagadishpur Res.	11/24/93	HA	PL	16.6	21.2	Fair	Large, protected
Karmahawa Tal	11/24/93	HA	PL	-	-	Poor	Disturb.
Lamboo sagar	11/24/93	HA	PL	-	-	Marginal	Large, forest
Mansarobar Tal	11/24/94	HA	PL	-	-	Poor	Disturb.
Nigiihawa Tal	11/24/93	HA	PL	-	-	Poor	Small, disturb.
Purnihawa Tal	11/24/93	HA	PL	-	-	Poor	Small, disturb.
Mid-western							
Bheri River	09/24/93	HA	PR	-	-	Poor	Disturbed
Babai River	02/22/93	DB	PR	18.3	15.6	2A,4JG 4A,1JM	Excel. habitat
Badia Tal	02/23/94	HA	PL	-	-	Marginal	Large, shallow intensively fished
Karnali River	09/23/93 02/20/94 02/16/94	HA DB DB	PR	- 18.3 -	24 12.8 -	Good None 3AG,2AM	Good habitat, recently more disturbed
West Rapti River	09/24/93	HA	PR	-	-	Fair	Monitoring

boats were observed crossing the river to the protected eastern bank, from the western bank where cattle and human use are extensive (see *Table 3*).

Tiger Tops, a local adventure resort, which often takes tourists down the river, rafted the Bheri to bridge route on 15 February, and saw 2 mugger and 3 gharial.

6. FAR-WESTERN ZONE

The Karnali has been an effective barrier to development further west. The recently completed bridge and the highway still under construction will place additional pressures on the Kailali district west of the Karnali River. This district is not as disturbed as the eastern areas, but crocodile reports and sightings were low since protected forest areas are not monitored.

6.1. Ghodaghodi Tal

Ghodaghodi Tal lies within a forest area 32 km west of the Karnali, and has received recent attention for both its religious and avian importance. The area contains depressions filled variably by rain, seasonal inflows, and ground water or sheet flows.

We visited Ghodaghodi and the surrounding lakes on five occasions with no sign of *C. palustris*. Discussion with local fisherman indicates that a *C. palustris* population once existed in the lakes, but none has been seen for the past 3 to 4 years. Some intimated that crocodiles, as well as turtles, were hunted when found.

Being on government land the lakes are marginally protected. Educating local people to coexist with crocodiles would help make this excellent mugger habitat. Flood water channels extend from the lakes along the road and through forested areas to nearby rivers, making dispersion relatively easy.

6.2. West to Mahakali

West of Ghodaghodi Tal, several permanent rivers exist which have variable flow rates through the dry season. The permanence of these rivers can be attributed to the large amount of forest remaining in their watersheds. Most of these rivers have intact forest cover along both banks up to their headwaters. The larger rivers constitute poor habitat as their floodplains are wide and filled with large stones. During low flow periods these rivers are wide and shallow, whereas smaller branches and tributaries ~~tand~~ are more channelized with habitable banks (see *Table 5*).

Table 4: Summary of Kailali District (Far-west) Habitat and Survey Information

Site Name	Date	Survey type	Habitat type	Air Temp	Water Temp	Count/ suitability	Remarks
Bainsawa Tal	09/19/93	HA	PL	-	-	Good	Protected
Chiraiyo Tal	09/19/93	HA	PL	-	-	Fair	1/2 protected
Dharaha Nadi	02/19/94	HA	SR	-	22.8	Poor	
Ghodaghodi Tal	09/18/93	DSB	PL	34	32.8	Fair	Disturbed
Kanara Nadi	09/21/93	HA	PR	-	31.4	Fair	Good hab in tributaries
Kateni Nadi	02/19/94	HA	PR	-	-	Fair	
Khutia Nadi	09/21/93	HA	PR	-	30.3	Marginal	Forested but low water
Nakroad Tal	09/19/93	HA	PL	-	16.7	Good	Protected
Ojahuwa Tal	09/19/93	HA	PL	-	-	Fair	Disturbed
Shivaganga Nadi	02/19/94	HA	SR	-	-	Poor	

After Dhangadhi, population pressures begin to increase due to proximity and access to India. Royal Suklaphanta Wildlife Reserve (RSWR), a large protected area in the southwest corner of Nepal, encompasses large areas of both seasonal and permanent wetlands and rivers. Of 12 wetland and river sites surveyed mugger was evidenced in one. Local people reported mugger populations in three others.

6.3. Rani Tal

We surveyed Rani Tal on two occasions and performed both day and night counts. We observed one adult mugger during a night count in the post-monsoon season. The lake is in the final stages of succession to grassland, so although there is a large water surface area, the maximum depth in mid February was 0.5 meters. No crocodiles were observed at this time, despite utilizing a tape recording of hatchling chirrups.

6.4. Other Lakes in Suklaphanta

Construction began on a large irrigation canal, the Mahakhali 2, but was never completed. The canal flows through a forested area designated to become part of RSWR, but in which people still live. In addition to some natural wetlands, the excavation of fill for the canal has created several more (see *Table 5*). Local people reported large numbers of *C. palustris* in Lalpani Tal, which includes the Dhaderi Khola and marsh wetlands upstream. Villagers claimed sightings of up to 50 muggers in Lalpani Tal. Their estimate is doubtless hyperbolic as the lake is a small oxbow surrounded by agriculture Muggers are likely present seasonally as the oxbow is attached to Dhaderi Khola during monsoon months and is a route

Table 5: Summary of Kanchan Pur District (Far-west) Habitat and Survey Information

Site Name	Date	Survey type	Habitat type	Air Temp	Water Temp	Count/ suitability	Remarks
Bahuni Nala Chaundhar Nala Shihali Nala	09/21/93	HA	PR	-	-	Good	Protected, slow, banks
Bhahara Nadi	09/21/93 02/19/94	HA	PR	-	34.6 17.2	Fair	Good banks, forested
Kalikich Tal	09/22/93	HA	PL	-	-	Fair	Protected, forested
Lalpani Tal	09/21/93	HA	PL	-	-	Marginal	Disturbed
Nunkhaini Tal	09/20/93	HA	PL	-	-	Poor	Disturbed
Peli Tal	09/22/93	HA	PL	-	-	Poor	Disturbed
Rani Tal	09/20/93 02/18/94	DNB DNBC	PL	30.5 22	31.5 21.9	1AM none	Shallow, but protected
Shikari Tal	09/21/93	HA	PL	-	-	Fair	Small
Tara Tal	09/22/93	HA	PL	-	-	Fair	1/2 protected
Mahakali 2 Canal	09/21/93	HA	PR	-	-	Fair	Protected

upstream into the RSWR. The Mahakhali 2 irrigation canal and the surrounding lakes are good habitats for future restocking (see *Table 5*).

6.5. The Mahakali River

The Mahakali flows along Nepal's western border. The river belongs to India which precluded facilitation of a survey. However, the large grassland for which RSWR was named is a floodplain of the Mahakali. In September 1993, the warden of RSWR reported a dead gharial adult, approximately 3 m in length, from the Mahakali river.

7. GROWTH RATES IN NEPAL

During Harry Andrews visit to Nepal, we clip-tagged, measured, sexed, and weighed all muggers held in captivity at the Government Gharial Breeding Center in RCNP. Follow-up measurements were made 6 months later to assess growth rates and mortality. From an original number of 67 hatchlings (59 from 1993 and 8 from 1991), 17 had died in the intervening 6 months. The average growth rate of the remaining 50 muggers was 1.5 cm in total length, 1.1 cm in snout-vent length, and an average weight gain of 50 g. The correlation coefficient between weight gain and total length growth was 0.67, while the slope of the relation was 1.6 and the intercept 3.2 cm. A relation of weight to total length for October gave a slope of 1.4, and the intercept - 36.7 cm, with a correlation coefficient of 0.97. In February, the same relation returned values of 1.4, -31.3 cm, and 0.83. Morphometrically there is a strong linear relationship between weight gain and total length.

In Madras, growth rates for *C. palustris* have been recorded at 40 - 50 cm per year (Whitaker, 1981). Saltwater crocodiles in Papua New Guinea were reported to grow 20.85 cm per year (Lever, unpublished data). Both these figures far exceed growth rates recorded in Nepal. Growth rates in Nepal during the months October to February would naturally be lower due to colder temperatures than in Madras; however, the largest probable cause is lack of food. Hatchlings in Madras require 30 g of food per day, consisting of fish, crabs, frogs, and tadpoles, with additional supplements from insects.

Fish prices are higher in Nepal. Despite having a contracted fisherman only 2-3 kg of fish can be supplied to the hatchling pens on a daily basis, and even this supply is not consistent. Approximately 300 - 500 g are distributed to the mugger hatchlings, therefore, the 50 animals are receiving less than 10 grams of food per day.

Average temperatures in Nepal's Terai remain above 30° C during summer months and above 15° C during the coldest winter months (see *Appendix 3*). In Chitwan, where the Gharial Breeding Center is located, the warmest six months are from April through September and temperatures average 29 ° C. Mean cold month temperatures from October through March average 20° C (HMG-Nepal, 1986).

8. SUMMARY

Although a country-wide survey is not complete for Nepal, it is obvious from the emerging data that crocodile populations are small. Extensive and destructive use of the limited habitat by local people is the primary cause for low populations. In the few areas where wild populations exist competition with humans has still led to low crocodile densities, even in protected areas and forest reserves. This competition is usually the result of illegal use of protected areas. The highest relative density was 6 sightings per hectare at Lami Tal, whereas everywhere else relative densities were below 1 sighting per hectare of wetland or kilometer of river.

The total number of crocodiles sighted, including reliable reports, amount to 32 adult, 5 sub-adult, and 2 juvenile *C. palustris,* and 14 adult and 5 juvenile *G. gangeticus*. Using Tiger Top's more complete survey of the Narayani, 35 adult *G. gangeticus* may be recorded as sighted.

In the future we need to calibrate sightings with an estimate of total population. We have started capturing and tagging *C. palustris* in order to obtain a better understanding of our survey results. Tagging gharials should also be considered.

The constant turnover and rotation of DNPWC staff make it difficult to maintain a long-term program under their auspices. Deficient record keeping for dead tagged hatchlings at the gharial project is due to staff changes. We are endeavoring to ensure that released animals be documented, with follow-up monitoring, to determine release success and dispersion.

Future releases should be concentrated in the west, particularly in Royal Suklaphanta Wildlife Reserve. In areas outside RSWR, extension work will be required.

If commercial utilization becomes an option for *C. palustris*, growth rates must be improved and an alternate supply of food procured. We have attempted frog capture with high success, but fish aquaculture must be included in the development of a mugger facility as well. Metabolisms could be increased by heating hatchling pools with solar water panels. A feasibility study exploring these issues will be completed in May 1994.

9. ACKNOWLEDGEMENTS

The formulation of this document was made possible by the interest and assistance of IUCN Nepal. The project was initiated with funding from USAID which allowed it to support a visit by Harry Andrews, the Deputy Director of the Madras Crocodile Bank, to visit Nepal and assess the direction of crocodile conservation in this country. Additional assistance and data were supplied by the Department of National Parks and Wildlife Conservation (DNPWC) staff, particularly the Director General, Dr. T. M. Maskey and the Chief Warden of Royal Chitwan National Park, Mr. R. Yadav.

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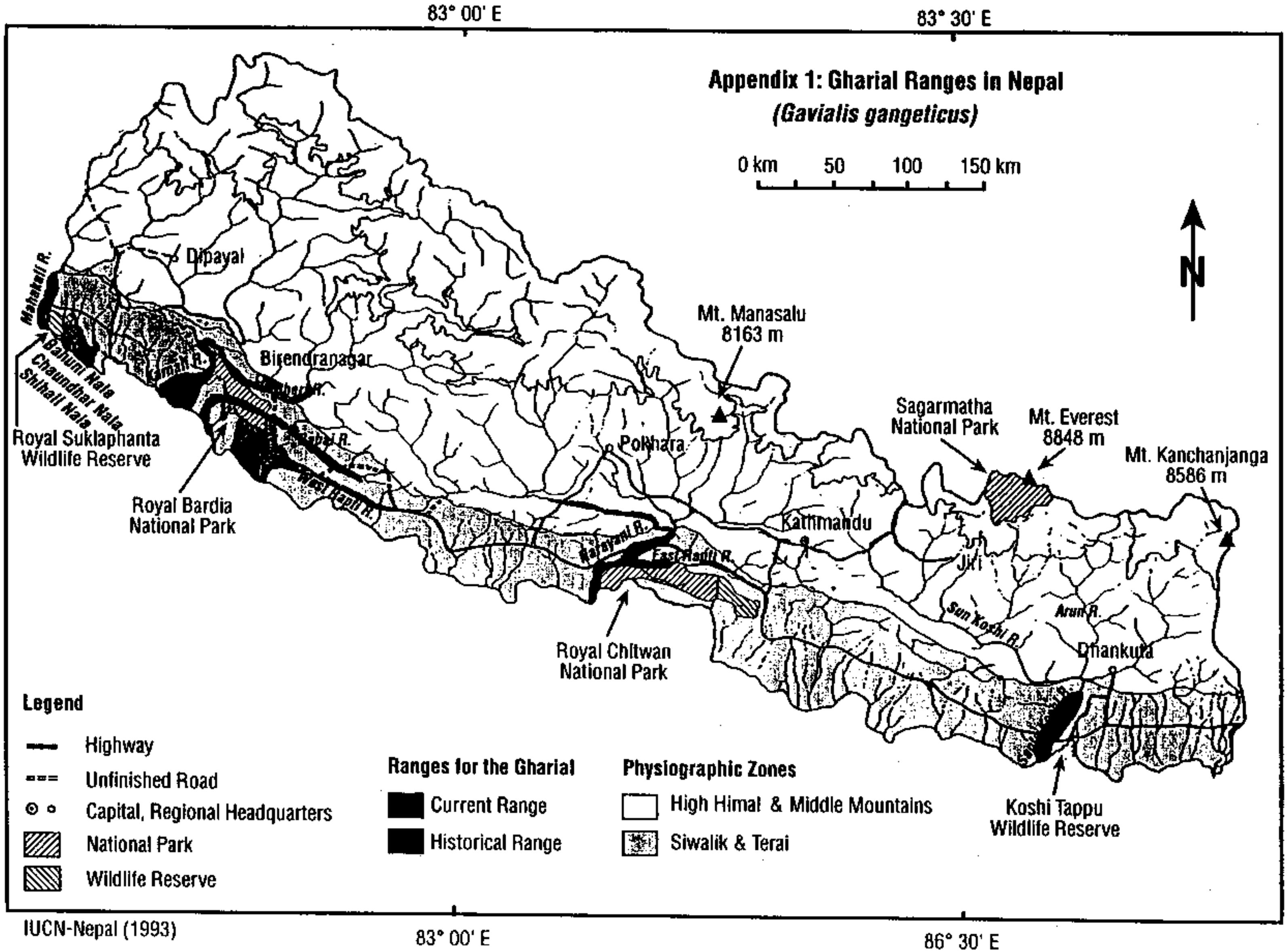

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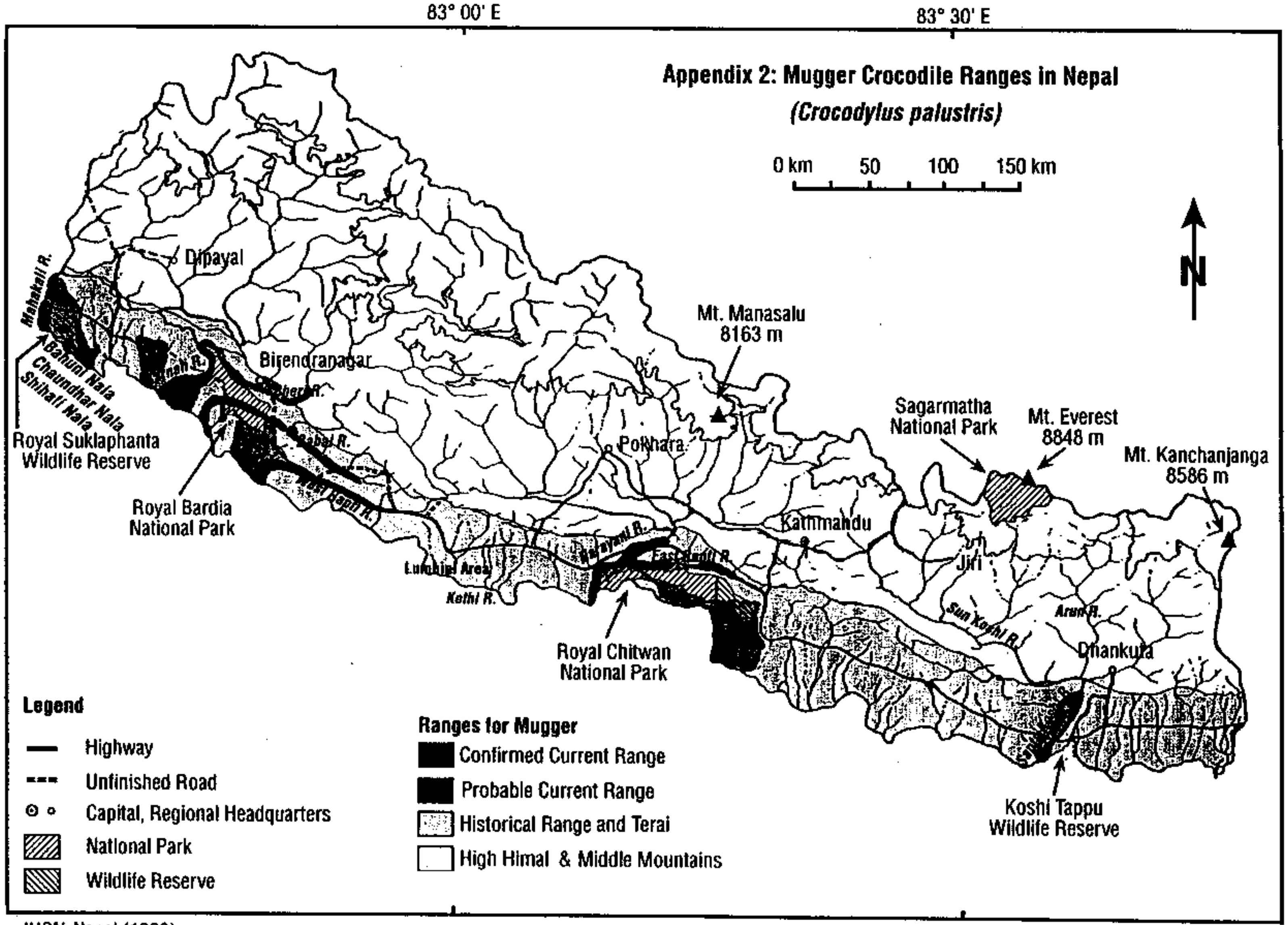

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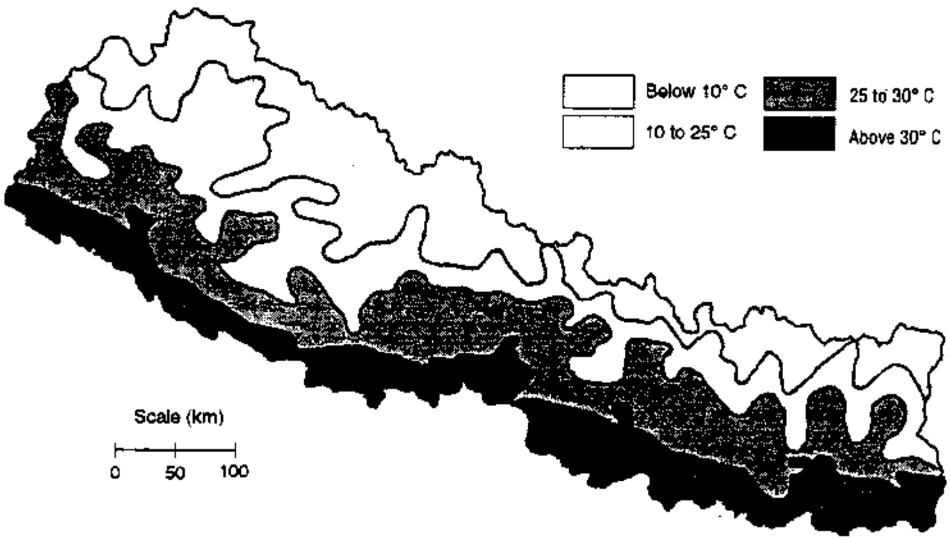
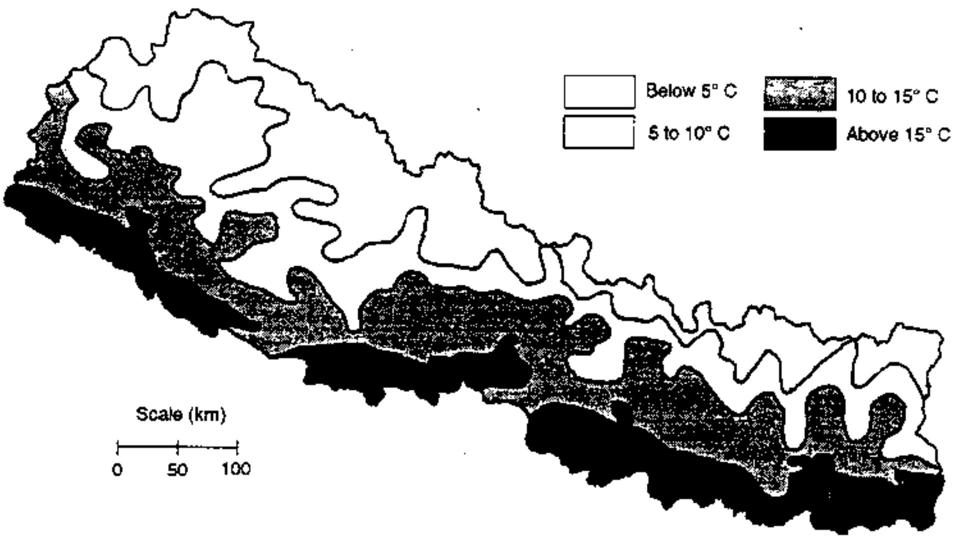
Appendix 3: Temperature Ranges for Nepal

Summer Temperature (May to July)



Winter Temperature (November to January)



IUCN Nepal

SINGLE-SITE AND REGIONAL SURVEYS OF CROCODILIANS OR CROCODILIAN SIGN: DESIGN AND INFERENCE CONSIDERATIONS FOR ESTIMATION OF POPULATION TREND[1]

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Counting individuals directly or indirectly (by nests, tracks, or other signs) in crocodilian population surveys is a popular tool for monitoring population status and trend. Relative to surveys of many other species, individuals are easy and inexpensive to count. Patterns observed in the survey data are thought to be representative of patterns in the population. Thus, survey programs are an attractive option for resource agencies desiring to monitor crocodilian populations.

In typical settings, counts (taken here to mean either a true count or some proportionate index of population size) are collected under some prescribed conditions at regular time intervals at one or more survey areas. Information on environmental conditions or survey characteristics may also be recorded. Translating the data into useful inferences on population trend relies on (a) correctly identifying a statistical model for counts, so that population trend can be quantified and judged for significance; (b) successfully removing outside sources of variability through survey design or analytical adjustment; and (c) adequately replicating the survey either in time or space, so that the survey has power to distinguish a real trend from chance patterns. Ways to meet these requirements are hardly ever obvious, but gaining experience in monitoring the population and stating the scope and objectives of the survey are the best means of narrowing the options.

I will illustrate how controllable and uncontrollable factors can impair the usefulness of the data, what assumptions about the data are necessary for making inferences on population change, and how a good survey design can alleviate difficult situations. Most of the discussion pertains to the collection and analysis of data at a single site. When appropriate, however, I will extend the discussion to the problem of regional population inference based on samples at multiple sites. Most examples derive from personal experience with crocodilian data, but some I borrow from the field of avian monitoring, where practitioners have long struggled with the same issues.

A detailed treatment of all issues pertaining to design and analysis of crocodilian population surveys is beyond the limits of a single manuscript. My purpose is to organize, describe, and provide bibliographic reference to problems likely to be encountered in crocodilian monitoring. I hope to provide enough detail to allow the reader to pursue further topics independently and to communicate design and analysis concerns effectively with a statistician.

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SOURCES OF VARIABILITY IN THE COUNT

Even in a constant-size crocodilian population, counts of individuals or their sign are not censuses, and hence will generally vary in successive surveys of the population. A reasonable way to think of the counting process is as follows. Each individual or item in the survey area has some probability, including probabilities 0 and 1, of being detected. Probabilities may vary among individuals in the same survey and within individuals in different surveys. Whether an individual is counted or not is a random event determined by its detection probability. Thus, variability of the count is due partly to chance and partly to how severe detection probabilities vary between individuals or items within and among surveys. While the chance component is beyond any kind of survey control, good and poor population surveys are distinguished by how well the investigator exerts control over factors that cause detection probability to vary (Seber 1982:53).

Detection probability of individuals or their sign may vary according to factors both within and beyond the control of the investigator. Detectability effects due to season, time of day, location, meteorological conditions, habitat structure, water attributes, animal physiology and behavior, counting procedure, observer characteristics, and equipment used have been described elsewhere (Magnusson 1982, Bayliss 1987, Woodward and Moore 1990). The investigator can control some of these factors. Others are not controllable, yet the investigator can prescribe favorable conditions under which surveys can be run. However, simultaneous ideal conditions for all factors rarely prevail, so conditions among samples must vary to some degree even in the most rigorous surveys.

By counting crocodilian sign, one can avoid some sources of detection variability associated with counting individuals. For example, nests (the most commonly surveyed form of crocodilian sign) are fixed and generally uniform in appearance, so detection probabilities associated with animal behavior, animal size, time of day, and many other factors may not be of concern. However, such surveys introduce new sources of variability that may limit their usefulness (Seber 1982:54). Whether or not an adult female builds a nest is a random occurrence with unknown probability, and the probability may vary among females. Further, each nest in the survey area has some probability of not being unique to an individual, that is, false or "sibling" nests may be available for inclusion in the count. Nest "creation" and "sibling" probabilities operate in opposite ways with regard to the population count, but because the probabilities may vary among individuals, there is no assurance that the probabilities completely offset one another.

ASSUMPTIONS FOR ESTIMATING POPULATION TREND

Constancy of count bias

If we could count every member of the population at each survey period, we could measure trend exactly. Even lacking a complete count, we could obtain an exact measure of trend as long as the number of individuals or items counted each time was a strictly constant proportion of the population. In other words, the count bias, the difference between population size and the population index, must be a constant proportion of population size at each survey occasion. If bias varies from count to count, then a trend in counts measures something other than a trend in population size (Seber 1982:53).

Because detection is a random occurrence, a count of individuals or items is almost certainly a biased estimate of population size. Because detection probabilities vary among individuals or items at each sample, there generally is high risk that the assumption of constancy of count bias is not met.

Effects on count bias variability are known and controllable

The investigator should know all the effects that cause count bias to vary and should control these effects through survey design. Control can be achieved either through standardization of survey methods (Seber 1982:53) or through post-hoc analytic adjustment of the counts for measured values of the effects.

Neither part of this assumption is likely to be completely satisfied in practice. In any survey, we can never enumerate all factors that cause count bias to vary, but we hope to at least list those that we can confidently presume to have the greatest effect. However, of factors that we can list, we are unlikely to be able to design a survey or concoct an analysis that will entirely remove all of their effects.

For example, season, water temperature, and water level influence the population distribution of the American alligator (*Alligator mississippiensis*) on wetlands in Florida, and variability in population distribution was believed to greatly affect detection probability during night population surveys (Woodward and Moore 1990). The season and water temperature effects were controlled by conducting counts in a narrow annual time frame. Water level could neither be manipulated nor anticipated. However, a measurement of water level was obtained in each survey for later covariate adjustment. Adjustment for water level smoothed wild swings in the count and improved precision for the estimate of trend (Fig. 1). Surface coverage by hydrilla (*Hydrilla verticillata*) also likely influenced detection probability, but its influence was not as effectively removed.

In the North American Breeding Bird Survey (BBS), a spring-season roadside count of all breeding birds detected through sight or song (Robbins et al. 1986, Droege and Sauer 1990), changes in observers on a survey route affect the between-year detection probability of

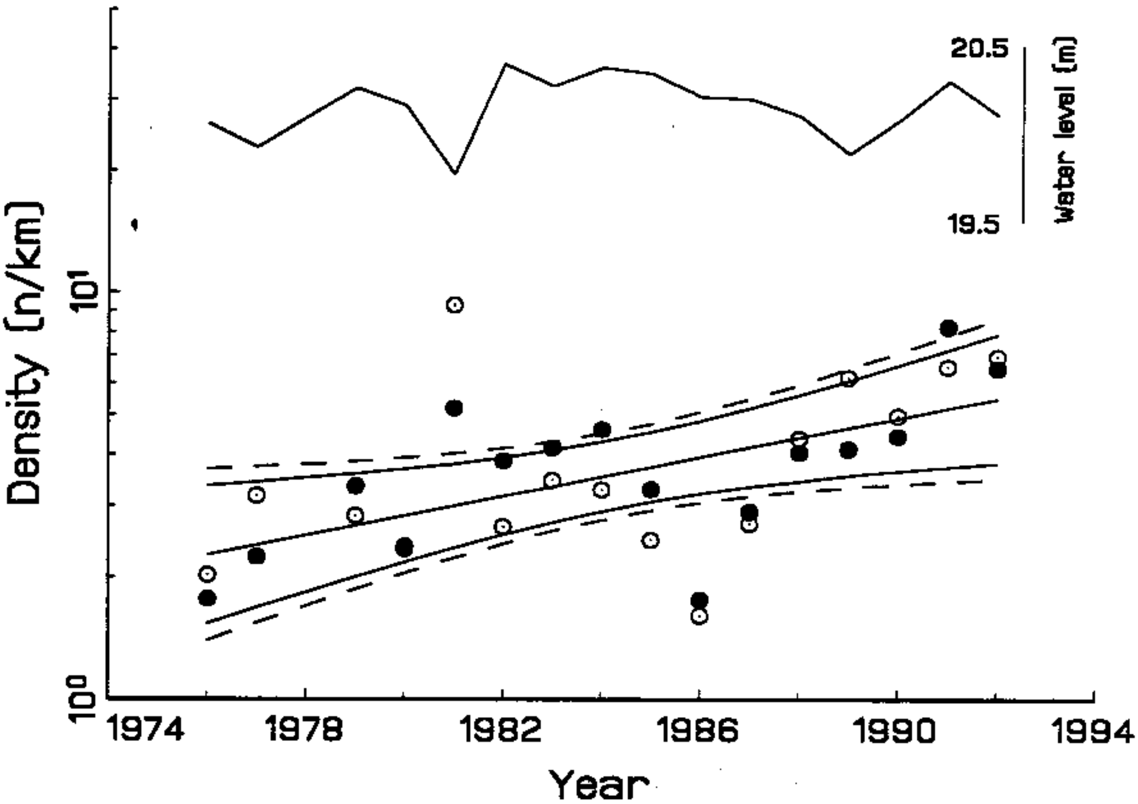

Figure 1. Mean summer (June, July, August) water level (m) on Newnans Lake, Florida, USA, and observed (⊙) and adjusted (•) densities of alligators 31-122 cm on Newnans Lake. Direction and magnitude of adjustment was determined by relative water level value. Estimated trend line and 95% confidence band for trend line are displayed (solid lines). The wider confidence band (broken lines) approximately expresses the cost paid in increased variability by ignoring variability in water level.

individuals (Sauer et al. 1994). Over the 27-year history of the BBS, new observers have typically been more proficient at counting birds than their predecessors, perhaps due to increased popularity of bird watching and due to improved quality screening of new observers. Accordingly, the proportion of birds detected has systematically increased over time. On average, ignoring the observer effect misleadingly portrays population increases that are too rapid or population declines that are too slow (Sauer et al. 1994). Thus, observer changes on a route are noted, and effects of the changes are removed analytically (Geissler and Sauer 1990) (Fig. 2). Within-observer changes in counting proficiency (W. E. Kendall, U.S. Fish and Wildl. Serv., unpubl. data), changes in traffic volume or roadside land-use patterns, and annual differences in proportion of males that sing are examples of many largely unknown and uncontrolled factors that affect detection probability in the BBS (Bystrak 1981). Factors that affect detection probability of crocodilians are likely just as varied.

Statistical model for counts

We assume that counts obey a statistical model that prescribes (a) the pattern in counts over time, (b) the relationship between counts and nuisance covariates, and (c) the probability distribution of model errors. Each element of this assumption is considered below.

Pattern in counts over time. We assume that some type of model describes the data pattern (Fig. 3). The most widely used are linear and exponential models of population growth (Harris 1986). Such models are easily estimated via standard linear regression methodology. However, because these models presume that the population grows or diminishes without limit, they may be unsuitable for rapidly changing populations. Models of asymptotic or size-limited population growth (e.g., logistic, von Bertalanffy, and Richards curves) are available, but these models are fit by nonlinear regression, a somewhat difficult procedure that is sensitive to absences of data (Seber and Wild 1989). Both linear and nonlinear growth models describe only monotonic growth, that is, they do not accommodate both positive and negative growth periods over the survey interval, and this limitation may be unrealistic for many populations. To model counts that rise and fall over time, one may augment linear models with curvature parameters to create polynomial, sinusoidal, and other "curvilinear" regression models, or one can use nonparametric smoothers (e.g., lowess, cubic spline, and kernel smooths) (Härdle 1990). Because these models may contain peaks and troughs, inference on population trend is conditional on specified periods of time within the survey interval. Finally, one can fit "jointed" or piecewise linear models (Draper and Smith 1981:252-257) to model interventions (abrupt population crashes or surges) that may result from management actions or extreme environmental conditions.

Relationship between counts and nuisance covariates. In situations where control over a detectability factor cannot be achieved sufficiently through survey standardization, it may be necessary to adjust the count by modelling the effect as a nuisance covariate (so called when the only purpose of the covariate is to isolate variability from a covariate of primary interest). The decision whether to use the covariate is rarely easy, and the consequences of an improper decision may be quite damaging to the analysis. If an important covariate is ignored in the

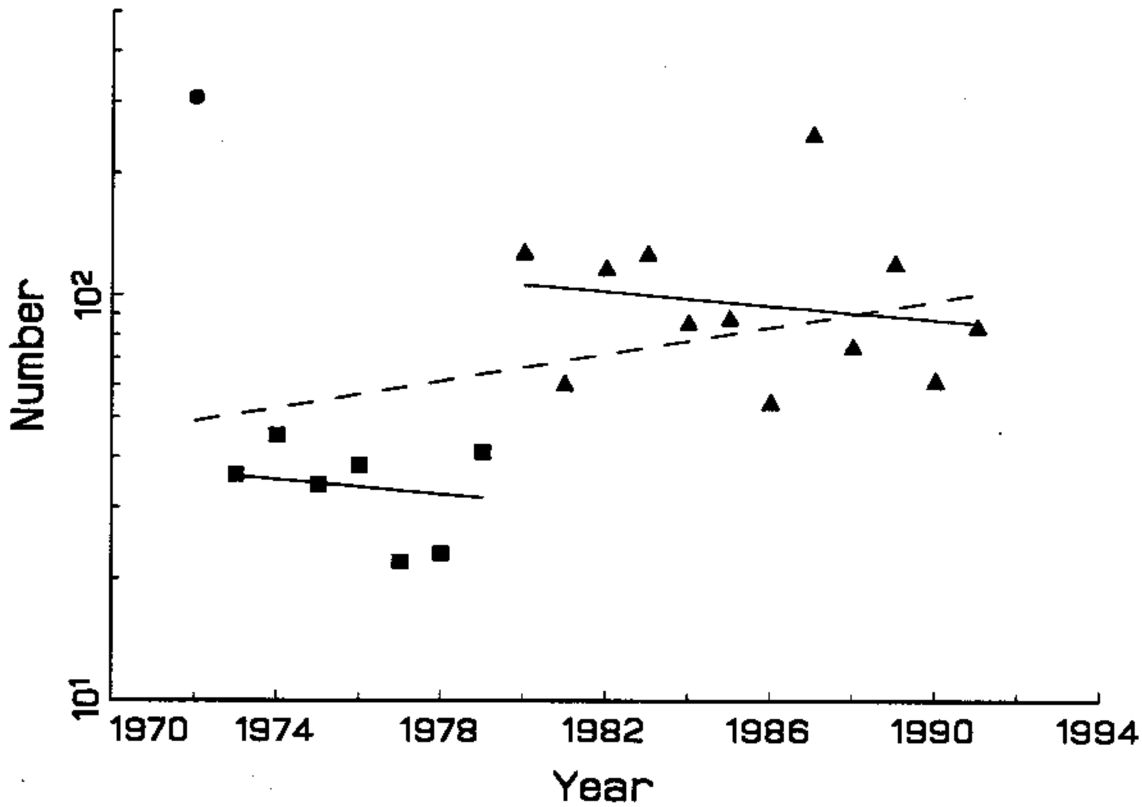

Figure 2. House sparrows (*Passer domesticus domesticus*) detected annually, 1966-1992, on Breeding Bird Survey route 14203, California, USA. Different observers are distinguished by unique symbols. Increasing trend (broken line) is suggested when observers differ in detection proficiency but the difference is ignored; within an observer series, a downward trend (solid lines) is obvious.

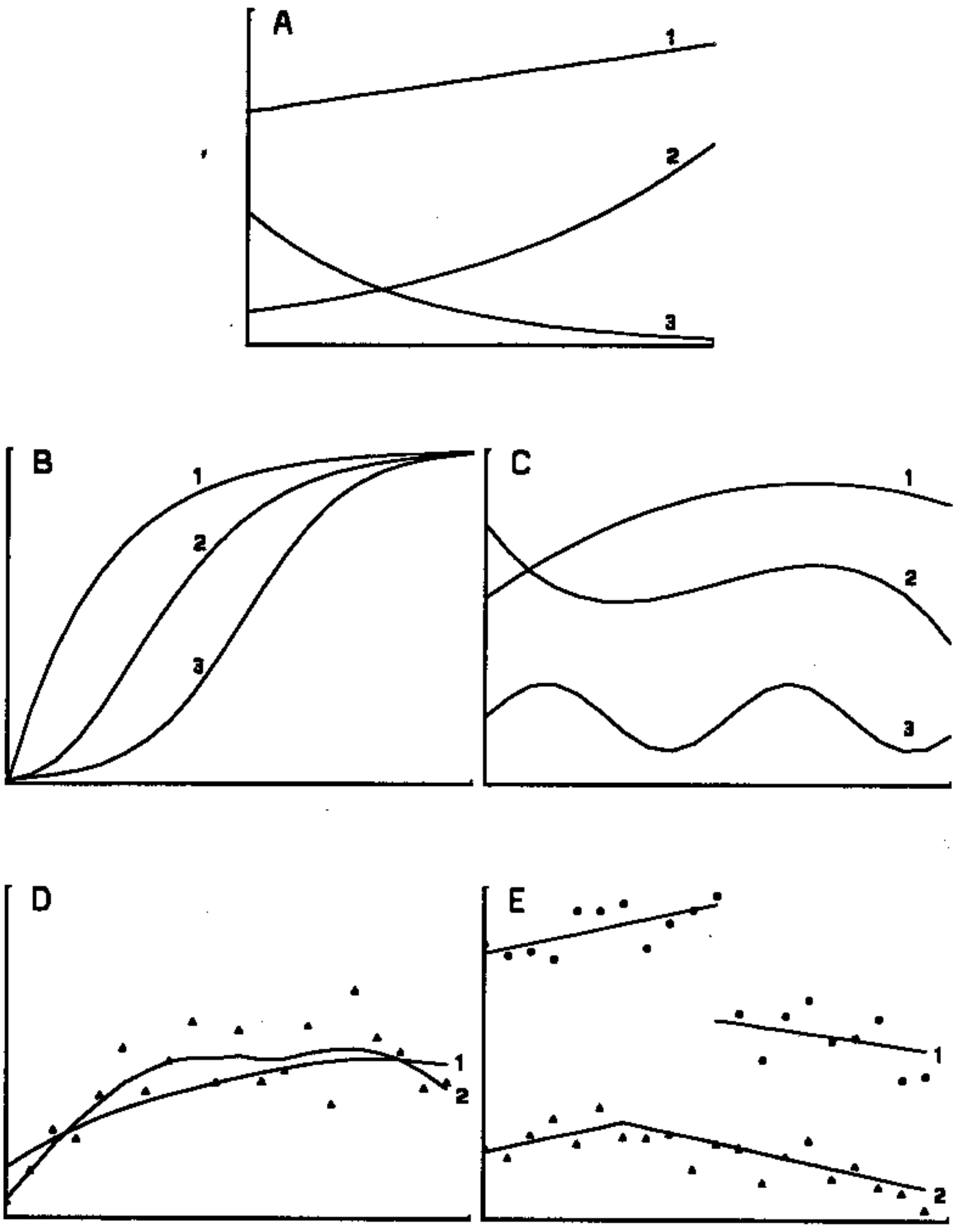

Figure 3. Examples of regression curves: (*A*) Linear (1) and exponential (2, 3) curves; (*B*) nonlinear Von Bertalanffy (1), Gompertz (2), and logistic (3) curves; (*C*) quadratic (1), cubic (2), and sinusoidal curves; (*D*) nonparametric lowess smooth with tension = 0.8 (1) and tension = 0.2 (2); and (*E*) discontinuous (1) and continuous (2) piecewise linear regressions.

analysis, the estimate of population trend can be biased (e.g., ignoring observer differences in counts of birds) or highly variable (e.g., ignoring water level in counts of alligators) (Rawlings 1988:243). An unimportant covariate that is included in the analysis "drains" information available for estimating trend, thus the trend estimate may be imprecise (Rawlings 1988:171).

The manner in which the covariate enters the statistical model may not be trivial. Usually, one assumes that the covariate affects the response variable (count, or a transformed value of count) in a linear, additive fashion. That is, if all other covariates are held constant, we expect a change in the covariate to elicit a proportionate change in the response. However, many biological phenomena operate nonlinearly or interactively.

Water temperature may affect detection of many crocodilians nonlinearly. Suppose the chance that a crocodilian is on the water surface increases with water temperature, up to a limit; beyond this limit, no association exists. If this nonlinear relationship is modelled linearly, one runs the risk of providing too much negative adjustment to counts at high water temperatures and too little positive adjustment at low temperatures. The linear model may cast a series of stable counts as an upward population trend if the counts were observed during a span of declining yet relatively warm water temperatures. Contrarily, the correct model makes little or no adjustment to counts in this temperature range, and no population increase is portrayed (Fig. 4).

Interactivity occurs when the relationship between a response variable and a covariate depends on the level of another covariate. In a hypothetical but realistic example of interaction, counts of crocodilian nests on a survey area may be positively related to observer effort. However, this relationship is not as obvious in open canopy conditions as in closed canopy conditions because all nests under the open canopy are easy to count regardless of amount of survey effort expended. Suppose that over the course of the survey, more of the area suitable for nesting is obscured by an encroaching canopy. Time therefore interacts with effort because the relationship between count and effort changes over time. If the interaction is ignored in this illustration, counts obtained in earlier years of the survey are overadjusted for effort, and later counts are underadjusted. The resulting trend estimate may be imprecise or biased (Fig. 5).

Covariates may be employed in all forms of linear, nonlinear, and nonparametric models though estimation procedures can be much more difficult than for simple linear regression. However, just as with simple regression, the methods are usually far simpler than the task of determining which covariates to model and their functional relationships to counts.

One common way to incorporate a covariate is through proportionate scaling. That is, one divides counts by corresponding covariate values and analyzes values of the resulting index (individuals per covariate unit). For example, counts of individuals are often divided by some expression of counting effort to obtain an effort-adjusted abundance index. Such scaling implies that the relationship between count and the covariate is represented by a straight line passing through the origin (i.e., a zero-valued covariate implies a zero count) (Packard and Boardman 1988, Butcher and McCulloch 1990). Any other form of the relationship makes the use of

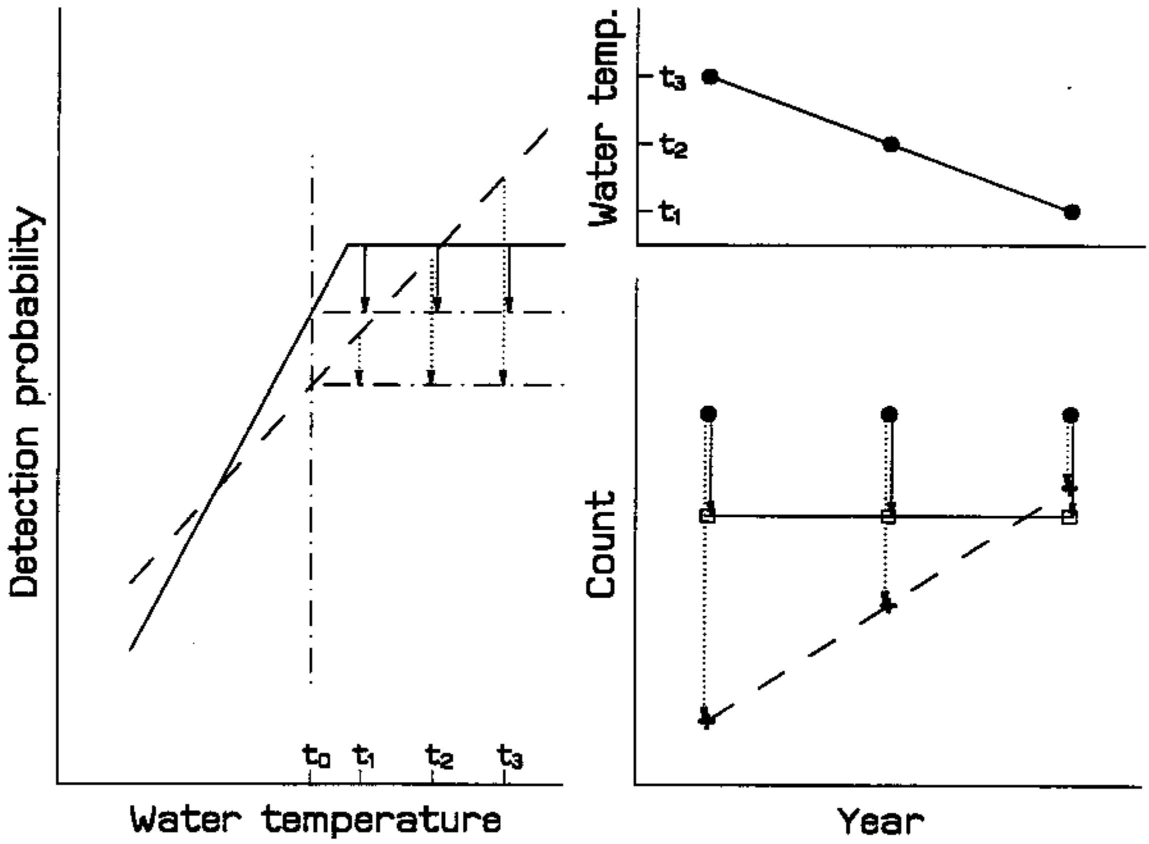

Figure 4. Effect of misspecification of the relationship between detection probability and a covariate. The true (solid line) and misspecified (broken line) hypothetical relationships between surfacing probability and water temperature are displayed (left panel). Water temperature decreases with time, but counts (●) are constant (right panel). Direction and magnitude of covariate adjustment for each temperature t_1, t_2, and t_3 to standard temperature t_0 are indicated with arrows for both surfacing probability relationships (left panel). Adjustments applied to the counts result in an increasing trend (+, broken line) for the misspecified relationship and a stable trend (□, solid line) for the true relationship.

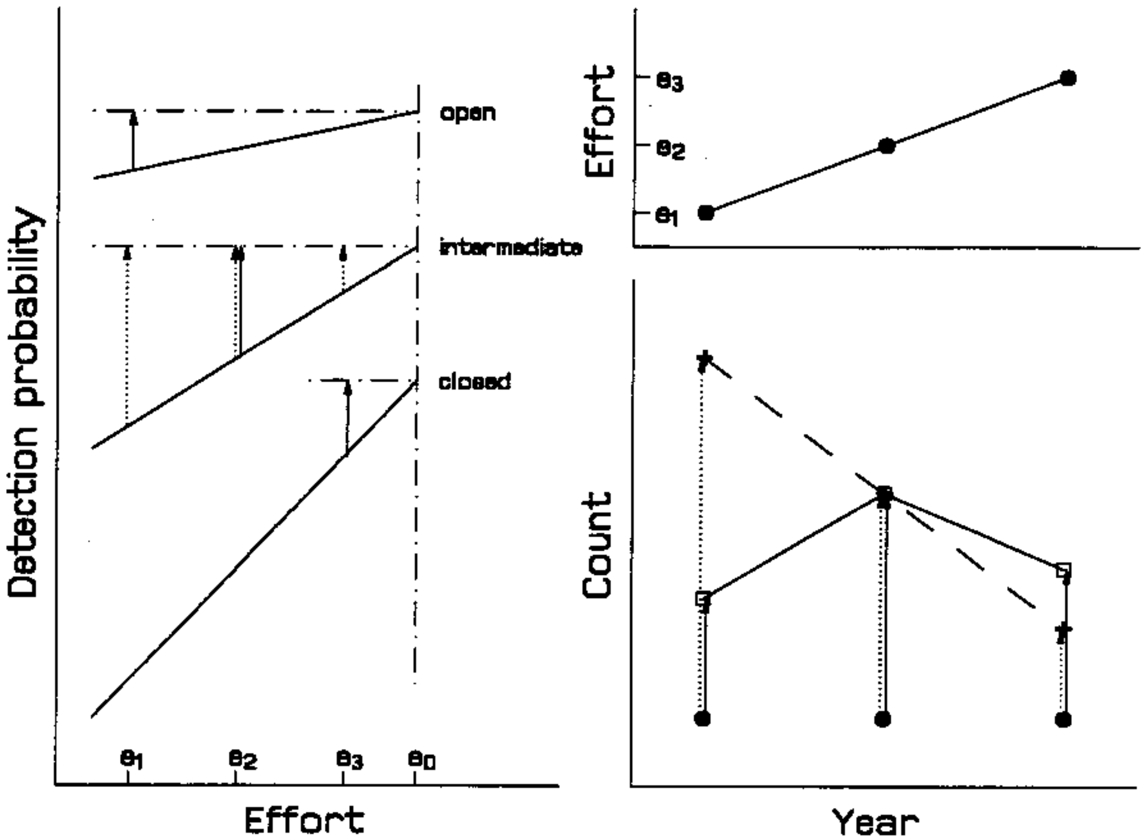

Figure 5. Effect of ignoring interaction between time effect and a covariate. In the hypothetical example, nest detection probability increases with effort, but at a rate dependent on canopy cover (left panel). Further, because the canopy over the survey area closes over time, time and effort interact. Suppose that effort increases over time, but counts (•) remain stable (right panel). Adjustment of survey efforts e_1, e_2, and e_3 to the reference level e_0 varies according to canopy cover (solid arrows, left panel), and the adjusted counts show a generally increasing pattern (right panel, □, solid line). However, if the interaction between effort and canopy closure (or time) is ignored, covariate adjustment for effort occurs at an intermediate fixed level of canopy closure (broken arrows, left panel), and the adjusted counts appear to decline (right panel, +, broken line).

proportionate scaling suspect. It is easy to imagine a relationship in which individuals counted increases very rapidly with increasing effort but increases slowly beyond some threshold of effort. In this circumstance, neither proportionate scaling nor linear covariate adjustment adequately model this relationship, but the latter method is more likely to fit at least a part of the data (Rawlings 1988:243). Butcher and McCulloch (1990) used data from the Audubon Christmas Bird Count, an annual survey characterized by varying observer effort, to illustrate other failures of this model for several bird species. The authors noted that failing to model an important interaction between effort and location resulted in a spurious negative relationship between effort and count for several extreme cases.

Colinearity, the existence of high correlation among 2 or more covariates, presents difficulties in linear and nonlinear regression situations. Highly correlated covariates introduce instabilities in the least-squares estimation procedure, and as a result, mean and variance estimates for effects involved in the correlation are unreliable (Rawlings 1988:244). With regard to crocodilian monitoring, colinearity among the time effect and any other single covariate or combination of covariates can prove treacherous for making inferences on trend. For example, if survey transect length is used as a covariate, trend estimates may be unreliable if transect length changed consistently over time. Remedies for colinearity include dropping offending covariates from the analysis or using complicated methods (ridge regression, principal components regression) that obtain estimate stability by permitting a small degree of estimate bias (Rawlings 1988:245).

With these problems and uncertainties, the use of covariates in population monitoring is almost never a straightforward issue. Even if a covariate is known to offer increased accuracy and precision for the trend estimate, its advantage may still be offset by two disadvantages. First, the benefit obtained may not be worth the added complexity of the model and the estimation procedure. Second, establishing only an associative relationship between the covariate and count will always leave the covariate's applicability to future data in doubt; alternatively, an experimentally-confirmed causative relationship would clarify the role of the covariate now and in the future (Rawlings 1988:170-171).

Probability distribution of model errors. Inference in most regression problems requires that model errors (disagreements between actual counts and counts predicted by the model) are independent and normally distributed with constant variance; otherwise, effect variances may be poorly estimated and tests of significance may be invalid. One would not expect this requirement to be often met for typical crocodilian monitoring data. In most situations, error variance is not constant but instead increases with the mean count (Eberhardt 1978). That is, counts become more variable as the average count increases. Further, counts centered to their means often exhibit a right-tailed skew. Accordingly, the lognormal, poisson, and negative binomial distributions are better suited to count data than is the normal distribution (Eberhardt 1978).

Fitting the lognormal is accomplished by log-transforming the counts and applying regression methods to the transformed values, now assumed to be normally distributed. This popular approach carries some caveats. First, estimates of trend or mean count back-transformed to their original scale by simple exponentiation suffer a bias that increases with the variance of the estimate. A simple bias-correcting adjustment may be made to the exponentiated value (Bradu and Mundlak 1970). Second, because a zero count value cannot be log-transformed, analysts often add a small constant to all counts prior to transformation. This practice biases the trend estimate, and the magnitude of the bias depends on the size of the constant, and most importantly, on the prevalence of zero or small (<3) count values over the survey period (Geissler and Link 1988, Collins 1990). Maximum likelihood estimation is a means of fitting the lognormal distribution directly without resorting to data transformation, but the method is iterative, requires familiarity with nonlinear optimization, and may be fraught with other difficulties (McCullagh and Nelder 1983, Seber and Wild 1989). For fitting models to data following poisson and negative binomial distributions, maximum likelihood estimation must be used (McCullagh and Nelder 1983).

Data collected in any time series potentially suffer serial correlation, a condition that violates the assumption of model error independence. Count data collected closely together in time often have positive serial correlation, meaning that the prediction error of the model at time $t+1$ is generally of similar direction and magnitude as the prediction error at time t (Draper and Smith 1981). In such situations, the variance estimate for trend is biased low and results in rejection of the null hypothesis of no trend more often than expected (type I error greater than desired) (Rawlings 1988:241). In Florida, counts 1-7 days apart were serially correlated unless water level changed substantially (≥2 standard deviations) during the time period (Woodward and Moore 1990). At stable water levels, no evidence of serial correlation occurred in counts taken ≥40 days apart, but unfortunately, counts separated by such a time span could not be considered replicates within a single season. Because serial correlation occurred in most counts taken more than once per year, replicated counts in Florida were often unusable for variance estimation by standard procedures. Methods exist for detecting and modelling serial correlation (Draper and Smith 1981, Rawlings 1988).

Site-specific patterns of population change in regional surveys

Multiple sites distributed within a region may be sampled for inferences on the regional population trend. We assume that sites are located at random within suitable habitat of the region and that site-specific patterns of population change can be accurately depicted with a small, consistent set of summary statistics.

Sites are located randomly within suitable habitat of region. Unbiased estimation of a regional population pattern depends on a random sample of sites. Rarely is strict randomization used in survey design. Rather, logistics of the survey, accessibility of sites, and prejudices and politics are too often the criteria by which sites are selected. At best, one may be able to randomly choose from a set of sites deemed in some way to be "surveyable" and representative of the region. However, this approach risks systematic exclusion of sites harboring important segments of the regional population, e.g., inaccessible forested wetlands that provide nesting habitat to females. At worst, one chooses the sites haphazardly with emphasis on human use status, convenience, and access. The importance of stating the limitations of the sampling frame in any presentation of the data cannot be overemphasized.

Random sampling of sites in 2 or more strata within the region is desirable if within-stratum site variability is appreciably less than regional site variability (Eberhardt 1978, Seber 1982:20, 451). For example, one may obtain variances for mean trend at sites both within riverine and palustrine systems, then pool the 2 values. If the pooled variance for mean trend is smaller than the variance obtained by ignoring ecosystem status of sites, then greater efficiency can be obtained by randomly sampling sites within riverine and palustrine systems than by sampling without regard to ecosystem.

Many estimation procedures exist for data taken repeatedly on a sample of individuals (Crowder and Hand 1990). The split-plot ANOVA design, or its variations (Rowell and Walters 1976), can be used when all sites are sampled in all time periods, or very nearly so. If sites are often skipped or if covariates are to be modelled, other procedures are required. One such procedure, route-regression (Geissler and Sauer 1990), was developed and is now routinely used for estimation in the multi-site BBS. In short, estimates of site-specific exponential population trend are weighted by relative abundance of the species at the site and by a quantity inversely related to the estimated trend variance for the site. Weighted site estimates within a physiographic stratum are then "bootstrapped" (intensively resampled by computer) to obtain stratum estimates of mean trend and variance. Stratum estimates, weighted by stratum area, are finally averaged into summaries for larger regions (e.g., states and provinces).

Pattern representable in summary statistics. Whereas single-site surveys may permit elaborate modelling of counts, multi-site surveys must emphasize models that are sufficiently flexible to capture gross population patterns yet provide enough reduction of the data for easy summarization over all sites. If straight lines are used to model count data for sites that may contain either straight or curved patterns, then the regional summary will take the form of a misleadingly straight and relatively precise trend. Better approaches are fitting models that include a parameter for curvature or determining whether count patterns correspond to an identifiable stratification of sites and estimating trends separately by stratum.

CONSIDERATIONS IN DESIGNING CROCODILIAN SURVEYS

Identifying and controlling survey conditions

The conditions that cause count bias to vary among years must be identified. A more difficult task is to exert control over these conditions so that relationships observed in count patterns can be inferred to the population.

One controls survey conditions either through standardization of sampling techniques or through post hoc analytic adjustment for covariates. Given that the complexity and the potential for problems multiply with the addition of covariates, survey standardization should almost always be preferred to covariate adjustment. A standardized survey should prescribe how sampling is done with respect to time, location, meteorological conditions, habitat conditions, observer characteristics, counting procedure, and equipment used. Generally, survey costs increase and magnitude of counts decrease with standardization, so the temptation to forego standardization in favor of sampling under varying conditions is strong. However, increasing reliance on covariate adjustment decreases the credibility of survey inferences. When covariates must be measured, they should correspond to conditions proximate to the time and location of the survey, and their values should be measured accurately.

The same recommendations for standardization apply to individual sites within a multi-site regional survey. However, careful consideration to selecting sites and determining the need for stratification are additional concerns in the design of regional surveys.

Experimental studies

A frequent objective in crocodilian monitoring is concluding if a management action causes a population response. The survey design determines whether the question can be successfully addressed. Carrying out the action at a single site constitutes only one replication of an experiment. A population change occurring at the time of the action cannot be attributed to an effect of the action or to a coincident unrelated effect. Therefore, a single-site survey is not a sufficient design for answering this question (Hurlbert 1984). Replicated experimental and control sites, perhaps paired with each other, should be established.

Modeling and inference

In single-site surveys, emphasis is placed on model identification and detection of rapid, short-term population change. The gamut of standard regression diagnostic tools (Draper and Smith 1981, Rawlings 1988) can be used to identify models that successfully fit the data pattern and to diagnose problems that can interfere with assessing population change. Replicated independent counts taken at each time period provide the best tool for identifying a model, because a candidate model can be tested using a variance term computed independently of the model (Rawlings 1988:122-126). Such counts need to be sufficiently close in time to assure that the same population is being sampled, but counts too close in time only provide information on measurement error, not sampling error.

In contrast, emphasis in regional surveys is on coarse estimation of population change at many sites. Under this strategy, estimates from fairly simple models are summarized over several sites, and the use of many sites reduces the influence of poor estimation at a minority of sites. Detection of a regional population trend depends in part on the success of defining appropriate strata for pooling sites with similar trend characteristics.

Index or covariate values which are missing either in isolated cases or in entire series usually increase the need for elaborate estimation procedures and decrease the quality of inferences that can be made. Consequently, every attempt should be made to acquire a complete set of data, balanced with respect to site and time period.

Power

The ability to detect trends of given magnitude with reasonable confidence is a primary need for biologists who monitor natural systems (Toft and Shea 1983). Unfortunately, methods of estimating power for a design are not in the statistical training of most biologists.

For data collected under a given design, statistical power is the likelihood of rejecting the null hypothesis when an effect is present. For trend estimation, power is the chance of rejecting the null hypothesis of zero trend when in fact a real trend does exist. A smaller threshold value of trend is detectable in a design with high power than one with low power. Therefore, one should be able to decide the smallest trend that is consistent with population "stability" and determine what design configuration yields a great likelihood of detecting a trend at least as large, given that the trend really does exist. Then, declaring "no statistical significance" for a test of trend carries more relevance to the notion of population stability than would be possible in a low power test. Historically though, no assessment of power accompanies the data analysis, so failure to detect a significant trend is uninformative. When power is not reported, there is no basis to conclude that a nonsignificant trend estimate suggests population stability.

In the usual application of power analysis for population monitoring, one wants to determine those designs most likely to reveal a significant population trend if the trend exists at a specified size or larger. Number and frequency of surveys, use of covariates, and all other aspects of the design influence power and the likelihood of detecting population trend. Therefore, for a list of designs that are feasible given the available resources, the biologist can use power analysis to find the design yielding the highest power for the monitoring objective.

Power analysis for single-site surveys is described in the literature (Gerrodette 1987, Link and Hatfield 1990, Gerrodette 1991), and software is available for performing the calculations (Gerrodette 1994). The use of covariates can quickly complicate matters in power analysis, but power may still be estimated (C. T. Moore, U.S. Fish and Wildl. Serv., unpubl. rep.). Power analysis for regional surveys is not well-documented, but some tools are available (J. R. Sauer, Nat. Biol. Surv., unpubl. rep.; J. P. Gibbs, Yale Univ., unpubl. software). For either type of survey, data from a pilot study should be available to provide an estimate of variance. Such data may be collected in a single year if replicate, independent observations can be obtained. For regional surveys, pilot data must also be available at a sample of sites. In single-site surveys of fixed time span, more power for detecting trends is available through within-year replication and increased standardization of the design. For regional surveys, power is increased primarily through site replication and proper selection of strata.

Auxiliary information

Because the assumption of constant count bias is critical for inferring population trend from counts, concurrent collection of auxiliary data that allow direct estimation of the count bias may be a worthwhile endeavor. Many variations of line transect or mark-recapture techniques (Seber 1982, Nichols 1987) permit the direct estimation of population size each year. Population size estimates can be used to investigate annual variability in the count bias, to corroborate the survey estimate of trend, and to search for possible failure of trend estimation assumptions.

SUMMARY

The discussion presented here only scratches the surface of the vast collection of issues relating to design and inference in crocodilian monitoring studies. Because it is so difficult to satisfy key assumptions with any certainty and to implement appropriate analysis methods, trend estimation based on counts is rarely as simple as it appears. Covariates may present more problems than they offer to resolve. The realism of modelling curved trends has to be weighed against the relative simplicity of straight-line models. One can easily determine the monetary cost of random site selection and survey standardization, but a much more difficult and usually overlooked determination is the cost in scientific credibility of opting for the alternatives.

Although the issues are difficult, steps can be taken prior to the survey that will help narrow the design and analysis options. First, a clear statement of survey scope and objectives must be made. Second, gaining as much knowledge as is practical on the population, the habitat, and likely limitations of the survey method is fundamental to assuring the success of the survey. Collecting data from small-scale pilot surveys is an invaluable component of this step. With such knowledge, the biologist and the statistician should be able to determine if the survey objectives can be achieved through the resources available, and if so, design a robust, efficient survey program and analysis plan that will meet the objectives.

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AERIAL SURVEYS OF CAIMAN NESTS IN WET SAVANNAS OF BRAZIL

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INTRODUCTION

Wet savannas are prevalent in Brazil and other areas in South America. Some of these are vast as is the case of the Pantanal, the "Cerrados" of the state of Roraima and the Bananal island, but the majority are spread in patches along rivers such as the floodplains of the Amazonas-Solimões, São Francisco, and Paraná Rivers. The size of caiman populations inhabiting these habitats may be difficult to assess by spotlight surveys because frequently they occupy remote and extensive areas, and also because of the visibility bias associated with the swamp vegetation. Alternatively, aerial surveys of nests may be used to get information about populations of crocodilians inhabiting wetlands (Chabreck, 1966; Taylor and Neal, 1984; Webb and Smith, 1987). Many South American countries have been using caiman populations for profit. Venezuela and Guyana have legal harvesting programs and, Brazil, Colombia, Guyana and Venezuela, have implemented ranching programs (Luxmoore, 1992; Thorbjarnarson, 1992). However, except for a few recent studies (eg. Campos, 1993), there is no tradition in use of aerial surveys of nests of caiman in South America.

In this study, we present 3 examples of use of surveys of caiman's nests from the air, in different areas of wet savannas in Brazil. In one case, we monitored caiman nests in a ranch of the central Pantanal during 5 consecutive years and related nest densities to rainfall.

METHODS

Monitoring nests of caiman in a small area of wet savanna

We searched for nests of yacare caiman (*Caiman crocodilus yacare*), on the floating grass mats and in the forest patches of an area of 43 km^2 of the Nhumirim Ranch (18°59' S, 56°37' W), Central Pantanal. We searched for nests in January-February from 1989 to 1993. Surveys in the forest patches were conducted from horseback or on foot and the floating grass mats were searched from an ultralight aircraft (Microleve ML-200). Flights were conducted repeatedly, until no new nests could be found.

Surveys in large areas of wet savannas

We conducted surveys in 2 areas of the Pantanal from a CESSNA-206 flying at a speed of 200 km/h, and 1 area of the floodplain of the Paraná River from an helicopter (Bell-206) flying at a speed of 110 km/h. In all cases, flight height was 61 m. Two observers were seated on the same side of the aircraft to count the nests on the same 200 m wide transect delineated by a rod attached to the wing strut (CESSNA-206) or by tapes fixed on the helicopter's windows. We used the "tandem double-count" model (Magnusson et al., 1978; Caughley and Grice, 1982; Bayliss and Yeomans, 1989) to improve the accuracy of the counts. The navigator used a chronometer to determine routes and survey units. The aircraft's position was checked regularly with a Global Positioning System device (Maggellan PRO-NAV 5000 model).

We sampled 2 rectangular blocks of wet savanna in the Pantanal during 9 and 10-Mar-92. Block 1, with an area of 992 km^2, was located between the paralels 18°47' and 18°55' S and the meridians 57°36' and 57°00' W. Block 2, (1,932 km^2) was located between the paralels 19°22'-19°46' S and the meridians 56°54'-56°15' W. The sampling intensity was 5% of the sampled area.

Along the Paraná River, we sampled 957 km^2 of floodplains in the area to be flooded by Porto Primavera Dam, between the paralels 20°48'and 22°30' S. Surveys of broad-nosed caiman (*Caiman latirostris*) were made from 29 to 31-Jan-93, and the sampling intensity was 10% of the sampled area.

RESULTS

Nests in a small area of wet savanna

The total numbers of nests found on the Nhumirim ranch changed to 27 (1991) from 93 nests (1990) (table 1). Nest densities on grass mats varied from 0.1 to 1.1 nests/km^2. The total number of nests was positively related with rainfall ($N_t = 0.10 * pp_{12} - 52$, $n = 5$, $r^2 = 0.80$, $F = 11.62$, $P = 0.042$), where N_t = total number of nests and pp_{12} = cumulative rainfall over the 12 months preceding nesting. The number of nests found on floating grass mats (N_f) was also related to rainfall ($N_f = 0.07 * pp_{12} - 50$, $n = 5$, $r^2 = 0.81$, $F = 12.85$, $P = 0.037$), but there was no relationship between the number of nests found in forest patches and rainfall ($n = 5$, $r^2 = 0.27$, $F = 1.09$, $P = 0.372$).

Table 1. Number of nests of *Caiman crocodilus yacare* found in the forest patches and on the floating grass mats, and accumulative rainfall (mm) over the 12 months preceding nesting (PP_{12}) in the Nhumirim ranch, central Pantanal.

YEAR	FOREST	GRASS MATS	TOTAL	PP_{12}
1989	49	43	92	1457
1990	45	48	93	1318
1991	21	6	27	820
1992	38	23	61	1249
1993	18	49	67	1386

Nests in large areas of wet savanna

Pantanal, using a CESSNA-206: In survey block 1, the first observer (ZC) sighted 6 nests and the second sighted 3. Two nests were sighted by both observers. Using the tandem model we estimated the probability of ZC to sight nests = 0.67 give an estimated density of 0.17 nest/km^2. The estimated number of nests ($\hat{N}$) for the whole block was 167 ($SE = 2$).

In survey block 2, ZC sighted 16 nests and the second observer sighted 10 nests. Both observers sighted 3 nests simultaneously. The probability of ZC to sight nests on this block was 0.30 and the estimated density in block 2 was 0.56 nest/km^2, giving $\hat{N} = 915$, $SE = 15$.

Paraná river basin, using helicopter: Only 4 broad-nosed caiman were sighted during the 12 hours/flights of the survey, indicating that individuals of the broad-nosed caiman cannot be directly surveyed from the air in this environment and time of year. However nests on the floating grass mats could be sighted more frequently. Observer 1 (ZC) counted 35 caiman nests and observer 2 counted 19 caiman nests. Eleven nest were seen by both observers. The probability of ZC sighting a nest was 0.58 and the mean estimated density of broad-nosed caiman nests was 0.49 nests/km^2 (SE=0.09). Extrapolating this density to the 1,280 km^2 of surface covered by marshlands and wet savannas in the area to be flooded by Porto Primavera Dam, we estimated 630 nests in this area.

DISCUSSION

Aerial survey of caiman nests are feasible from conventional fixed-wing aircraft, helicopters and ultra-lights. Fixed-wing aircraft are practical to study abundance and distribution of caiman nests on median to large areas (1,000 to >140,000 km^2), but it is not possible to determine the individual position of every nest. The cost of fixed-wing flight on the Pantanal is US$1/km (Mourão et al, 1994). Helicopters are practical for small to median areas (<1,000 km^2) and they allow the collection of information on abundance, distribution and individual positions of caiman nests, with a cost over US$6/km. Ultralight aircraft are useful on small areas (<100 km^2) to get information about abundance, distribution and individual position of caiman nests, at a cost of US$0.8/km. Aerial counts from an ultralight aircraft was a practical method of monitoring the changes in the number of yacare caiman nests on Nhumirim ranch among years, .

Both, the total number and the number of yacare caiman nests found on the grass mats in the Nhumirim ranch were influenced by cumulative rainfall over the year prior to nesting. This result suggests that the regulation of the yacare caiman ranching activities (IBAMA's regulation # 126 of 13 Feb. 1990) must be reviewed. This regulation establishes a constant quota of nests to be harvested, independent of weather variations among years. We suggest a monitoring program of the caiman population in the caiman ranching areas, and the establishment of the harvest quota on an annual basis. That program could be financially supported by the caiman ranchers, but executed by an independent institution. These monitoring surveys can be done by traditional spotlights surveys or by aerial surveys of nests. Spotlights have been the most common method of caiman surveys (Chabreck, 1966; Woodward and Marion, 1978; Webb et al. 1983), however spotlights counts are time consuming (Bayliss, 1987) and subject to visibility bias (Woodward and Marion, 1978; Bayliss, 1987). Alternatively aerial survey is an efficient and cost effective means to monitor caiman nests in remote and hard-to-access areas of wet savanna.

SUMMARY

Wet savannas are frequent in Brazil and other areas in South America. Aerial surveys of nests may be used to get information about populations of crocodilians inhabiting these habitats but, there has been no tradition of use of aerial surveys of wildlife in South America. We present examples of use of different types of aircraft to survey nests of caiman. We used a CESSNA-206 to count nests of yacare caiman on floating grass mats in 2 large blocks of the Pantanal. The estimated densities were 0.17 nest/km^2 and 0.56 nest/km^2. Survey of broad-nosed caiman nests using an helicopter in an area of the Paraná river resulted a density of 0.49 nest/km^2. We used an ultralight aircraft to monitor the number of yacare caiman nests from 1989-1993 in a small area (43 km^2). Estimated densities varied from 0.1 to 1.1 nest/km^2 and were positively correlated with rainfall during the previous year.

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ESTIMATING CROCODILIAN ABUNDANCE IN FOREST LAGOONS

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INTRODUCTION

Night spotlight counts are the most widely used method of surveying crocodilian populations (Magnusson 1982) and are used throughout the world as an index for evaluating population trends (Woodward and Moore 1993). The relationship between a count and the total population is usually assumed to remain constant over time and any change in counts should reflect a proportionate change in the total population (Woodward and Moore 1993). A more appropriate assumption is that we can account for the factors affecting the sighting proportion (i.e. Wooward and Marion 1978, Messel et al. 1981, Pacheco 1993).

Night counts are also used to compare crocodilian abundance between different localities (i.e. two or more lagoons). The basic assumption here is that the sighting proportion is the same among the populations surveyed.

Given the problematic assumptions and huge time effort involved with the use of night counts, aerial nest counts are being used to evaluate population trends in countries like Brazil. It is enough to say that US$850 per hour of helicopter is the main reason why this method is not feasible everywhere.

The purpose of this paper is to review the factors that should be taken into account when initiating a long-term monitoring program of crocodilians in lagoons using night spotlight counts. Forest lagoons are the focus of the paper, but the same considerations apply to any lagoon habitat.

FACTORS THAT AFFECT NIGHT COUNTS AND HOW TO ACCOUNT FOR THEM

Three types of factors affect crocodilian night counts: methodological, environmental, and biological.

Methodological factors.- The problems in methodology are those caused by human errors and include: differences in observer's way of surveying, differences in type of light (e.g. power, colour, location of light beam with respect to observer), differences in type of boat used (size, shape, with or whitout an outboard motor). Usually, methodological factors are relatively easy to control, but they are important and must be standardized.

Environmental factors.- The effects of several environmental variables have been evaluated and it has been found that those that usually significantly affect the sighting proportions are: water level, wind speed (corelated with wave height), cloud cover, and temperature (Murphy 1977, Woodward and Marion 1978, Messel et al. 1981, Wood et al. 1985, Hutton and Woolhouse 1989, Larriera 1993, Pacheco 1993).

Variation due to water level can be controlled by doing all surveys during low water level periods, when a larger number of crocodilians is detectable. During high water level periods crocodilians tend to disperse to flooded areas away from observer's sight.

The effect of environmental variables on counts can be evaluated using regression techniques (i.e. several counts are conducted in one locality under different environmental conditions):

$$\text{Count} = a_0 + a_1\,\text{var}_1 + a_2\,\text{var}_2 + \ldots\, a_n\,\text{var}_n, \quad \text{where:}$$

Count = number of individuals seen
var = environmental variable ("n" variables)

This methodology will tell us which variables significantly affect our counts and whether this effect is positive or negative (Woodward and Marion 1978, Hutton and Woolhouse 1989, Pacheco 1993). Thus, standardization of surveys can be done by conducting all the surveys under certain conditions so the variability in sighting proportion among counts is reduced. For instance, if we find that air temperature affected counts positively, while wind speed and cloud cover affected counts negatively, surveys should be conducted when air temperature is above certain threshold, say 23° and when both wind speed and cloud cover are below certain thresholds, say 2 km/h and 2/8 respectively (cloud cover is measured in eights). The values presented here are just examples, actual values will vary among regions and species. As a further complication, different age classes do not respond in the same way to environmental variables. For instance, maximum air temperature of the day affects the counts of larger size classes, but not those of hatchlings and juveniles of Black caiman (Melanosuchus niger) (Pacheco 1993). Therefore, it is best to do the analysis that one is considering separately for each size class.

If the total population size has been estimated for the locality where several surveys were conducted, it is possible to use the sighting proportion (for each size class) as the dependent variable in the regression analyses. In this way, predictive models can be obtained. That is, based on the environmental variables prevailing during a single count it is possible to estimate the sighting proportion and, with it, the total population size in subsequent years (i.e. Hutton and Woolhouse 1989). The assumption here is that changes in density do not affect the sighting proportion. This assumption is later examined and usefulness of these models in the long run discussed.

Other environmental variables like habitat also must be taken into account (Woodward and Moore 1993). For instance, counts from rivers should not be compared with those from lagoons assuming that the sighting proportion is the same. Within lagoons, both amount and type of aquatic vegetation will also affect the sighting proportion. It may be very difficult to account for this variables statistically (although not impossible), so it might be best to control for differences in habitat by comparing counts only among localities with similar types of habitat. Aerial photographs may be useful to choose similar localities.

Biological factors.- Two biological factors have extremely important effects on night counts: the wariness of the population/individuals and population density.

Wariness. The effect of wariness on the counts is easy to visualize. Less wary populations will have a greater sighting probability than more wary ones. Wariness is affected mainly by size (age) structure of the population and human activities (Webb and Messel 1979, Montague 1983, Pacheco 1993). If comparisons in abundance among localities are to be done, what is important is to determine how to account for the differences in the sighting proportions due to wariness. In short, abundances of two localities can be compared if their sighting proportions are similar. The first assumption here is that populations with similar wariness indices will have similar sighting proportions.

The easiest way to assess wariness is to compare it among the populations under study. Two wariness indices may be used: the escape distance of individuals (the distance from the boat at which individuals submerge) and the proportion of individuals that could not be approached to make species identification (usually known as the "eyes only" category).

Given that wariness is affected by body size (Webb and Messel 1979, Pacheco 1993), comparisons of escape distances should be done separately for the different size classes. Variances tend to be very large, precluding the use of ANOVA, so alternative nonparametric tests may be necessary (e.g. Kruskal-Wallis).

The use of "eyes only" (EO) as an index of wariness can only be tested statistically if one has several measurements. One way to avoid conducting several surveys in each locality is to compare the proportion of EO from each locality with the average EO from the surveys conducted in one locality (e.g.

where the total population estimate was done). Differences can be tested with a two sample t-test with arcsine transformation (Zar 1984).

The second assumption here is that environmental conditions will not affect the wariness of the populations. This assumption may not hold for the simple reason that environmental conditions affect the sighting proportion of different size classes differently (see above) and, in turn, wariness is affected by size class. Therefore, it is advisable to test whether environmental conditions affect the wariness indices. Regression techniques can be used (with wariness indices as dependent variables). The results of the standardization counts can also be used here. The coefficient of determination (R^2) can be used to assess whether the amount of variation in wariness due to environmental variables is so high that wariness indices cannot be compared among populations.

Density. There are no references in the literature concerning the effect of density on the sighting proportion of crocodilian night counts. Nevertheless, results from my experience suggest that density does affect the sighting proportion.

Following Hutton and Woolhouse (1989), multiple regression models were built to estimate the sighting proportion of different size classes of M. niger in the Beni region of Bolivia (Pacheco 1993). Models were built on data gathered in 1992, when a total population size estimate for the lagoon used to standardize methodology was done.

The estimate for the hatchling size class was 91 individuals, with a 95% interval of 65-113 (Lincoln-Petersen estimate) (Pollock et al. 1990). In 1993 a single survey was conducted in the lagoon and, based on the model for size class II individuals, the presence of 314 (95% interval 127-768) size class II individuals was estimated. Since the model can be considered statistically useful (independent variables wind speed and cloud cover, R^2=0.84, P=0.0001, details on the models will be published elsewhere), and considering the estimate for size class I in 1992 was accurate, there is a large overestimate of the number of 1993 size class II individuals. Recapture data rule out the possibility that 1992 size class II individuals were confused with individuals that entered size class II in 1993. In fact, size class II in 1993 was apparently formed almost exclusively by 1992 hatchlings.

On the other hand, the number of individuals in size classes >II (29, 95% interval 13-64) estimated with another model (independent variables wind speed, cloud cover, and maximum temperature of the day, R^2=0.98, P=0.0001), closely agrees with the expected number based on 1992 population estimates for those size classes (32).

When comparing the densities (individuals/km of shoreline) from one year to the other, it was found that size class II individuals accounted for almost the whole increase in density for nonhatchling caimans, from 0.84 ind/km in 1992 to 7.23 ind/km in 1993. In other words, the 1992 hatchlings grew to size class II in 1993 and increased nonhatchling density (size classes II-VI), but density of size classes >II did not increase. Thus, these results suggest that density is playing an important role in determining the sighting proportion and this may invalidate population estimates from models that do not account for these changes. Given the possible implications of this finding, it is urgent to test (with more detail) how important the effect of density on sighting proportions can be.

Final comment.- Statistical tests and procedures suggested here should be discussed with a statistitian.

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AERIAL SURVEYS FOR MONITORING TRENDS AND ESTIMATING POPULATION SIZE OF *Crocodylus niloticus* or the Theory and Practice of Aerial Survey in Africa

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INTRODUCTION

Aerial survey is generally accepted as being the most cost-effective way of surveying large stretches of crocodile habitat. However, unless the survey is carefully planned, the results may not be of much value. It has been widely used in parts of Africa (Table 1) for a variety of reasons. It is seldom used as a pure research tool (i.e. surveys are driven by management objectives).

Table 1. Some Aerial Surveys of Nile Crocodile in Africa (Density = Crocodiles per kilometre).

Water Body	Country	Density	Authors
Okavango river	Botswana	Nest Survey	Graham *et al.* (1976)
Okavango river	Botswana	Nest Survey	Graham *et al* (1992)
Lake Margherita	Ethiopia	1.25	Turner (1977)
Upper Awash river	Ethiopia	7.00	Turner (1977)
Lake Baringo	Kenya	1.40	Hutton (1992)
Sebaki-Galana river	Kenya	0.00-1.50	Hutton (1992)
Ewaso Ngiro river	Kenya	0.07-0.90	Hutton (1992)
Tana River	Kenya	0.00-4.83	Hutton (1992)
Lake Turkana	Kenya	13.4	Graham (1968)
Lake Turkana	Kenya	0.52-28.06	Hutton (1992)
Elephant Marsh	Malawi	Nest Survey	Bruessow (1992)
Lake Cahora Bassa	Mozambique	1.90-11.5	Games *et al.* (1992)
Upper Rufiji river	Tanzania	0.98-3.15	Games and Severre (1993)
Lower Rufiji river	Tanzania	6.75-11.83	Games and Severre (1993)
Lake Tagallala	Tanzania	18.07-23.38	Games *et al* (1993 a,b)
Ruaha river	Tanzania	1.56-1.68	Games (1992;1993 a,b)
Kilombero river	Tanzania	0.28-7.74	Games (1992;1993 a,b)
Ugalla river	Tanzania	0.67	Games (1992;1993 a,b)
Lake Victoria (Rubondo Island Only)	Tanzania	0.82	Games (1992;1993 a,b)
Rungwa river	Tanzania	0.20-0.46	Games (1992;1993 a,b)
Victoria Nile	Uganda	0.02-26.27	Parker and Watson (1970)
Victoria Nile	Uganda	0.50-1.67	Hutton (1991)
Lake Albert	Uganda	0.06	Parker and Watson (1970)
Luangwa river	Zambia	6.2-14.8	Howard (1992)
Lake Kariba	Zimbabwe	5.00	Taylor (1993)

In Africa there may be a large difference between the theory and practice of aerial survey. I will attempt to discuss both in this paper by examining some of the issues and methodology surrounding aerial surveys of crocodiles in east and southern Africa. Two published papers are considered to be invaluable reference works on surveys (Bayliss, 1987; and Graham, 1988) and this report draws liberally on these two sources.

METHODS

Assumptions

In theoretical terms, aerial survey of crocodiles is based on the following assumptions.

1) That crocodiles often emerge to bask during the day.
2) That larger crocodiles (>2m) can readily be seen from the air at speeds in excess of 80 knots and heights of greater than 100 metres.

This is true of both actual counts of crocodiles and nest counts. Nests are often identified by the presence of an attendant female. They can also be identified by the easily recognisable slide.

In practical terms we have found that there are several other things that need to be assumed. These are:

- that there is water in the river to be surveyed!
- that suitable aircraft will be available for the entire survey - there are sufficient operating hours left - the aircraft does not break down *etc*. Is a replacement aircraft available if something goes wrong?
- that there are suitable experienced pilot(s) and observers (who are not prone to airsickness) available for the entire survey
- that avgas is available in the correct places (either in drums [and it hasn't been stolen] or at a registered filling point [on the day you need it]).
- that the survey crew is not arrested and detained (some airspace in Africa is considered sensitive by governments).

Planning

Perhaps the first question that needs to be asked is - what are the objectives of the survey? The answers to this question need to be clearly stated before the beginning of the survey. Surveys can be "once off" attempts to count crocodiles and estimate their population sizes within given water bodies but it is strongly recommended that all surveys are treated as part of a series aimed at establishing trends - even if the likelihood of further funds seems remote (Magnusson, 1982). The financial situation can always change and it would be a great pity if data from the first survey could not be used to complement later surveys. Examples of objectives for surveys could include:

- the collection of data to enhance a management programme (cropping and egg collection)
- counts and population estimates for CITES proposals
- academic research where an estimate of numbers was needed

Once the objective(s) have been defined then the task of gathering information can begin. Unfortunately some surveys do not spend enough time defining the objectives of the investigation. The issue can also be complicated and clouded by politics. The source and amount of funding can also dictate to some extent what happens during a survey. For example, if the funds are sourced from producers then they may require information specific to egg collection. Similarly if a survey has been planned and then some funds are withdrawn then it is necessary to re-prioritize the survey. For example a shortage of funds will mean reduced flying time and deciding which rivers are more important. Information may come to light just before takeoff (e.g. no water in the river - don't laugh - this can easily happen in remote and unknown areas) which may also require a re-prioritization of the survey.

The importance of information on the waters and areas to be surveyed cannot be stressed enough. In many parts of the continent, however, information has proved to be anecdotal, especially if the area has not been surveyed before.

The time of year is important. It is best to survey most water bodies at low water, prior to the rains, as the crocodiles will be concentrated. If the survey is part of a series to establish trends then it is important to try and survey at the same level of water rather than time of year. As an example, a section of river (Section A) may become too shallow to support large crocodiles which will then move downstream to a deeper section (Section B). The first survey at high water will show a given number of crocodiles in section B. The second survey, at low water, will show that there has been a marked increase in crocodiles in Section B and a marked decrease in Section A. One may feel that this is obvious and any fool can figure out what has happened - but the picture may become more complicated if incomplete. In the scenario above, for example, lack of survey funds may mean that the shallow (crocodile-less) section (Section A) was not surveyed and the resultant conclusion is that the population is healthy and increasing in Section B. This may not be the situation at all and in a case like this local knowledge would be invaluable.

Rivers that have not been seen before from the air may prove to be totally unsuited to aerial survey and funds spent on including them could be used to far greater advantage elsewhere. For example, the river may have a dense overhanging riverine fringe or be a myriad of small swampy channels covered in aquatic vegetation. Swamps are usually poor candidates for aerial survey to count crocodiles.

Another problem is how to cover the habitat. Again, if the survey is to be used to establish trends, then it may not be as much of a problem if the survey aim is a "total" population estimate. To establish trends the surveys need to be repeatable. If the river is wide (e.g. 1km or so) there are several options available. One could elect to survey a single bank and extrapolate for the other bank (extremely dangerous as crocodiles are seldom evenly spaced within a habitat). Alternately one could fly down the centre of the river and count both sides simultaneously. This has its own set of problems which include centrally placed sandbanks (not seen as they are directly under the aircraft) and getting too far away from one or both banks making spotting difficult. If the river is narrow then it could be surveyed on a single pass with counting from alternate sides of the aircraft (make sure that the observers on the side away from the river are not counting as well if the double counting method is being used).

As aerial survey is based on the assumption that crocodiles emerge from the water to bask during the day, the time of flying is important. As an example, a survey of a small section of the Rufiji river in Tanzania showed a density of 7.2 crocodiles per kilometre when surveyed at 0930 hours and a density of 2.7 per kilometre when surveyed at 1230 hours. The best time to spot crocodiles can also vary with local conditions. If the area is extremely hot then the animals may bask early and return to the water by mid-morning. Conversely an overcast day will mean that they may spend a longer period out of the water (overcast conditions, however, are generally considered to lessen the chances of spotting crocodiles from an aircraft - albeit this has not been tested statistically). The importance of this becomes obvious if the survey is a wide ranging one with long transit times between the airfield and the river. Sometimes it may be impossible to survey at optimum times. If the survey is part of a series for establishing trends then it is important to arrive at the river and start the survey at the same time to the previous surveys.

Equipment

A range of aircraft can be used for aerial survey to count crocodiles. The Cessna 180, Cessna 182, Cessna 185 and Cessna 206 (especially if these have a Robertson short takeoff and landing - STOL - conversion as this gives the aircraft a lower stalling speed and allows it to fly at a slower speed) have proved to be particularly useful. Perhaps one reason for the popularity of these aircraft is their availability in Africa. Another reason is that these are all single engined, high wing aircraft. The 180 and 182 are four seater aircraft while the 206 is a six seater. Again this can influence the design of the survey. The Piper super-cub is another aircraft that has been used on some surveys. Helicopters are usually far too expensive and consequently are not often used. In any case, Parker and Watson (1969) reported that there was little advantage in using them. The use of microlight aircraft has yet to be widely applied in crocodile survey in Africa but they hold great promise. One disadvantage is that in surveys covering large areas they would need to be transported by vehicle. Also, the results from surveys carried out from microlights may not be compatible with surveys done with more conventional aircraft.

Maps are essential for any survey. Unfortunately in some parts of Africa these may be a problem as under-funded "Surveyor General" offices often are without stocks. The scale of the map used depends again on the objectives of the survey. It is usually best to get 1:250 000 maps of the areas for basic navigation and then to see if 1:50 000 maps are available for the actual survey. On long rivers the cost of a set of 1:50 000 maps can be high.

Global positioning systems are now readily available and are below the US$ 1 000 mark. Their main advantage is that it is possible to have an "unlimited" number of samples within a stratum. By this I mean that, on the first survey, the recorder can assign the sample boundaries by recording them as numbered points (called waypoints in GPS terminology) within the GPS memory. It is not necessary to use physical features such as a sharp bend or a waterfall etc. as the sample boundaries. On the second survey, if one wants to use the same samples then a dedicated GPS operator will be needed as it is physically impossible to keep track of the waypoints and count crocodiles at the same time. Their main disadvantage is reliance on a machine for navigation and, if it fails for some reason, the recorder may not be able to locate his exact position immediately. Two important requirements to check are that there are sufficient free waypoints for recording and that you have spare batteries. Familiarisation with the machine before starting the survey will help to reduce mistakes. A GPS with a detachable aerial will be more useful than one with a built in aerial as it can be held on your lap. A GPS with a built in aerial usually needs to be placed on the dashboard and this means that it must be read from a distance and the recorder has to lean forward to enter waypoints.

Personnel

Good pilots are an asset to any survey. Ideally the pilot should be a biologist with sufficient experience and confidence to fly at slow speeds close to the ground and to undertake tight "elevator" turns. In some cases it is possible for the pilot to double as an observer, but on many surveys this has not proved to be practical.

The choice of observers can also have a bearing on the survey. Personal experience has led me to believe that it takes some time for a crocodile "search image" to be formed (varying from heads to whole bodies). The easiest crocodile to see is one that is diving into the water from a bank. Observers experienced with large mammal counts on open plains tend to miss a lot of crocodiles when they first start crocodile surveys. This could also be partly due to searching in the wrong places (e.g. crocodiles can rest partially submerged on the downstream side of sandbanks and the observers may be concentrating their search on the river banks).

We have found that the recorder and/or coordinator of the survey should sit behind the pilot as he will tend to favour his side in the turns.

Design

Any count of a wild population will always record the minimum number of crocodiles within a given habitat. From this number an estimate of the population can be calculated. It will never give the real total. "**TOTAL**" counts are an attempt to provide an estimate of crocodiles along a given stretch of river or lake. **SAMPLE** counts take results from small sections of the river and extrapolate them to the whole river. Sample counts have the advantage in that they are easier to manipulate statistically than total counts. The quality of an estimate can be assessed in two ways, related to their **PRECISION** and **ACCURACY**.

PRECISION

If the survey is to be part of a series aimed at monitoring trends then it must have some measure of precision. Counts are precise if they give similar results on different occasions. These results may not be close to the real total. The measure of precision is usually the co-efficient of variation or CV. The CV is the standard error of a count expressed as a percentage. A CV of between 5% and 15% is considered essential in order to monitor changes. Large CVs will mean that only drastic changes can be detected. In the following account the ideal way of conducting a survey is outlined.

- *Stratification of the river*

Crocodiles are never spread evenly along a body of water, be it a swamp, lake or river. Their density will be affected by the physical characteristics of a river, the human population density along rivers or lakes, the protection category of the land through which the river passes, the exposure factor of a lakeshore to the prevailing winds *etc*.. If all the samples are clumped together then the CVs will be large. The practical implication of this is to stratify the river into sections of (hopefully) similar densities. Here again local knowledge of the water body in question would be invaluable.

- *Sampling fraction*

The sampling fraction is the percentage of the length of the fraction that is sampled. Of all the factors which can be manipulated during the planning phase of a survey this may have the strongest influence on the CV. The CV decreases by the square root of increased fraction of stratum sampled.

- *Stratum length*

For a given sampling fraction the CV decreases by the square root of increasing stratum size. As the stratum size is fixed (usually in the planning phase) a larger sampling fraction has to be applied in smaller strata to achieve a given target CV.

- *Number of samples*

The greater the number of samples the narrow the confidence limits will be. A stratum should be broken up into as many samples as possible. This is made easier by the use of GPS rather than by navigation on the physical features of the river.

- *Crocodile density*

The CV is proportional to crocodile density and areas with a high density require a large sampling fraction in order to achieve a target CV.

ACCURACY

The closer an estimate is to the actual number of animals in an area the more accurate it is. As we cannot know the true number of animals in the area we estimate the biases that are inherent in a survey. The bias is simply the difference between the true number and the estimate and is because one can never see all the animals in the area (and even if you did how would you know?).

In crocodile surveys there are two types of bias - **OBSERVER BIAS** and **CONCEALMENT BIAS**.

- *Observer bias*

Observer bias is usually estimated using the double counting method (Magnusson, Caughley and Grigg, 1978). This method requires that two spotters sit on the same side of the aircraft and observe independently. The observer/recorder records three categories of sightings:

- Crocodiles seen by himself only
- Crocodiles seen by the other observer but not by himself
- Crocodiles seen by both observers.

This is possible by having the other observer call out his sightings to the observer/ recorder. If the observer/ recorder sees the crocodile(s) that the observer is indicating then they are assigned to the category of "seen by both observers". If the observer/ recorder sees the crocodile(s) and the observer does not indicate or say anything then they go into the category of "seen by himself". Finally those seen and indicted by the observer to the observer/ recorder who would not have seen them if they were not pointed out to him go into the category of "seen by the other observer but not by himself". Experience shows that the observer/ recorder should sit behind the observer as it is easier to see the observers hand movements when he is indicating crocodile sightings. If the observer was behind the observer/ recorder he would have to tap the observer/ recorder on the shoulder every time.

In a six seater aircraft this can arrangement can be on both sides of the aircraft; in a four seater it is usually only on the right hand side unless the pilot is sufficiently skilled to double as an observer.

- *Diving and concealment bias*

This usually is not part of an aerial survey but some information does exist to allow an adjustment for these biases (Hutton and Woolhouse, 1989). If it as at all possible to do a spotlight count some estimate of bias for a given section of river can be estimated. However, if the aim of the survey is monitoring of trends, then a bias estimate may not be necessary. In any case, spotlight counts do not reveal all the animals (only a greater proportion) as they suffer from diving and concealment biases as well.

Recording and Reporting

The importance of reporting cannot be over emphasised, especially if the surveys are to be part of a series. Several copies of the report should be lodged in relevant places such as the Directors office, the research division and any other interested bodies (e.g. WWF or IUCN *etc.*). As much relevant information should be included in the report such as time, weather conditions, coordinates, observers *etc.* This helps future researchers in their attempts to replicate the surveys. It also helps if a re-analysis of the data needs to be carried out - often the surveys are under a strict deadline and the data may benefit from a more leisurely re-analysis at a later date. There is nothing more depressing than to try and figure out what happened five years previously from scraps of paper and fading memories.

INTERPRETATION AND ANALYSIS

Tandem Counts

Tandem counts are usually analyzed using a method proposed by Magnusson *et al* (1978). The population estimate (N), observer bias, the variance (V) and the coefficient of variation (CV) are calculated by:

$$N = \left(\frac{(S_1 + B + 1)(S_2 + B + 1)}{(B + 1)}\right) - 1$$

the variance with:

$$V = \frac{(S_1)(S_2)(S_1 + B + 1)(S_2 + B + 1)}{(B + 1)^2(B + 2)}$$

and the CV by:

$$CV = \left(\frac{\sqrt{V}}{N}\right)100$$

where:

S_1 = crocodiles seen by the observer
S_2 = crocodiles seen by the observer/recorder
B = crocodiles seen by both.

Sample Counts

The CV is estimated by first calculating S_d^2 with:

$$S_d^2 = \frac{(\Sigma\ d^2 - (\Sigma\ d)^2)\ /\ (n)}{(n - 1)}$$

where:
d = density of the samples
n = number of samples

The variance of the count (V) was then calculated by:

$$Var\ N = \left(\frac{Z^2}{n}\right) S_d 2$$

where:
Z = total length surveyed
n = number of samples

and the CV calculated by

$$CV = \left(\frac{\sqrt{V}}{N}\right) 100$$

where:
V = variance of the count
N = number of crocodiles

DISCUSSION

As a general observation it could be stated that aerial survey as a tool to count crocodiles and estimate population sizes is on shaky scientific ground. The problem is that management decisions need to be made. There is usually never enough money or time to carry out extensive surveys of crocodile habitat and it is better to have the decision made on some aerial survey data rather than on no information at all.

Surveys that are part of a series to establish trends are generally more useful than "once off" surveys. However, initial "once off" surveys, aimed at locating good crocodile habitat for the trend surveys may be necessary. That one should consider all surveys as part of a series aimed at establishing trends is a good attitude to have.

Essentially, in surveys aimed at establishing trends, one tries to standardise as many variables as possible and the main ones are listed below:

- Same aircraft type
- Same pilot
- Same observers
- Same time of year or water level
- Same time of day.

With the advent of the GPS it is possible to survey the whole length of a river which is then broken down into continuous samples. Random samples can then be chosen from the continuous samples. Is this a statistically valid method?

What about grouping samples of similar densities? e.g. all samples with densities of below 1 croc/km. Isn't this stratification in hindsight?

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THE REPRODUCTIVE EFFICIENCY OF THE NILE CROCODILE (Crocodylus niloticus) IN SOUTHERN AFRICA

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ABSTRACT

The reproductive efficiency of the Nile crocodile (Crocodylus niloticus) in captivity will be addressed. Attention will be paid to factors influencing the reproductive performance of female crocodiles in two captive-breeding operations. The effect of efficiency of reproduction on the success of commercial units will be highlighted.

The reproductive cycle of the Nile crocodile (Crocodylus niloticus) has been described in various publications.

Sexual maturity, according to Jacobsen (1989) is reached when the crocodiles are 2 to 3 m long, weigh 70 to 100 kg and are twelve to fifteen years old. Kofron (1990) states that although females may start laying at seven years of age, sexual maturity is only attained after they reach a total length of about 2,62 to 2,87 m. Males, on the other hand, reach sexual maturity at a length of 2,7 to 2,95 m.

Haller and Haller (1992) also mention that females may start laying at seven years of age but that high hatchling survival rates were experienced when females laid their first clutches at the age of twelve to thirteen years. According to Thorbjarnarson (1992), sexual maturity is reached when the female is approximately 2,5 m long.

With regard to clutch sizes, the following is summarised from the literature: Pitman, in Cott (1961), examined 775 nests in Uganda and found a range of 25 to 95 eggs, with an average of 60,4 eggs per nest. Pienaar (1966) mentions 40 to 75 eggs per clutch for the Kruger National Park in South Africa.

According to Modha (1967) clutches varied from 14 to 46 eggs (mean 33 eggs) for Lake Rudolf. Further data from Cott (1969), this time from 123 Ugandan nests, reflected a mean of 55,4 eggs per nest.

Neill (1971), on the other hand, found that clutch sizes varied from 25 to 95 eggs per nest with an average of 55 to 60 eggs, depending on locality. Taylor (1973) reported clutch sizes varying from 50 to 81 eggs with an average of 63 eggs from 18 clutches in Botswana.

Blake (1974) found that in Zimbabwe the number of eggs per nest varied from 14 to 77 with an average of 45 eggs per nest. A total of 132 clutches were examined by Pooley (1982) in Zululand with a range of 18 to 73 eggs, the mean being 45. Jacobsen (1988) states that females lay 16 to 80 (usually 40 to 50 eggs).

Hailu (1990) examined clutches over a five year period in Ethiopia and noted that the average numbers of eggs per clutch per year were 36,5; 44,1; 43,8; 46,3 and 38. Loveridge, Hutton and Lippai (1992) found that mean clutch sizes at Mwenda in Zimbabwe were mostly between 40 and 48. At Ruziruhuru in 1967 the mean clutch size of 31 nests was 42,0 $\pm$ 1.6. This remained fairly steady from 1976 to 1991, although the trend moved downward from 48,8 $\pm$ 4.4 in 1976 to 43,7 $\pm$ 3.0 in 1990. The mean clutch size for Deka from 1969 to 1981 was 40,4 $\pm$ 1.2.

Thorbjarnarson (1992) states that females lay an average of 50 to 60 eggs.

In captivity, according to Marais and Smith (1988), females produced 34 to 71 eggs with a mean of 50,14 in 1986 and 34 to 75 eggs in 1987, the mean being 53,5 eggs. Captive bred females younger than 16 years of age averaged 50,33 eggs per clutch over two seasons whereas mature wild-caught females averaged 59,38 eggs per nest during the same two seasons. In Smith and Marais (1990) it is reported that on four commercial farms in South Africa the average numbers of eggs per clutch were 39, 43, 50 and 52.

Data on egg sizes is also contained in various publications:

Pienaar (1966) describes eggs sizes as measuring about 50 by 80 mm.
Modha (1967) found that eggs from 15 clutches varied from 55,5 to 89,0 by 43,0 to 54,0 mm.

Pooley (1982) examined twenty clutches in Zululand and found that egg sizes varied from 56,0 to 90,0 by 46 to 56 mm. Some freak large eggs were also found.

Data on egg weights is as follows:

Modha (1967) recorded weights of 76,0 to 133,0 grams while Pooley (1982) sampled five clutches in Zululand and found that egg weights ranged from 91,0 to 128,4 grams. Haller and Haller (1992) reported that the first non-viable eggs had mean weights of only 46,7 grams as opposed to the 65,8 grams of the first viable eggs laid by females. The mean weights of the eggs increased steadily as the females grew older and averaged 96,5 grams six years later. Mean egg weights for females from the ages of 13 to 16 years increased from 89,1 to 96,5 grams. The mean from 442 eggs from the Galana river in Kenya was 88,7 grams.

Data on hatchling sizes appears to be more consistent and Cott (1961) gives sizes at birth as being 28 cm to 30 cm in length compared with Pienaar (1966) who stated that the young measure from 26,0 to 30,0 cm in length.

Modha (1967) examined nineteen clutches from Kenya and hatchling lengths ranged from 26,0 to 34,0 cm (mean lengths 26,3 to 32,5 cm).
Pooley (1982) measured 103 hatchlings from five clutches from Zululand and the range was 26,3 to 31,2 cm.

The purpose of this paper is to establish the reproductive efficiency of captive Nile crocodiles by looking at performance in two commercial units over a two year period. This data is also compared with that from the literature.

Both study units are situated in the Western Transvaal in South Africa where weather conditions are similar and the crocodiles are housed in large breeding enclosures open to the visiting public. Male to female ratios correspond and the crocodiles at both units are fed similar diets.

The females in Unit A, bar one or two exceptions, are captive bred and most of them under 16 years of age. Older and more mature males are housed with them.

Females in Unit B, on the other hand, consist of mature captive bred females older than 16 years of age and are mixed with large wild-caught females from Botswana.

We will evaluate the levels of efficiency in the two units with regard to:

Egg numbers

Egg size

Egg weight

No. of hatchlings

Fertility

Hatchling size

Hatchling weight

Hatchling yield

Female productivity

Laying commenced on 25 October during the first season in Unit A and continued until 24 November. In the second season, laying commenced and ceased earlier, with the first eggs being laid on 9 October and the last on 18 November. In South Africa, spring starts in September and summer in December.

Laying started earlier in Unit B with the eggs being deposited on 14 September and the last on 29 October during the first season. Laying times for the second season were virtually identical, beginning on 14 September and ceasing on 29 October, as shown in figure 1.

During both seasons, more than 52% of the females in Unit A laid their eggs between the hours of 18:00 and 21:00 while more than 39,5% of the females laid between the hours of 15:00 and 18:00.

In Unit B, 60,7% of the females laid between the hours of 21:00 and 24:00 during the second season while during the first season only 37,5% of the females laid in the same period, as seen in figure 2.

FIGURE 1

DATES OF EGG LAYING BY NILE CROCODILE FEMALES

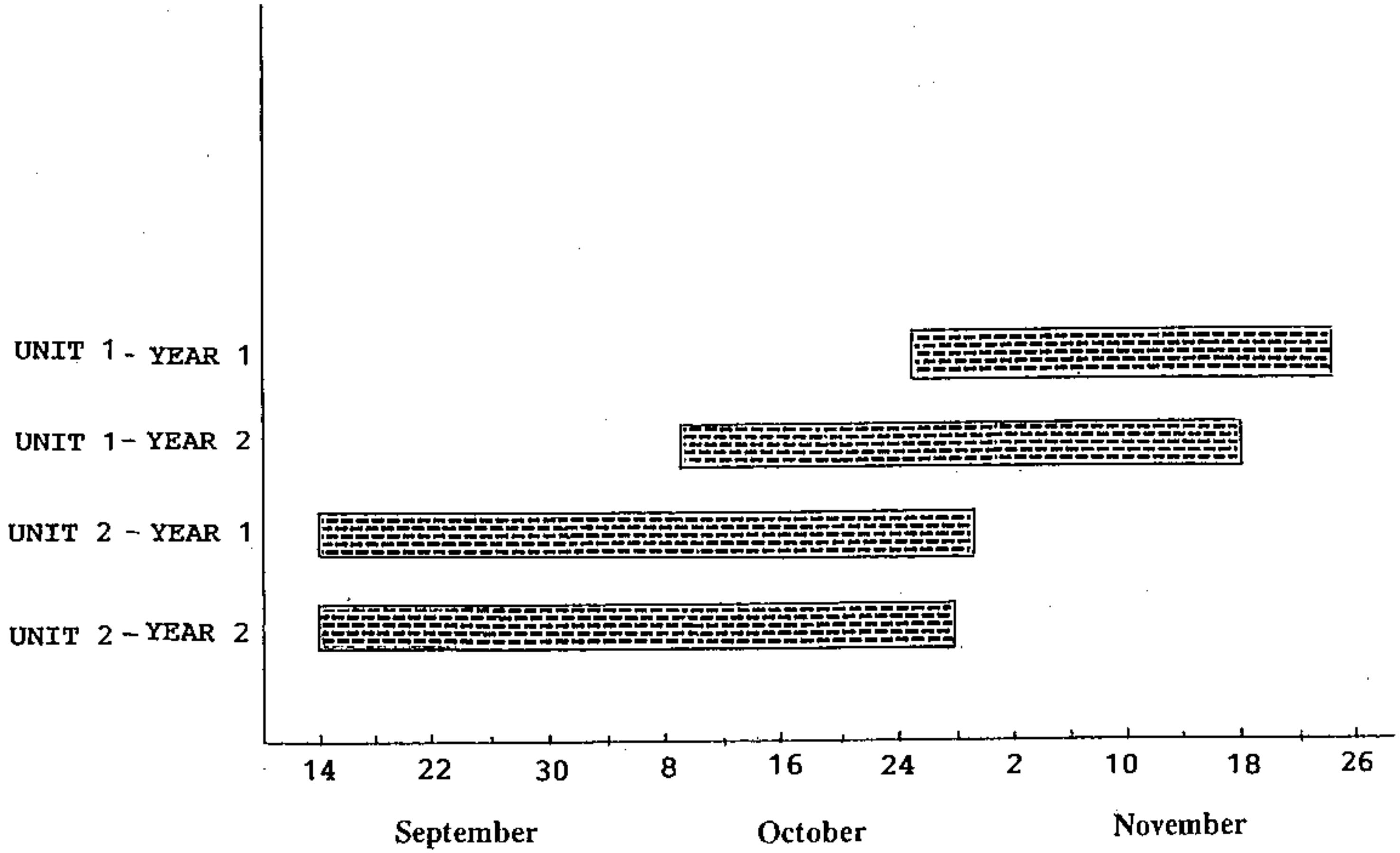
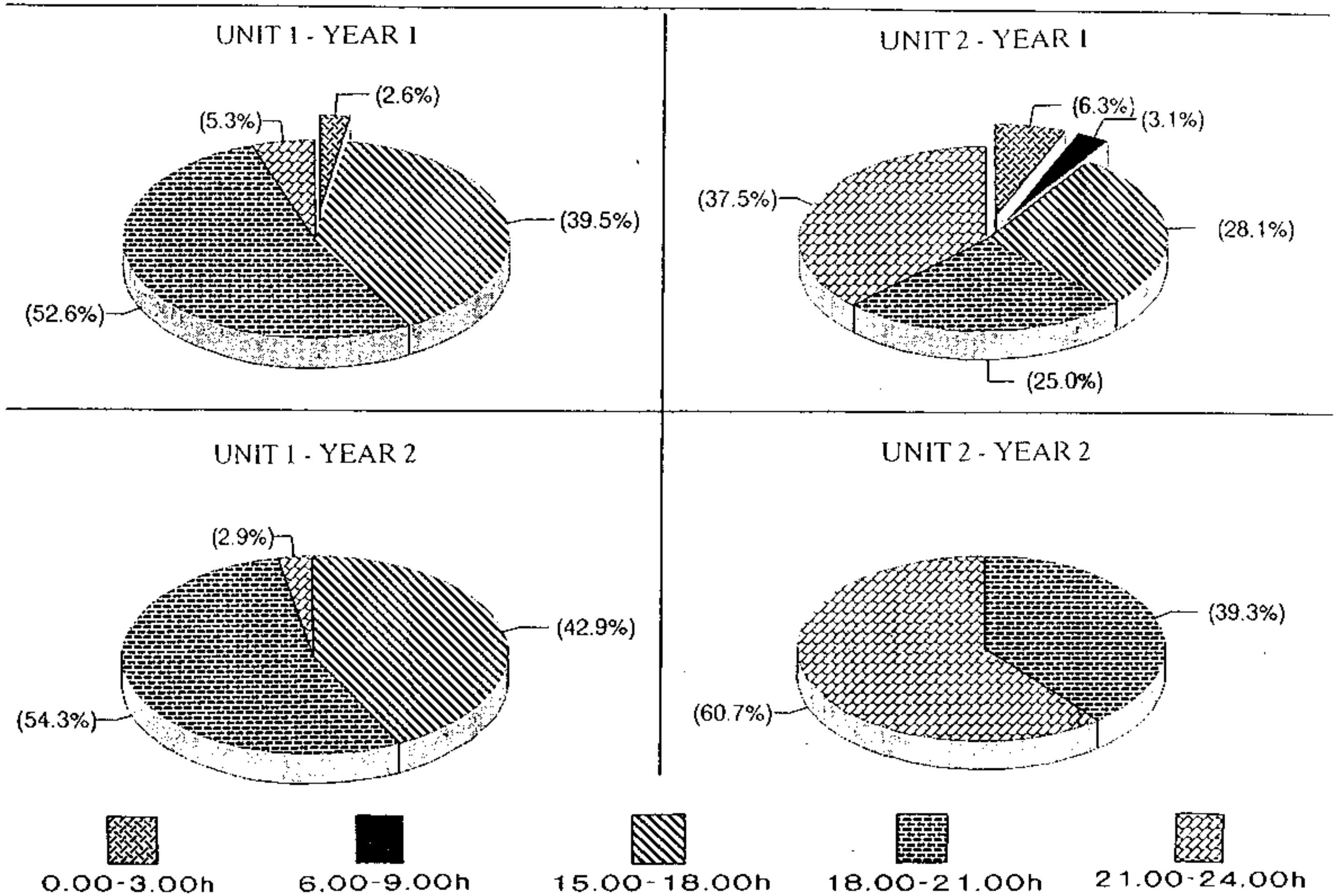


FIGURE 2

LAYING TIMES OF NILE CROCODILES AT TWO PRODUCTION SITES



Data on the number of eggs produced in the two units during the two seasons, as well as data on the number of females laying, the number of nests, the average number of eggs per nest and the percentage of females that laid during the seasons is portrayed in figure 3.

Figure 3.

Number of eggs laid	**UNIT A**		**UNIT B**	
	YEAR 1	**YEAR 2**	**YEAR 1**	**YEAR 2**
Total number of females	136	136	83	83
Number of nests	44	46	62	62
Average eggs per nest	37,09 8 - 66	36,61 12 - 53	46,84 3 - 66	53,65 34 - 79
Total number of eggs	1,632	1,684	2,904	3,326
% of females laying	32,4	33,8	74,7	74,7

Individual egg mass varied from 71,5 grams to 143,6 grams with a mean of 91,4 grams. Egg length and width varied from 60 mm to 90 mm by 41,4 mm to 58,2 mm with a mean of 69 mm by 46 mm.

Data on total egg biomass per clutch showed no clear relationship when compared with the size of the female and the biomass varied from 1,146 grams to 6,082 grams with a mean of 3,332 grams. The females that produced these eggs varied in length from 215 cm to 280 cm with a mean of 259 cm. The biomass of eggs, when compared with the total weight of a female, represented about 3 to 4% of the female's total body weight.

It is of interest to note that a jungle fowl lays approximately twelve eggs per year. If we compare that with a domestic fowl, which is bred from the jungle fowl, we find that the domestic fowl produces about 280 eggs per year, each weighing in the region of 50 grams, whereas the female weighs in the region of 1,6 kg. Each egg produced weighs about 3% of the total weight of the fowl.

This great number of eggs laid by a domestic fowl in comparison with the jungle fowl's lesser produce leads one to speculate that a similar result may be obtained from captive-bred crocodiles. A practical endeavour into this, however, would take a considerable amount of time and patience knowing how long it takes for the female crocodile to reach sexual maturity. Still, it is food for thought.

Moving from conjecture to fact, the following information in figure 4 is more relevant to the producer.

Figure 4.

	UNIT A		UNIT B	
	YEAR 1	YEAR 2	YEAR 1	YEAR 2
Total number of eggs	1,632	1,684	2,904	3,326
% Fertility	67,1%	86,8%	88,7%	84,6%
% Hatched of total	49,0%	67,6%	82,6%	81,7%
% Hatched of fertile eggs	73,1%	78,0%	93,1%	96,6%

It is evident that the number of nests and the clutch sizes depend on both the size and maturity of the females, as well as factors such as enclosure design, weather conditions, diet, sex ratios, available nesting sites, stress levels, and to a large degree management regimes. It certainly does not appear as though the presence of visitors has any influence on laying.

Fertility may also be influenced by the factors just mentioned. Hatchability, on the other hand, could be influenced by egg quality and the collection and handling of the eggs as well as incubation.

An analysis of egg yield and female productivity is summarised in figure 5.

Figure 5.

	UNIT A		UNIT B	
	YEAR 1	YEAR 2	YEAR 1	YEAR 2
Hatching yield per laying female	18,18	24,76	38,68	43,82
Female productivity index	5,88	8,38	28,89	32,73

The hatchling yield per female relates only to the females that produced eggs whereas the female productivity index is a reflection of the number of hatchlings produced when compared with the total number of mature females housed in the unit.

Hatchling data was only available for Unit A and their lengths varied from 26,5 cm to 30,2 cm with a mean length of 28,1 cm. Hatchling weights varied from 42,7 grams to 61,7 grams with a mean weight of 54,9 grams. These hatchlings are much smaller and weigh less than those produced in Unit B.

DISCUSSION

Sexual maturity in the Nile crocodile is attained at the age of twelve to fifteen years when the females are about 2,5 m in length. Even though females as young as seven years of age, sometimes not even two metres in length, may produce eggs, many of these eggs are not viable and hatchlings from such eggs are very small. The mortality rate amongst such hatchlings is very high.

From the literature it appears that there is great variation in clutch sizes, with anything from 14 to 95 eggs per clutch being reported. The average number of eggs per clutch also varies quite considerably, from 33 to 45 or as many as 60,4 to even 63. Most authors, however, consider the average to be in the region of 54 eggs per clutch.

In Unit A the number of eggs per clutch ranged from 8 to 66 with an average of 37,09 in the first season and 36,61 in the second season. The range in Unit B was from 3 to 79 eggs with an average of 46,84 in the first season and 53,65 eggs in the second season. The larger number of eggs per clutch laid in Unit B can be contributed to the fact that the females there are larger and more mature than those in Unit A.

The eggs produced in Unit A were quite similar in measurements and weights when compared to the literature. Although sufficient data is not available for Unit B, it is known that the eggs laid there were much larger and weighed considerably more.

Hatchling sizes also compared favourably with those reported in the literature with a range of 26,5 cm to 30,2 cm (mean 28,1 cm) in Unit A. Their weights varied from 42,7 grams to 61,7 grams with an average weight of 61,7 grams. These hatchlings were also much smaller than those hatched at Unit B.

Fertility was quite poor in Unit A in the first season (67,1%) but improved considerably by the next season as the females matured. In fact, fertility in the second season in Unit A compared very favourably with the two seasons in Unit B. Hatchability of fertile eggs, on the other hand, was much better in Unit B during both seasons. One may ask the question of whether this was purely as a result of management or did the fact that the females in Unit A were barely sexually mature also play a role.

The hatchling yield per laying female clearly indicates that the females in Unit B were more productive. In fact, they produced nearly twice as many hatchlings per laying female as those in Unit A over the two seasons.

The female productivity index is, however, of greater importance to the producer. Here we look at the number of hatchlings produced per female, considering all mature females in the units, whether or they laid eggs or not. From this index we see that the female productivity on Unit A is a mere 5,88 hatchlings per female in the first season and 8,38 in the second year. The same figures for Unit B are considerably better with 28,89 hatchlings per female in the first season, improving to 32,73 in the second season.

From this it is evident that large, mature females are more productive than their younger counterparts and the fact that many of the females in Unit B were mature when captured from the wild does not seem to have any adverse effect on their reproductive abilities. The larger, more mature females in Unit B produced more eggs per clutch and the hatching rate of their eggs was much better than the results experienced in Unit A. More than 74% of Unit B's females laid during the two seasons compared with less than 34% of the females laying in Unit A.

Record keeping on a commercial crocodile is of vital importance and the producer must know which females are laying and what results are achieved with such eggs. Should the owner of Unit A wish to produce 5,000 hatchlings per season with a female productivity index similar to that experienced to date, he would have to maintain in the region of 600 mature females. Unit B, on the other hand, would need about 150 females of the same age and quality of those presently maintained if 5,000 hatchlings are required from them.

The cost implications of this should be clear to the commercial crocodile farmer.

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SEASONAL CHANGES OF SPERM MORPHOLOGY AND REPRODUCTIVE TRACTS OF *CROCODYLUS SIAMENSIS*

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Successful breeding of crocodilians in captive require through knowledge of reproductive biology. The basic-annual reproductive cycle of fresh-water crocodile (*Crocodylus siamensis*) has not been worked out. The present studies were designed to compare the morphology of reproductive tracts and sperm of crocodile in breeding and non-breeding season. Ten matured crocodiles were sacrificed in winter, summer and rainy season. Sperm from 3 parts of the epididymis were aspirated by 18-gauge needle. The electroejaculation for semen collection was done in breeding season. Testis, epididymis and spermatozoa were processed for histological studies. Spermatogenesis begins in winter (breeding season). There were a rapid increase in spermatocytes, spermatids, and numerous spermatozoa was densely packed in the seminiferous tubules. The weight of testes are rapidly 10 folds increase in winter compared to non-breeding season. Leydig cells appeared inactive in non-breeding season. Some spermatozoa still remained in caudal part of the epididymis. The epithelium of all 3 parts of epididymis were active in breeding period. The spermatozoa of both breeding and non-breeding season were not different in morphology. The results indicated that reproductive activities of the crocodile testes coincide in all three seasons. To elucidate the temporal cyclicity relationship throughout the year and to determine when the cycle actually begin, blood samples and correlated organs may frequently collect for interpretation of changes in hormonal levels and tissue histology.

Key Words : *C. siamensis*, seasonal change, spermatozoa, crocodile

INTRODUCTION

Breeding of reptiles requires skill and it is necessary to understand the relevant reproductive data. The testicular germinal epithelium changes in *Rana temporaria* have shown to be sensitive to the seasonally hormonal changes, being least sensitive during the autumn and winter and most sensitive during spring (1). In the majority of fish and amphibian species, fertilization occurs externally. In contrast, in reptiles, birds and mammals, fertilization is internal and semen must be deposited in the female reproductive tract. Male and female reproductive cycles are not synchronized in temperature zone reptiles. Artificial insemination is often attempted higher in the female tract than occurs naturally in fowl (2), cow (3), ewe (4), goat (5) because of evidence that fertility is improved, especially when the semen has been stored. This storage is thought to occur in female reproductive tract (6). The survival of sperm and mechanism of sperm storage in male or female reproductive tract, where the cells may retain their viability for as long as 5-7 months is still unsolved problem (7,8). During February, the testes of male Alligator mississippiensis start to enlarge and become larger by April (9,10). Immature animals show no discernible seasonal increase in testicular weight and no increase in size, thickness and convolution of the ductus deferens and have extremely low level of plasma testosterone (10). There is no evidence for over winter sperm storage in the males. Artificial insemination in the alligator was reported by Cardeilhac (11). In the family crocodylidae, the two species Crocodylus porosus and Crocodylus siamensis are common in Thailand. However C. siamensis is more interesting because this species is less harmful and has become an endangered species in nature. The management of wild populations of crocodilians and successful breeding of crocodilians in captivity require through knowledge of reproductive physiology and an understanding of the environmental factors regulating their breeding cycles. Therefore, the purposes of the present studies were designed to investigate the reproductive cyclicity of male crocodile on the morphology of reproductive organs, and to study the ultrastructure of epididymal and ejaculated crocodile spermatozoa.

MATERIALS AND METHODS

Male crocodiles (Crocodylus siamensis) were captured from Samutprakarn Crocodile Farm and Zoo in Samutprakarn province. The weight were about 30-50 kg. They were kept in the pen and the ambient temperatures were 20-35 °C. Because crocodile is a seasonal breeding animal, the breeding season is in winter (November to February). In summer (March to June) and rainy season (July to October) are out of season. Semen that was obtained by electroejaculation during winter by using a rectal probe, lubricated with K-Y jelly and inserted approximately 20 cm into the cloaca. Electrical current was generated by a generator in 4 series, each series of 20 pulses of 8 to 25 volts with a range of 25 to 250 mA. Electrical current was varied from animals to animals. Ejaculated semen was examined for the presence of spermatozoa by a light microscope. The crocodiles were sacrificed each season. The epididymal spermatozoa were obtained from caput, corpus and cauda epididymis part by using 18 gauge needle withdrawn as much semen as possible. Spermatozoa were concentrated by centrifugation and resuspended in 2.5% glutaraldehyde in 0.1 M cacodylate buffer (pH 7.4) with 2% tannic acid for at least 4 hr. After 3 washes in cacodylate buffer, they were postfixed in 1% Osmiumtetroxide for 1 hr. Dehydration was done through a graded ethanol and followed by propylene oxide twice for 20 min. Infiltration with mixture of propylene oxide and araldite resin overnight. The specimen was embeded in the araldite resin, sectioned with a Sorval MT-2 ultramicrotome and stained with uranyl acetate. The grids were viewed with a Hitachi : HU-11-C TEM.

For SEM, sperm after fixation were suspended on glass coverslips with graded ethanol series. The coverslips were processed under critical point dryer (Hitachi HCP-Z) and coated with gold 1.4 kV, 12 mA (Palaron E-500) for 2.5 min. The photographs were taken with Hitachi S-430 SEM.

Testes and three parts of epididymis from sacrificed crocodiles were processed for routine histological studies in paraffin sections and stained with haematoxylin and eosin.

RESULTS

The testis of crocodile in breeding season is greatly enlarged. The weight of one testis is range from 80 to 90 g. The size of a testis is 10 to 15 cm long, 5 cm wide and 4 to 5 cm in thickness. While it is decrease approximately 10 times in weight in non-breeding season. The size of non-breeding testis is 4.5 to 5 cm long, 1 to 1.5 cm wide and about 1.5 cm in thickness. The testis from LM study reveals that they are in active phase in winter. The testis is largely made up of closely packed large seminiferous tubule (300 to 480 µ in diameter). The spermiogensis is found to pass through various stages (Fig. 1A), and spermatozoa are filled in the lumen. Leydig cells are observed among the seminiferous tubules. They are quite active in breeding period and less active in non-breeding (Fig. 1C,1D). In non-breeding testis, the tubules are quite small (100 to 150 µ in diameter) and compose of only a few layers of germ cells comparing to in breeding season testis (Fig. 1B).

Three parts of epididymis are separated by their locations. The caput, corpus and cauda epididymis (Fig. 2,A-G) are lined with pseudostratified ciliated columnar epithelium composed mainly of the principal cells. The basal cells are at the base of the epithelium. The epithelium is thicker in caput and cauda parts than corpus epididymis. In cauda epididymis the epithelium is folded. All three parts are filled with large sperm mass when they are in breeding season, but sperm mass disappeared in non-breeding season.

By SEM study, (Fig. 3) the spermatozoa of Crocodylus siamensis is a vermiform appearance about 92 to 110 µ long. It consists of the head, midpiece, principal piece and endpiece. The head is 20 to 24 µ long by 1 to 1.5 µ wide at the largest diameter. Midpiece is shorter than the head region and surrounded by a distinct surface labulations of mitochondria (Fig. 3D). It is approximately 5 to 6 µ from the connecting piece to the beginning of the principal piece. The tail region (principal and end piece) is longest of all the regions, the length is about 65 to 80 µ. It was demarcated from the midpiece by a constriction as shown in Fig. 3B.

The spermatozoa obtained from epididymis of breeding season crocodiles are not differ from that obtained from non-breeding season. Although only a few spermatozoa can be observed in the beginning of summer. The spermatozoa taken from those three parts of the epididymis contains a cytoplasmic droplet (Fig. 3A,3B, 3C). The cytoplasmic droplet in crocodile is spherical with diameter of approximately 3 µ and are found at different locations from the posterior half of the head, around the neck, the connecting portion and along the midpiece. The surface of the cytoplasmic droplet is consisted of many small spherical lobulated structures or only two or three lobules. Some spermatozoa shows detached cytoplasmic droplet.

DISCUSSION

Reproductive cycle of crocodile was synchronized with seasonal changes and surrounding environment. Annual reproductive cycle of A. mississippiensis in Louisiana has been studied by many investigators (12,13,14). During February, the testes of alligators start to enlarge, they are larger by April/May and the testicular regression begins in mid-June through July (9,10). The present result shows very active spermatogenesis in mid-December. The large diameter seminiferous tubules in breeding season consist of primary spermatocytes, secondary spermatocytes, numerous spermatids and spermatozoa. It causes the increase of germ layers in the tubules by the influences of gonadotropins. Alligators exhibited a marked response to mammalian LH-RH (15) while male turtle, Chrysemys picta, on the other hand, showed no increase in gonadotropin or testosterone after injections of LH-RH. The leydig cells in the crocodile indicate the high activity by LH. It should be annualy compared of the plasma testosterone levels with the spermatogenic activity and also the association of mating behavior. Mesner et al., 1993 (16) found that leydig cells in turtle are active during the phase of maximum testicular enlargement and are in fact the major source of testosterone. Leydig cells in turtle have potential to become steroidogenic at any time of the year (17). During testicular regression in crocodile, the diameter of seminiferous tubules decreases. It has a thin wall of tubule and has only 4-5 layers of epithelium and contains fewer spermatozoa in the lumen. The interstitium is composed mainly of connective tissue. The same evidence was observed in alligators by Lance 1983 (10). The leydig cells of the present studies are observed to be mixed of some active and the majority of inactive cells among the inactive seminiferous tubules. It is possible that the crocodile mating behavior could be stimulated in non-breeding season correlated with the function of the remain active leydig cells. It is known in leydig cells of turtle to contain tubular or SER at all times (20). The mechanism of gonadal regression is still unknown. The epithelium of all three parts of the epididymis reveals active function during spermatogenesis. The lumen of tubules containing sperm is frequently enlarged, and the sperm masses remain separate from the wall. The epididymis is the usual site of sperm storage in postnuptial reptiles (18,19).

Spermatozoa of both breeding (in winter) and non-breeding season (especially in beginning of summer and late rainy season); when degeneration of spermatogenic epithelium and in a regeneration of the same, are not different in morphology. The long and narrow of the sperm head is slightly curved like turtle sperm and similar to that of birds. The study of the semen picture is of fundamental importance in the diagnosis of male sterility. In the field of reproductive physiology have reported of several types of abnormal spermatozoa and certain type of immature spermatozoa. One such type of immature spermatozoa is that having a cytoplasmic droplet. Rodolfo (21) reported the occurrence of sperm with droplets in the semen of boars experiencing even moderate sexual activity. Lagerlof (22) reported that a large number of these immature spermatozoa in bulls occurs both the beginning of degeneration of the epithelium. Green (23) described the presence of vesicular structure at the anterior end of the ejaculated ram spermatozoa. Roa and Hart (24) and Baylor, Nalbandov, and Clark (25) reported finding the cytoplasmic cap on ejaculated spermatozoa, as well as on sperm from the testes and epididymis obtained from bull. The cytoplasmic droplet is closely associated with the crocodile spermatozoa from both epididymis and ejaculation in the present study and are found at different locations. In all probability, representing successive stages in the descent of the drop seemed to become organized into a compact cytoplasmic droplet. Mature spermatozoa and the sperm with cytoplasmic droplet can be found in the breeding season. Of non-breeding period around the winter the amount of sperm with cytoplasmic droplet are observed. It may be due to the spermiogenesis and mating behavior of multi-egg clutches of crocodile. It is well known that in temperate species, spermatogenesis and oogenesis occur at separate times of the year (19,26). For <u>C. siamensis</u>, the peak times of egg laying vary from April to July. It is generally thought that <u>C. siamensis</u> suspected of having two breeding seasons. The immature spermatozoa with cytoplasmic droplets observed could be ejaculated at the time when temperature and photoperiod appear to be optimal. The double clutching has also been reported for some C. *palustris* and is suspected in some C. *porosus* (27). The length of time that sperm remain viable within the female reproductive tract is unknown. Stored sperm are capable of successful fertilization, as well as newly inseminated sperm. Storage of sperm within the oviduct of avian (28), and lizard (29,30) resulting in the production of their respective gametes at different times of the year. Sperm may be stored for as few as 5-6 days in the horse (31) to 7 years in the snake *Acrochordas javanicus* (32). Presumably survival involves special morphological adaptations of the spermatozoa, the uterus or both have not been explored in C. *siamensis* crocodile. It would be interesting to study the ultrastructure of the head, acrosome status, mitochondria and the axonemal arrangenment in epididymal sperm, If the sperm could be stored in the uterine tube, what would it look like. Experiments to test this possibililty are currently performed.

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Fig. 1. Seminiferous tubule in the testis of C. siamensis in breeding season (A) and non-breeding (B) (x400). Note the size of tubules and germ cells. C and D are the correlated leydig cells of A and B (x1000). L = leydig cells

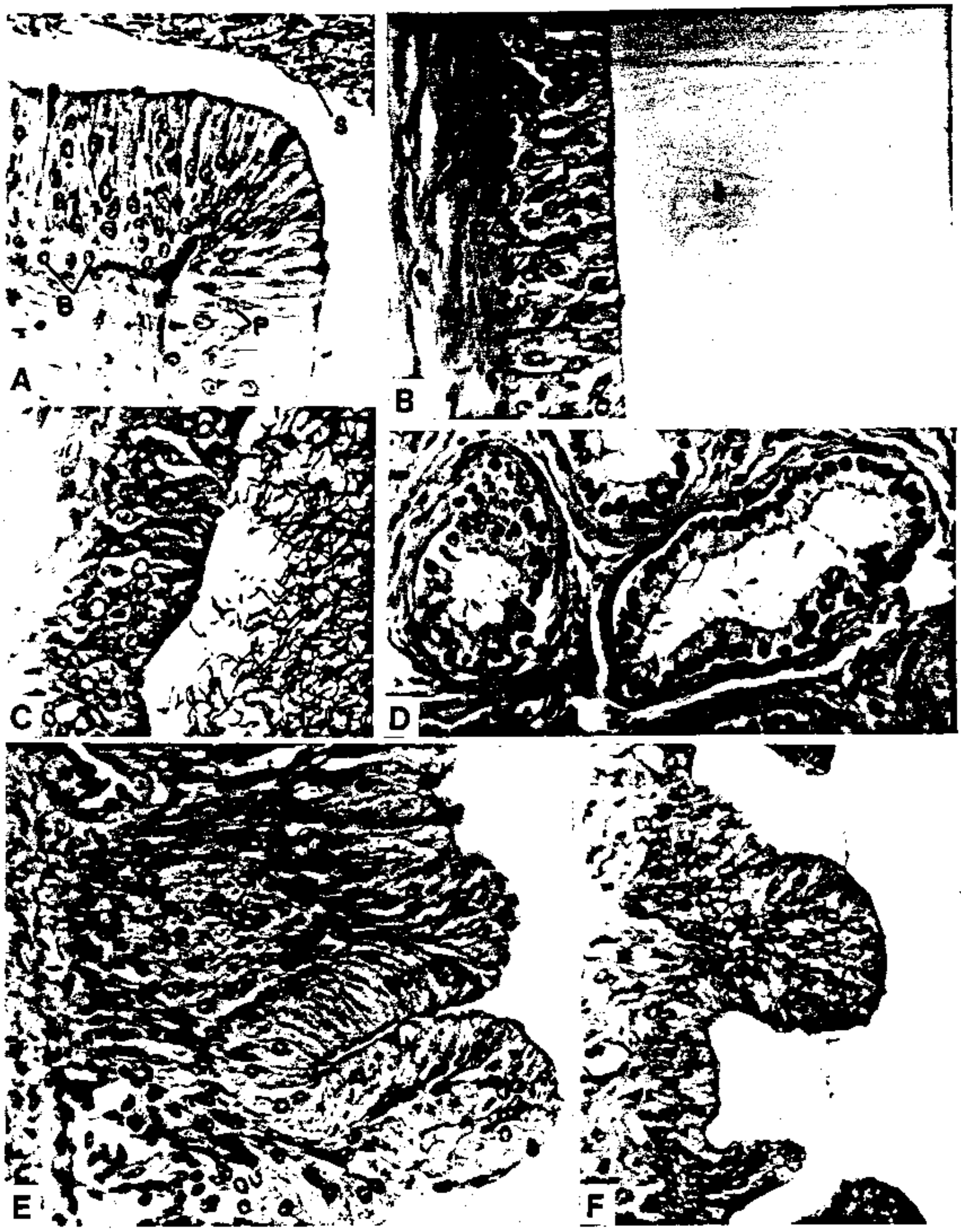

Fig. 2. The epididymis of <u>C. siamensis</u> : caput (A), corpus (C) and cauda (E) of in breeding season compare with those of non-breeding epididymis: caput (B), corpus (D) and cauda (F) respectively. (x400). P = principal cell, B = basic cell, S = sperm mass,

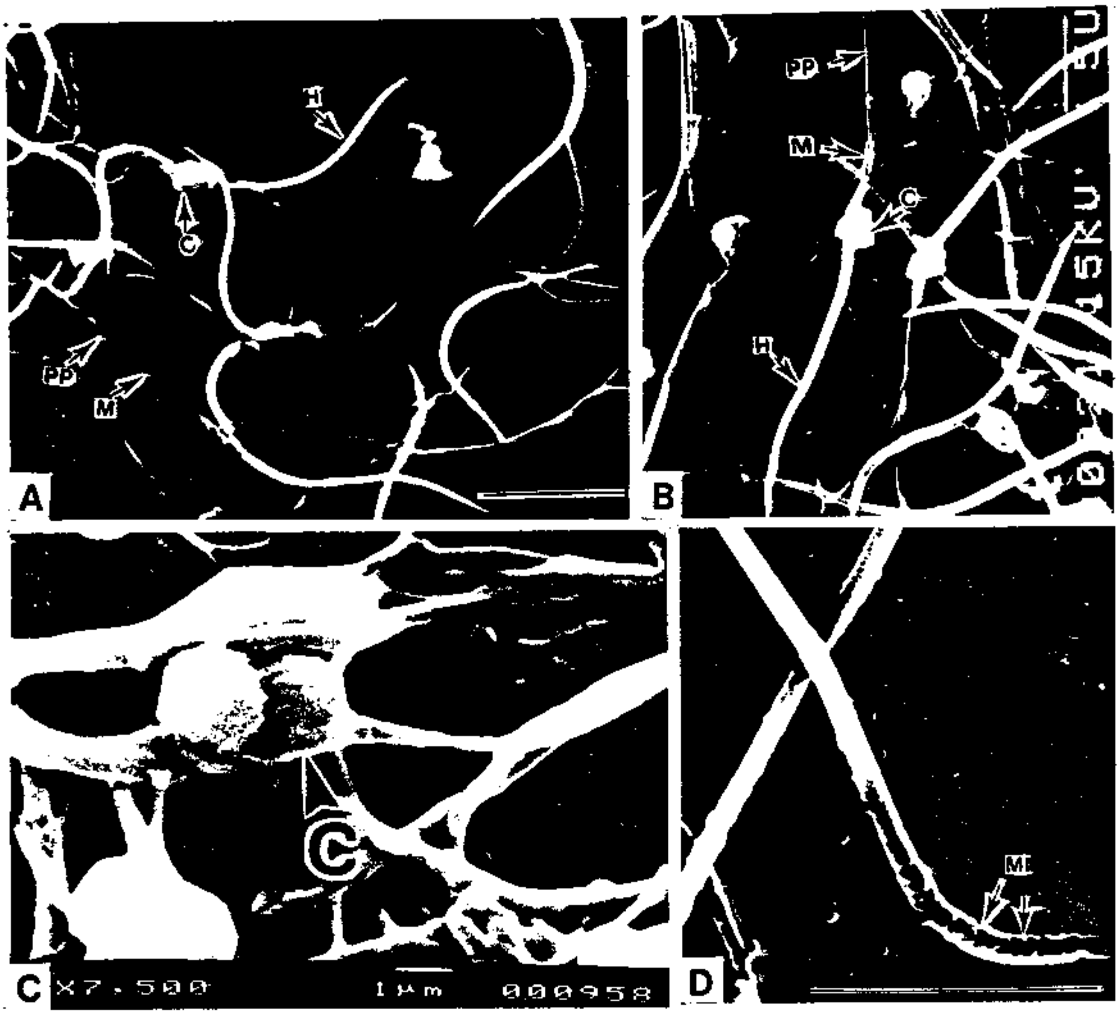

Fig. 3. SEM of the crocodile spermatozoa, from the epididymis (A), Bar = 10 u; from electroejaculation (B). The higher magnification of small spherical lobulated cytoplasmic droplets (C), and lobulated mitochondria in midpiece region (D), Bar = 5 u; H = head, M = midpiece, pp = principal piece and C = cytoplasmic droplet.

Hematology and Serum Chemistry Values of Captive False Gharial (*Tomistoma schlegelii*) in Thailand

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Abstract

This study was conducted to further strengthen knowledge of hematology and serum chemistry of false gharial (*T. schlegelii*), the endangered extremly long snouted crocodile. Blood samples collected from 10 healthy, captive false gharials with a male : female ratio of 1.1, were analyzed for hematological and biochemical values and reviewed as followed hematocrit 15.2%, hemoglobin concentration 7.1 mg/dl; erythrocyte count $0.34x10^6/mm^3$; leukocyte count $4.35x10^3/mm^3$, and heterophil were present in largest proportions (64.9%); thrombocyte count $14.10x10^3/mm^3$; thrombocyte per 100 white blood cells 96.7%. Red cell indicies included MCV, MCH, MCHC were 445.6 fl, 207.2 pg and 46.4 g/dl, respectively. Blood cells dimension have been studied. Significant statistical differences between the male and female groups were only detected for MCHC. Analyses of 17 blood chemistry values were determined. Female false gharial exhibits values of triglyceride, calcium and phosphorus greater than male group ($P<0.05$).

Introduction

False gharial or false gavial (*Tomistoma schlegelii*), the extremly long slender-snouted crocodile, is an endangered animal that occurs in the lakes, swamps and freshwater rivers of Malay peninsula, southern Thailand and the islands of Sumatra and Borneo, Kalimantan and Java (Humphrey and Bain 1990, Suvatti 1967, Stell 1989, Grenard 1991).

Knowledge of normal blood values of crocodiles is useful in evaluating their health status, in monitoring the course of a disease as well as the responding of a prescribed treatment or understanding the physiology of crocodile. No study on the characteristics of blood has been carried out in the Tomistoma. This study was conducted to strengthen knowledge of hematology and blood chemistry of captive false gharial, *T. schlegelii*, in Thailand.

Materials and Methods

Blood was obtained from 10 adult captive false gharials (5 males, 5 females) from Sampham crocodile farm, Sampham distric, Nakhon Pathom province, Thailand. Average size of these false gharials are 3.5 meters. Blood samples were Collected from the post-occipital venous sinuses and kept in tubes either containing EDTA or without anticoagulant. Hematological and biochemical parameters studied and methods employed were as follows.

Hematocrit (Hct) was determined according to standard microcentrifugation method. Blood cell count, including erythrocyte (RBC), leukocyte (WBC) and thrombocyte were taken using Natt and Herrick's solution (Natt Herrick 1952) and counted using hemocytometer chamber. The hemoglobin concentration (Hb) was determined by cyanmethemoglobin (Drabkin and Austin 1935). From data on RBC count, Hct and Hb, mean corpuscular volume (MCV), mean cell hemoglobin content (MCH) and mean cell hemoglobin concentration (MCHC) values were calculated. Thin blood smear were carried out and stained with commercial Dip-Quick$^{(R)}$ stain (Clinical Diagnoties, Ltd., Part., Bangkok, Thailand). Differential leukocytes counts and number of thrombocyte per 100 WBC were observed under 1000x. Erythrocyte, leukocyte and thrombocyte dimensions were measured by ocular micrometer. The erythrocyte cell and nuclear surface were calculated. For biochemical analysis, blood centrifugation and separation of serum were done within 6 hours after samples were collected. Serum sodium potassium and chloride were estimated using ion selective electrode electrolyte analyzer (NOVA Biomedical, FL, USA). The remaining serum biochemistry values were determined on a computer process-controlled autoanalyzer (ABBOTT SPECTRUM$^{(R)}$ system) using clinical reagents (ABBOTT laboratories, TX, USA). In each parameter investigated, means standard deviations (SD) and range were calculated. The statistical significance between means was tested by t-test. For each variable significance was accepted at P<0.05.

Results and Discussion

This is the first report on hematological and biochemical values in false gharial. Table 1 shows hematological results obtained from determination of whole blood samples in male and female. While the number of crocodiles sampled was small, significant statistical difference between male and female groups were only detected for MCHC (P<0.05).

The Hct of false gharials in the present study was less than the PCV of *Alligator mississippiensis* (20%), *Caiman sp.* (26%), *Crododylus acutus* (26%) and *Crocodylus niloticus* (35%) but higher than PCV of *Crocodylus siamensis* (14%). The concentration of hemoglobin (7.1 g/dl) in our study are similar to those found in *C. siamensis* and *C. mississippiensis*. These values were lower than Hb of *Caiman sp.* and *C. acutus* (Sypek and Borysenko1988, Siruntawineti et al. 1992). The values of blood cell count including RBC, WBC and thrombocytes of *T. schlegelii* were lower when compare with *C. siamensis* (Siruntawineti et al. 1992). For differential leukocyte count (Fig.1), a large proportion (65%) of leukocytes in peripheral blood were heterophils with proportion of lymphocytes, eosinophils and monocytes (34%, 9% and 4% respectively). Although lymphocytes are the most numerous leukocytes in *C. niloticus* (Pienaar 1962), we found a higher number of heterophils than lymphocytes in *T. schlegelii*. Our previous study (Siruntawineti et al.1992) of *C. siamensis* also showed a much higher number of heterophils than lymphocytes.

The erythrocyte dimension and surface area are presented in Table 2. For the dimension of thrombocytes and leukocytes are given on Table 3 and 4, respectively. Cell length and cell width of *T. schlegelii* were in the range of these values in crocodilia (Sypek and Borysenko 1988) :- cell length 16-17 μm, cell width 9-10 μm. Nevertheless we found the nuclei of erythrocyte are almost round (length 4.85 μm, width 4.45μm) and N/C ratio was lower than this found in *C. siamensis*, *C. nilolicus* and *Caiman crocodilus* (Siruntawineti et al. 1992, Pienaar 1962). The thrombocyte per 100 WBC and its dimensions of *T. schlegelii* are similar to those in reptiles (Sypek and Borysenko 1988) (25-350 Thrombocytes/100 WBC and length 8-16 μm, width 5-9 μm). In Table 4., monocyte is the largest leukocyte while small lymphocyte is the smallest leukocyte.

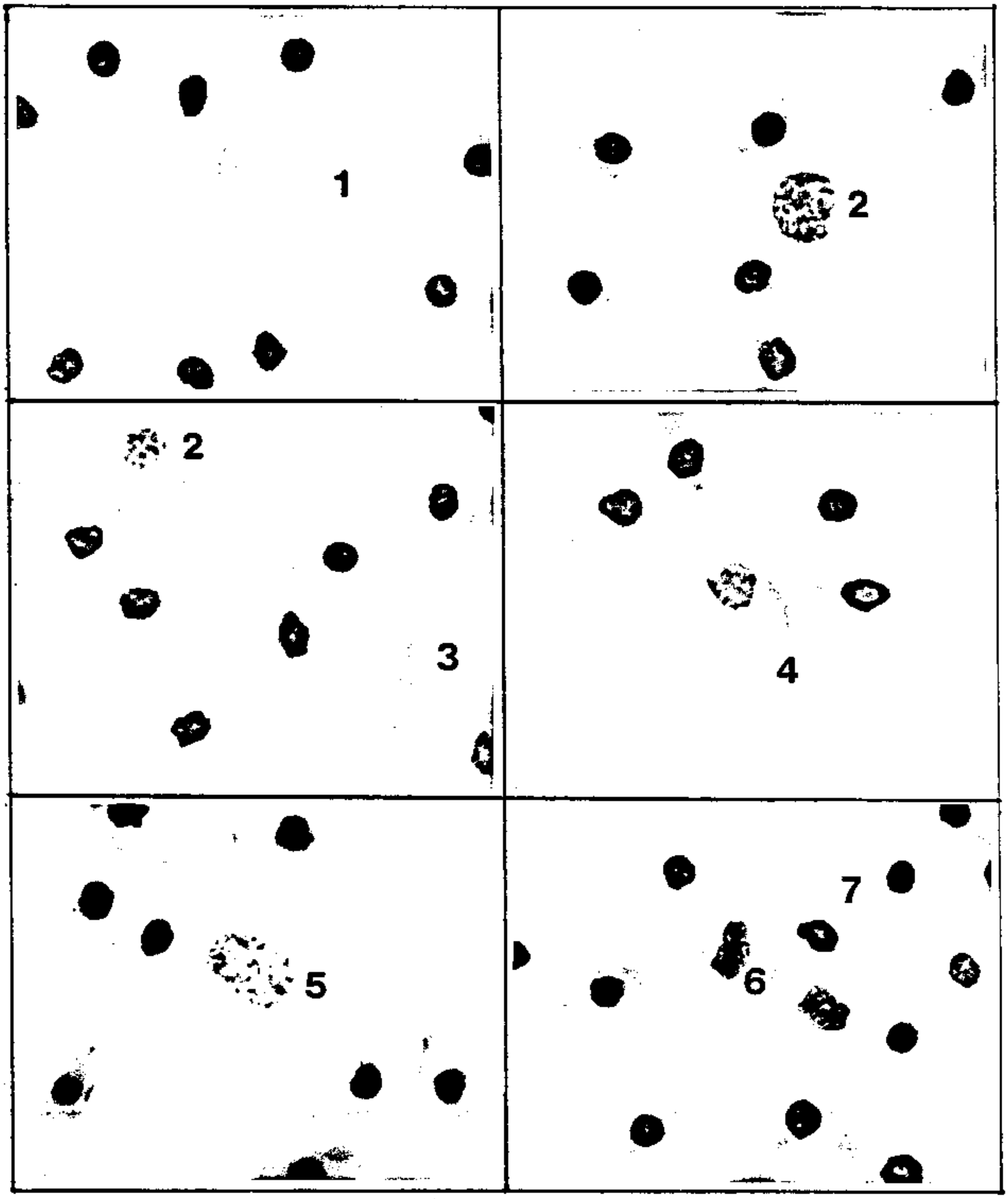

Fig 1. Blood cells of false gharial (*Tomistoma schleglii*). 1000X.

1. Heterophil; 2. Small lymphocytes; 3. Large lymphocyte;

4. Eosinophil; 5. Monocyte; 6. Thrombocytes; 7. Erythrocytes.

Table 1. Hematologic values of false gharial *(T. schlegelii)*

Parameters	Male (n = 5)	Female (n = 5)	Total (n = 10)
Erythrocytes ($10^6/mm^3$)	0.35±0.09[a]	0.33±0.05	0.34±0.08
	(0.24-0.51)	(0.26-0.38)	(0.24-0.51)
Hematocrit (%)	15.4±5.2	15.0±2.6	15.2±4.1
	(10.0-23.0)	(11.0-19.0)	(10.0-23.0)
Hemoglobin (g/dl)	7.5±2.7	6.7±1.4	7.1±2.2
	(4.8-11.3)	(4.6-9.0)	(4.6-11.3)
MCV (fl)	429.9±57.0	461.3±55.4	445.6±55.5
	(360.7-512.8)	(400.0-520.5)	(360.7-520.5)
MCH (pg)	207.7±32.6	206.8±34.8	207.2+31.8
	(175.4-256.4)	(174.7-245.2)	(174.7-256.4)
MCHC (g/dl)*	48.2±1.6	44.6±2.3	46.4±2.6
	(45.8-50.0)	(41.8-47.1)	(41.8±50.0)
Leukocytes ($10^3/mm^3$)	3.80±1.50	4.90±1.53	4.35±1.61
	(2.00-6.50)	(2.50-7.00)	(2.00-7.00)
Differential leukocyte count			
Heterophils (%)	68.6±8.7	61.2±6.3	64.9±8.4
	(52-76)	(50-68)	(50-76)
Lymphocytes (%)	22.4±4.6	25.8±2.9	24.1-4.2
	(18-31)	(22-30)	(18-31)
Eosinophils (%)	6.4±2.9	10.6±3.1	8.5±3.6
	(3-11)	(6-14)	(3-14)
Monocytes (%)	3.8±2.5	4.0±3.6	3.9±3.1
	(0-7)	(1-11)	(0-11)
Basophils (%)	-	-	-
Thrombocytes ($10^3/mm^3$)	13.10±2.96	15.10±2.56	14.10+2.94
	(8.00-15.50)	(11.50-19.50)	(8.00-19.50)
Thrombocyte/100 wbc (%)	95.6±11.9	97.8±18.7	96.7+15.7
	(77-107)	(76-131)	(76-131)

[a] mean ± SD (range); n = size of sample ; *$p < 0.05$

Table 2. Erythrocyte dimensions and surface area of *T. schlegelii*, n = 25

Parameters	Mean ± SD	Range
Cell length (μm)	16.32±2.46	10.93-19.00
Cell width (μm)	9.03±1.08	7.60-11.40
Cell ratio L/W	1.83±0.34	1.28-2.50
Surface area of cell (μ^2)	116.18±23.99	73.40-153.11
Nucleus length (μm)	4.85±0.48	3.80-5.70
Nucleus width (μm)	4.45±0.56	2.85-5.23
Nucleus ratio L/W	1.11±0.19	0.80-1.67
Surface area of nucleus (μ^2)	16.96±3.01	10.63-23.41
N/C Ratio[a]	0.15±0.04	0.10-0.23

[a] N/C = Nuclear surface/Cell surface

Table 3. Thrombocyte dimensions of *T. schlegelii*, n = 27

Parameters	Mean ± SD	Range
Cell length (μm)	8.57±1.95	6.65-14.25
Cell width (μm)	5.88±0.81	4.75-7.60
Cell ratio L/W	1.49±0.46	1.00-3.00

Table 4. Leukocyte dimensions (μm) of *T. schlegelii*

Leukocytes	No. of Cells	Mean ± SD	Range
Heterophil	25	14.44±1.69	9.50-17.10
Lymphocyte			
small	25	9.50±1.40	7.60-12.35
large	21	13.17±1.05	11.40-15.20
Eosinophil	25	10.93±1.25	8.55-13.3
Monocyte	7	16.15±1.45	14.25-18.05

Table 5. Serum chemistry values in false gharial *(T. schlegelii)*

Parameters	Male (n=5)	Female (n=5)	Total (n=10)
Glucose (mg/dl)	78.2±10.6[a]	72.3±8.6	75.3±10.1
Creatinine (mg/dl)	0.17±0.07	0.25±0.09	0.21±0.09
Uric acid (mg/dl)	2.9±1.8	3.4±1.6	3.2±1.7
Protein, total (g/dl)	3.2±1.5	4.2±1.2	3.7±1.4
Bilirubin, total (mg/dl)	0.46±0.16	0.48±0.12	0.47±0.14
Conjugated (direct)	0.17±0.09	0.19±0.10	0.18±0.09
GOT (U/L)	19.5±3.5	16.4±4.0	18.0±4.1
GPT (U/L)	22.7±12.4	17.8±3.6	20.2±9.4
Alkaline phosphatase (U/L)	13.2±8.9	22.3±9.5	17.8±10.3
LDH (U/L)	386.7±202.9	465.7±125.1	426.2±173.1
Cholesterol (mg/dl)	106.2±39.8	114.8±14.6	110.5±30.3
Triglyceride (mg/dl) *	41.2±5.4	51.3±8.8	46.2±8.9
Calcium (mg/dl) *	8.7±1.7	11.6±2.4	10.2±2.5
Phosphorus (mg/dl) *	2.6±0.7	4.2±1.4	3.4±1.4
Sodium (mEq/L)	154.0±3.3	157.8±4.1	155.9±4.2
Potassium (mEq/L)	4.4±0.7	4.4±0.3	4.4±0.6
Chloride (mEq/L)	119.8±1.9	120.2±2.3	120.0±2.1

[a] mean ± SD ; * $P < 0.05$

Values for serum biochemical measures are presented in Table 5. Differences between sex, were found in triglyceride, calcium and phosphorus ($P<0.05$) which in female exhibits those values greater than in male. As far as we know, there is no study that deals with any blood parameters of the Tomistominae or Gavialinae, therefore no comparisons with previous data are possible. Nevertheless we can see that mean glucose values in *T. schlegelii* were similar to those in *A. mississippiensis* but lower than in *C. acutus*. In this study, uric was similar to the previously published for *C. siamensis* (3.9 mg/dl) feeding with mixed diet and slightly higher when compared those in *A. mississippiensis* (2.5 mg/dl). Serum concentration of total protein was lower in false gharial when compared with *A. mississippiensis*, *Caiman sp.* and *C. niloticus*. There spective concentrations of calcium, sodium, potassium and chloride were higher than in *A.mississippiensis* and *C. acutus*.

Acknowledgement

We thank Sampham crocodile farm Co., Ltd.for their supporting of specimens and other necessary facilities.

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SOMATIC INFLUENCE OF ANABOLIC TREATMENT IN CAIMAN C. YACARE

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ABSTRACT

Thirty caimans (Crocodilus yacare) two years aged were treated subcutaneously with anabolics (nandrolone phenproprionate) in order to achieve somatic increase, thirty, used as control, received placebo.

The obtained results demonstrated the effectiveness of treatment o weight and lenght gains, and also that anabolic treatment influences the growth in a positive way, even in cold-blooded animals.

The hormonal treatment, made on captive crocodiles breed, in a specialized farm of Mato Grosso do Sul (Brazil), is compatible with normal management.

INTRODUCTION

The Caiman Crocodilus Yacare is one of the two subspecies of the Alligator family that lives in Brazil.

Currently the breeding for commercial purposes of this sub-species is allowed in that country. The caiman is native to a spread geographical area called Pantanal comprising the Southern Mato Grosso (Brazil), Paraguay and Bolivia (Joanen and Mc Nease 1971; Hutton 1987; Matassino and al., 1991; Pelosi and al., 1991).

The above mentioned countries are engaged in the protection and preservation of these species, adopting such measures as banning hunting and also promoting research into breeding methods in order to use only animals in captivity to obtain skins. The breeding of crocodiles could offer a new income source for the local inhabitants.

The skin surface of a caiman is in proportion to its body mass. The growth is in proportion to feeding amount and is influenced by biological, genetic, physiological and pathological parameters characterizing every species and single animal. Also environmental and breeding conditions are in direct relation to the level of organic synthesis.

The interactions between the species' physiological parameters, environmental physioclimatology and feeding habits are stronger in poikiloterms than in other animals for zootechnical production.

The anabolic activities of a number of steroid hormones in warm blooded vertebrates are well known. These hormones and their derivates increase protein synthesis, particularly in the skeletal muscles, so inducing weight gain and their use is becoming widespread in breeding animals of zootechnical interest.

The pharmacological mechanism of anabolic hormones is differentiated. Androgenic hormones, in fact, would seem to act directly on the skeletal, so potentializing the deposit of new proteins, while the primary site of oestrogens seems to be the hypothalamus or anterior hypophysis with an increase of Growth Hormone secretion acting at the level of striated muscles, triggered by the increased secretion of somatomedine.

The aim of this research is to obtain maximum increase in both weight and length of growing caimans using anabolic hormones of synthesis.

The experiment was carried out on a farm at Miranda in the South Mato Grosso, the "Granja Caiman srl" a Company legally authorized by I.BA.MA. (Ministry of the Environment) to breed caimans and other wild species (Law 81-p, 4/4/88).

The entire breeding cycle was monitored with animals' biological cycle developing in captivity from the egg laying phase to, the animals' slaughtering.

Adult males and females were kept in special pools while the growing animals were kept in a closed area and their feeding was monitored.

MATERIALS AND METHODS

Sixty animals, born in the Granja caiman L.T.D.A. in April, 1988 and aged two and half years at time of the trial, were divided into two groups, the first for experimental and the second for control purpose, of 30 animals each.

The animals were tagged on their 2nd vertical tile crest, kept in two separate areas, treated with the same methods and given the same quantities of feed made of cereals and animal proteins, including meat and fish, produced in the farm, in daily amounts of about 5% of their body weight. The trial group was treated with a dose s.c. of 10mg of nandrolone phenpropionate every fifteen days for three months. The control group received a placebo.

At the beginning of the trial, on the 10th of October 1990, all the animals were weighed and measured for lenght to be able to compare the total weight and length of the animals in both groups.

Weighing and lenght measuring were carried out every fifteen days to assess growth before further hormone treatment. The animals were checked for any side effects due to the treatment.

The obtained results were statistically analyzed using variance test. Differences were considered to be significant when $p<0.05$.

RESULTS

Table 1 and graphs A and B show the results expressed as total weights, average weights and weight gains for each phase and for both groups.

The average lengths, reached by the animals in both groups, are shown in table 2 and graph C.

Total weight gain for the animals utilized in the trial and the control groups at the end of the experiment, was 70310 Kg versus 55620 ($p<0.01$) and average weight gains were 4843 Kg versus 2395 ($p<0.01$).

The highest weight gains for animals in the trial and control groups were 6615 versus 4075 ($p<0.01$) obtained halfway through the experiment for both groups (4th weighings at 30 months and 15 days of age).

Graph A shows weight gains for trial and control groups. Both lines coincide except for a short tract between the first and second weighing where the control group curve is reduced.

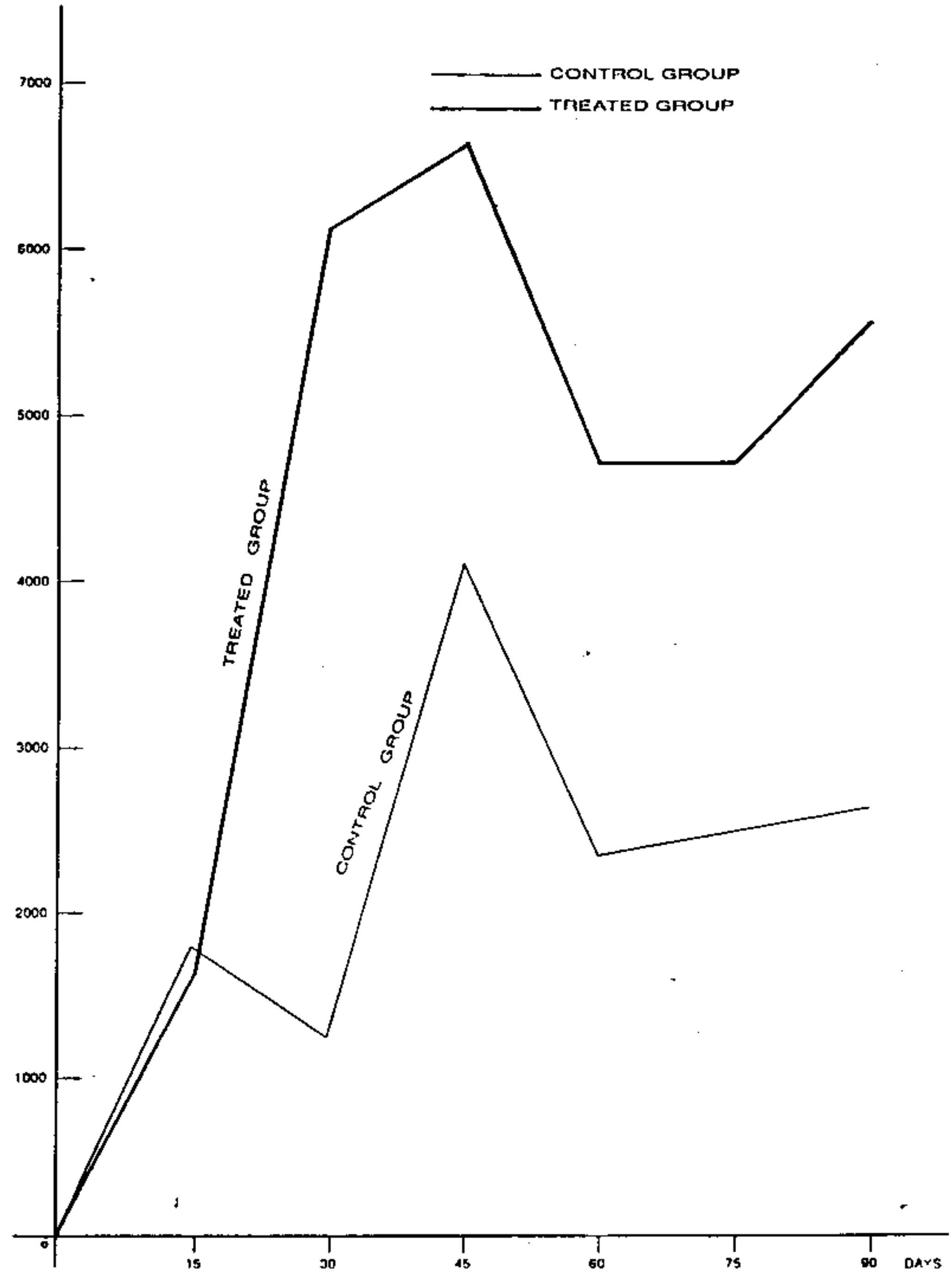
Average length for the two groups at the end of the experiment were 87.5 versus 83.3 ($p<0.05$) and average increases scored 6.1 cm versus 4 cm. ($p<0.05$). The graphs describing the lenght coincide for both trial and control groups.

Tab. 1 *Fortnightly weight and increases (expressed in g). throughtout the experiment*

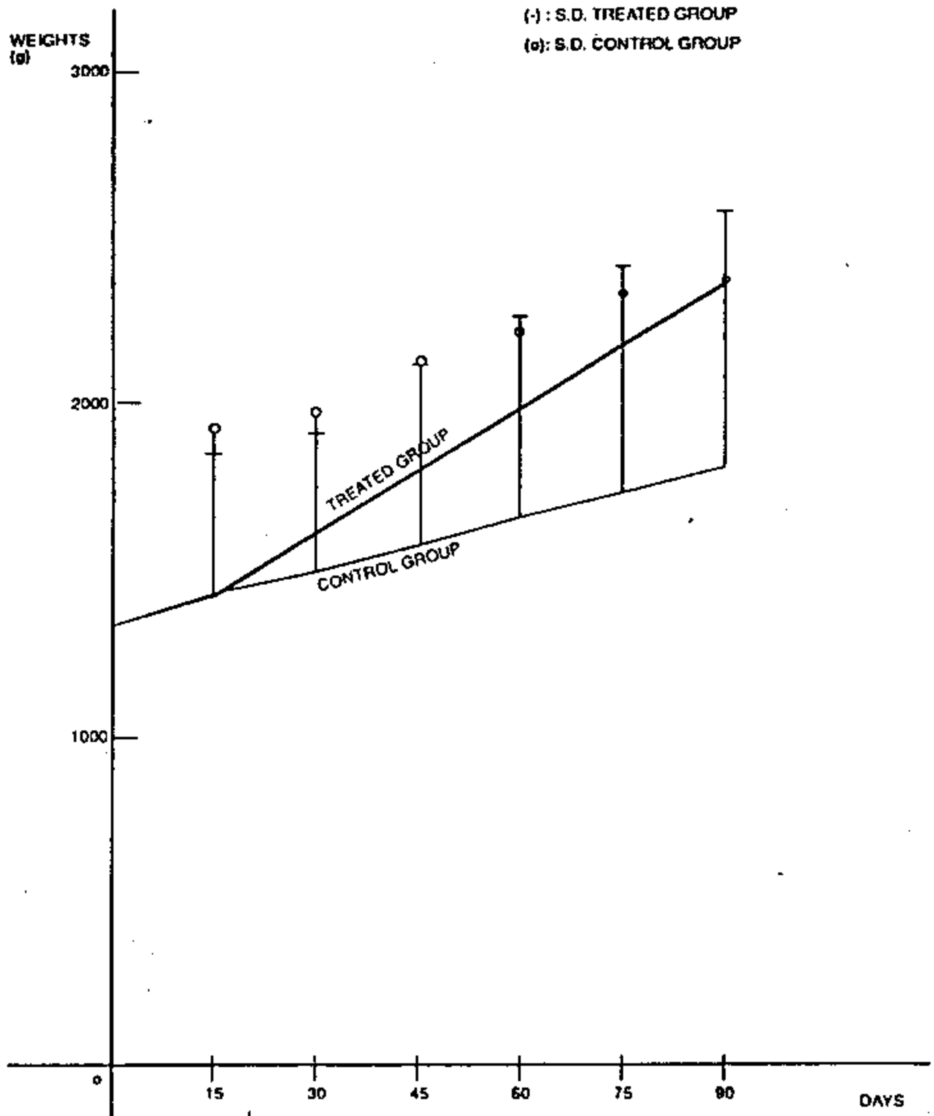
	CONTROL GROUP			TREATED GROUP		
DAY	TOTAL WEIGHT	MEAN±SD	INCREASE	TOTAL WEIGHT	MEAN±SD	INCREASE
0	41.250	1.375±311	/	41.250	1.375±311	/
15	43.000	1.433±497	1.750	42.900	1.430±304	1.650
30	44.205	1.473±496	1.205	48.790	1.626±280	5.890
45	48.280	1.609±496	4.075	55.405	1.846±254	6.615
60	50.590	1.686±488	2.310	60.080	2.002±251	4.675
75	53.030	1.769±495	2.440	64.760	2.158±249	4.680
90	55.620	1.854±495	2.590	70.310	2.343±243	5.550

Tab. 2 *Lentghs and increases (expressed in cm) Throughtout the experiment*

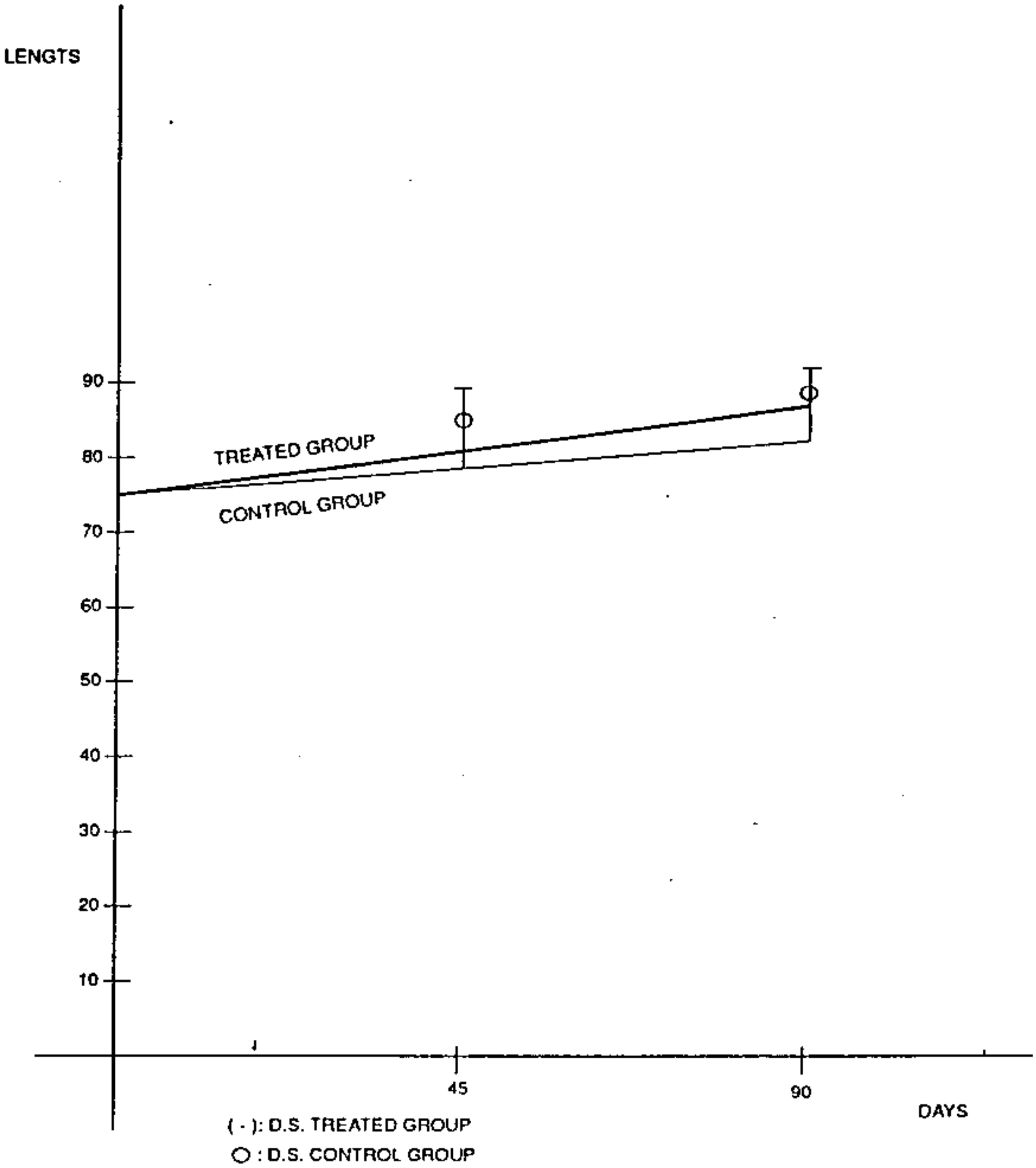
	CONTROL GROUP			TREATED GROUP		
DAY	TOTAL LENGHT	MEAN±SD	INCREASE	TOTAL WEIGHT	MEAN±SD	INCREASE
0	2.259	75.3±6	/	2.259	75.3±6	/
45	2.377	79.2±6	3.9	2.445	81.5±5	6.2
90	2.500	83.3±5	4.1	2.624	87.5±5	6



GRAF. A - FORTNIGHTLY INCREASES (expressed in g) OF BOTH THE CONTROL AND TREATED GROUPS THROUGHOUT THE EXPERIMENT



GRAF. B - FORTNIGHTLY WEIGHTS (expressed in g) OF BOTH THE CONTROL AND TREATED GROUPS THROUGHOUT THE EXPERIMENT



GRAF. C - LENGHTS (expressed in cm) OF BOTH THE CONTROL AND TREATED GROUPS THROUGHOUT THE EXPERIMENT

DISCUSSION AND CONCLUSIONS

Statistically significative differences were observed for both weight and length gains.

As concerns weight gain, the statistically significative differences were evident since the second weighing and were maintained until the end of the experiment, so demonstrating the efficiency treatment. The greater weight gains reported for both groups, halfway through the experiment, for animals of the same ages, indicate this is a favorable period for growth in which a specific pharmacological treatment could give good results for weight gain. The drop observed in the control group curve resulted by a physiological weight decrease due to normal slowing down of the anabolic phase. This drop was completely counteracted by specific hormonal treatment with syntabolin as shown in graph A.

The animals weighing less, in the trial group, at the beginning of the experiment, had proportionally better results from the anabolic treatment because the pharmacological treatment may be able to compensate specific organic deficits.

Reactions to the experimental treatment took longer to appear in the case of lenght increase probably because this biological variable recognizes a prevailing genetic component and is therefore less influenced by drug treatment.

The biological parameter directly and immediately influeced by treatment with nandrolone phenpropionate is the weight. The anabolizing action of syntabolin became clinically evident with an increase in muscle and in body weight probably due to increased nitrogen, potassium and phosphorus retention.

Treatment with anabolics and in particular with nandrolone phenpropionate with a marked anabolic mineral action has positive effects on metabolism inducing increased growth even in cold blooded animals.

It is particularly interesting that the skin of the animals in the trial group became softer only after the second treatment and remained in this condition, compared to that of the control group. We believe that the experiment here described is of particular interest among biotechnological methods applied to the breeding of caimans.

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Growth model of males Spectacled caiman (*Caiman crocodilus*) at Hato Cedral, Venezuela

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Introduction.

Growth studies of crocodiles have been mainly made in captivity elsewhere. In Colombia, Rodriguez (1988 and 1989) proposed a model of growth in caiman (*Caiman crocodilus fuscus*). Rodriguez and Rodriguez (1989) made a similar study but on *Crocodilus acutus*.

In Venezuela, Ribero Blanco (1974) developed a model of growth in *Caiman crocodilus crocodilus*, whose individuals were bred up to ten months old. Gorzula (1978) and Ayarzagüena (1983) proposed growth models in individual reaching up to five and four years old respectively. In the same way, Thorbjarnarson (1990) developed models of growth on females and males captured from natural environment.

In other species, Nichols *et al.* (1976) proposed a growth model on females and males of *Alligator missisipiensis*. Webb *et al.* (1978) and Ramo *et al.* (1992) reported models on natural populations of *Crocodilus porosus* and populations of *Crocodilus intermedius* respectively.

This study proposes a function of growth in males of spectacled caiman from data on harvested individuals of the Programme of Commercial Harvest of *Caiman crocodilus*.

Methods.

Based on size structure proposed by Ayarzagüena (1983), the estimation of age as a function of length was made following the model described by Von Bertalanffy (Jones, 1984).

The sample consisted of 719 males harvested from natural population in 1990 at Hato El Cedral. To these animals were measured the total length, from head to tail. Once these measures obtained, the average total length (Lta), maximum (Ltmax) and minimum total length (Ltmin) were calculated.

The parameters used to define the growth curve are follows:

1) Infinite total length (Ltinf)= 1.05 x Ltmax= 281.4 cm
2) Growth constant was calculated by the following equation:
   k = Z x (Lninf - Ltmin) / (Ltinf - Lta)

where the mortality (Z) is -Ln(S) and survival (S) has a value of 78% per year. Furthermore, longevity (L) was estimated by L= -Ln(0.001) / Z.

Results.

Table 1 shows age at which one male is recruited to one class to another with the following parameters:

Sample= 719 spectacled caiman class IV
Average total length (Lta)= 218 cm
Minimum total length (Ltmin)= 182 cm
Infinite total length (Ltinf)= 1.05 x Lta= 281.4 cm
Survival (S)= 78% annual
Mortality (Z)= -Ln(S)= 0.248461
Growth constant (k) =
Z x (Lninf - Ltmin) / (Ltinf - Lta)
Longevity = -Ln(0.001) / Z
Age for size class =
-Ln(1-(Ltmin / Lta) / k
Minimum length for class II = 40 cm
class III = 120 cm
class IV = 180 cm

Table 1. AGE CLASS FOR SIZE STRUCTURE

	Class II	Class III	Class IV
Minimum length (cm)	40	120	180
Males			
Cedral			
Minimum age	1.09	3.94	7.23
Age class	4	4	19
Masaguaral			
Minimum age	0.58	5	10
Age class	5	5	10
Females			
Only Masaguaral			
Minimum age	0.58	6	------
Age class	5	15	------

As seen, any male that is recruited at class II is on average 1.09 years old, 3.94 years old being at class III and 7.23 years old at class IV. These results are lesser than those reported by Thorbjarnarson (1990). It indicates how the recruitment (R) and the stay (Nt) of males are in average and theoretic terms of the populations under study.

Table 2. RECRUITMENT (Nt) AND STAY (P) FOR SIZE CLASS

	Nt(II)	Nt(III)	Nt(IV)	P(III)	P(IV)
Cedral males	67%	67%	100%	33%	33%
Masaguaral					
males	80%	80%	100%	20%	20%
females	83%	100%	----	17%	---

As seen in Figure 1, results indicates that spectacled caimans at Hato El Cedral grew faster than those reported by Thorbjarnarson (1990). It might be due to various factors:

1) an exclusively compound sample of individuals being at class IV is used in the estimation of parameters involved in the Von Bertalanffy's growth equation.

2) the growth curve obtained by Thorbjarnarson (1990) is based on sample of individuals that influences the whole size categories.

3) at Hato El Cedral, a control of water level on artificial ponds is made. Whereas at Hato Masaguaral spectacled caiman are unfavoured because ponds become very dry in the drought season.

Conclusions.

The growth of spectacled caiman populations seems to be controlled by particular conditions of each population itself been studied. Hence, it is necessary to carry out a study under the same line of research in order to develop an average model.

The methods, that has been initially designed on fish communities, can be used for other population if assumptions of the model are respected.

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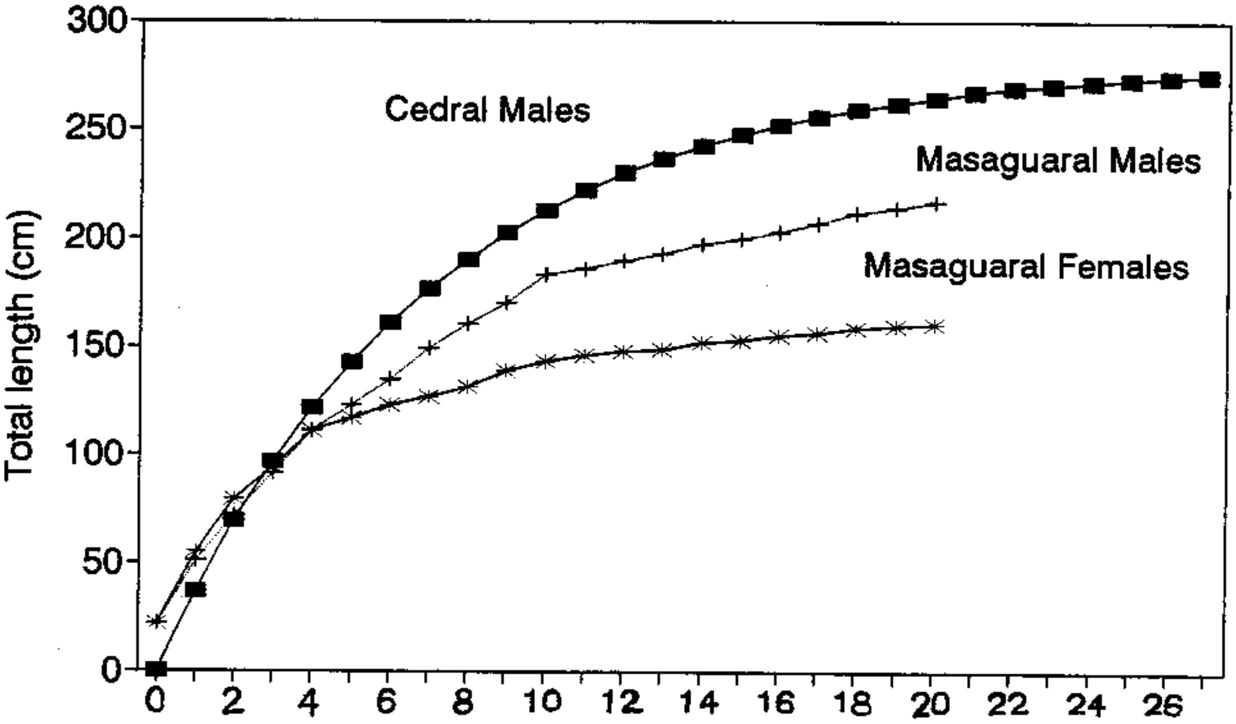
Figure 1. Growth function

Lt=Linf*(1-exp(-k*t))



Viruses and Mycoplasms from Faeces of Farmed Nile Crocodiles

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In South Africa Nile crocodiles (Crocodylus niloticus) are hatched and reared from eggs laid by captive breeding stock. This type of production should reduce the risk of introducing egg-transmitted infections. Two viruses have been reported from Nile crocodiles, poxvirus and adenovirus (Jacobson, Gardiner & Foggin, 1984; Foggin, 1987; Horner, 1988; Pandey, Inoue, Oshima, Okada, Chihaya & Fujimoto, 1990; Huchzermeyer, Huchzermeyer & Putterill, 1991; Buoro, 1992). Poxvirus has also been found in captive caimans (Jacobson, Popp, Shields & Gaskin, 1979; Penrith, Nesbit & Huchzermeyer, 1991) as well as in C. porosus and C. johnstoni (Buenviaje, Ladds & Melville, 1992). The morphology of the crocodile pox viruses was discussed by Gerdes (1991). Attempts to grow these viruses in tissue culture or in embryonated eggs have failed so far and they were all visualized by electron microscopy in ultrathin sections of affected tissues. The high cost of crocodile eggs and the short period of availability contribute to difficulties encountered when attempting to work with embryonated crocodile eggs for direct virus isolation or establishing cell lines. In this paper we report on viruses and mycoplasms found by transmission electron microscopy (TEM) of negative stained crocodile faeces.

During investigations into mortality in farmed crocodiles faeces were obtained from the colon of hatchlings and growers submitted for postmortem examination. For the preparation of the faeces a 10%-20% homogenate was made in a neutral buffer, this was clarified by differential centrifugation at 3,000 rpm and 8,000 rpm and the supernatant was then pelleted at 18,000 rpm for 60 mins. The resulting pellet was resuspended in a few drops of distilled water, applied to a carbon coated formvar grid and stained with 3% phosphotungstic acid pH 6. Negatively stained virus particles were, where possible, identified by their morphological characteristics.

One naked and three enveloped viruses as well as a mycoplasm were found by TEM and are listed in Table 1.

The adenovirus demonstrated one of its 20 characteristic triangular faces (Horne, Brenner, Waterson and Wildy, 1959). The adenovirus particles (Fig. 1) were found in 3 crocodiles ranging in length from 31 to 47cm, all from the same pen, from a group which had been imported from Mocambique. While adenoviral infections are common in Zimbabwe (Foggin, 1987), they are rarely seen in South Africa, probably due to the lack of contact with wild virus carriers. However, in these cases the virus was also detected in tissues, in the nuclei as well as in the cytoplasm.

Table 1: Viruses and mycoplasms detected by TEM in negative stained crocodile faeces.

agent	farm	date mth/yr	crocodiles n	mean length cm
Adenovirus	A	01/93	3	41,3 (±9,0)
CVLP	B	06-07/93	4	122 (±11,3)
Influenza-C-virus	A	01-02/93	8	54,7 (±14,4)
Paramyxovirus	A	01-04/93	7	79,6 (±42,3)
Paramyxovirus	C	12/91	1	90
Mycoplasma	A	04/93	1	40
Mycoplasma	C	12/91	2	65 (±15)

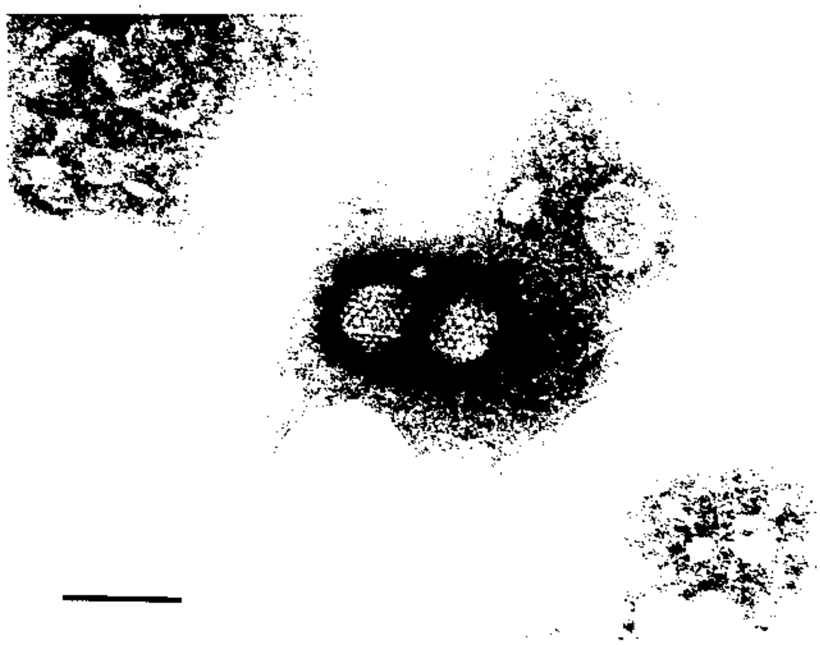

Fig. 1 Adenoviral particles from negative stained Nile crocodile faeces, bar 100nm.

The paramyxovirus, particles were typically spherical and filamentous forms enclosed by an envelope bearing clearly visible spikes (Fenner, 1976) (Fig. 2). Nucleocapsid material was not clearly visible and measurements to make accurate family and genus identification were not possible. They were found in the faeces of crocodiles that had been fed poultry from a farm were Newcastle disease had occurred. The virus particles were found over a period of 3 months in crocodiles ranging in length from 32 to 144cm from several pens of 3 different houses on the one farm. Seroconversion in crocodiles fed on mortalities from an outbreak of Newcastle disease has been reported from Zimbabwe (Thomson, 1972). However, paramyxovirus was also found in a single crocodile from a farm, where no poultry had been fed.

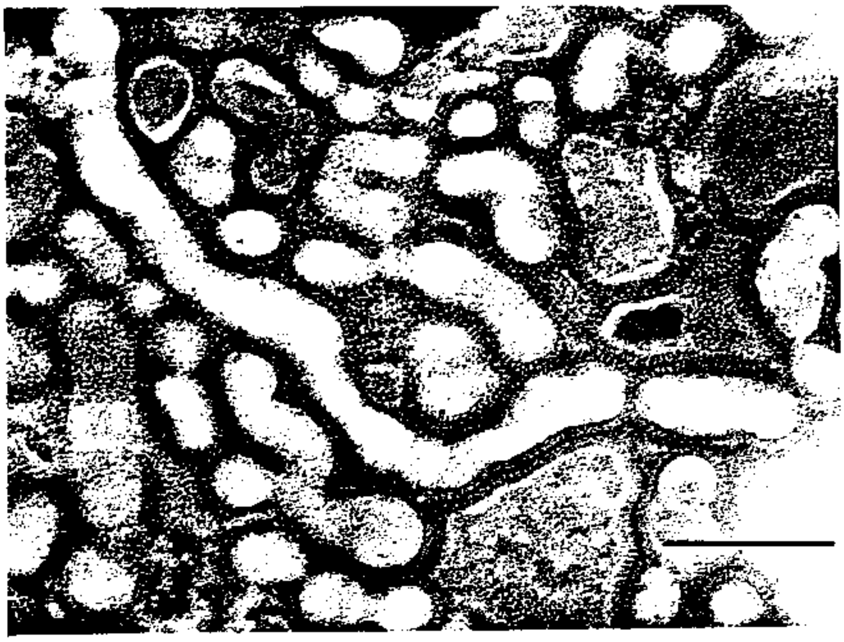

Fig. 2 Paramyxovirus from Nile crocodile faeces, bar 200nm.

The influenza-C-virus particles appeared mostly as filamentous forms with the surface projections in a regular hexagonal arrangment (Compans, Bishop and Meier-Evert, 1977) (Fig. 3). They were found over a period of one month in 8 crocodiles ranging in length from 31 to 81 cm from 2 pens in one house of a farm, where high mortality occurred. Concurrently the animals had been exposed to severe stress caused by overstocking, handling and irregular temperatures. This could have rendered the crocodiles more susceptible to the infection, which may or may not have contributed to the high mortality rate.

The identification of fringed particles in faeces can, at best, be only subjective and small, pleomorphic particles bearing longer, well-spaced projections were tentatively identified as coronavirus-like to distinguish them from true coronaviruses and from duodenal brush border vesicles (Schnag, Brookes, Meduedec and Morey, 1987). The coronavirus-like particles (CVLP) (Fig. 4) were found over a period of one month in 4 out of 5 2-3-year old crocodiles from a farm with severe mortality in that age group. CVLP are considered to be nonpathogenic in other species and differ from the true coronaviruses in their fringe morphology, size and shape. They were, however, present in an enormously high concentration in two of the samples.

Fig. 3 Influenza-C-virus from Nile crocodile faeces, bar 100nm.

Fig. 4 Coronavirus-like particles from Nile crocodile faeces, bar 200nm.

Mycoplasms (Fig. 5) were found in two instances approximately two years apart in two specimens from one and a single specimen from another farm . There did not appear to be any distinct pathology. Bacteriophages were also found regularly.

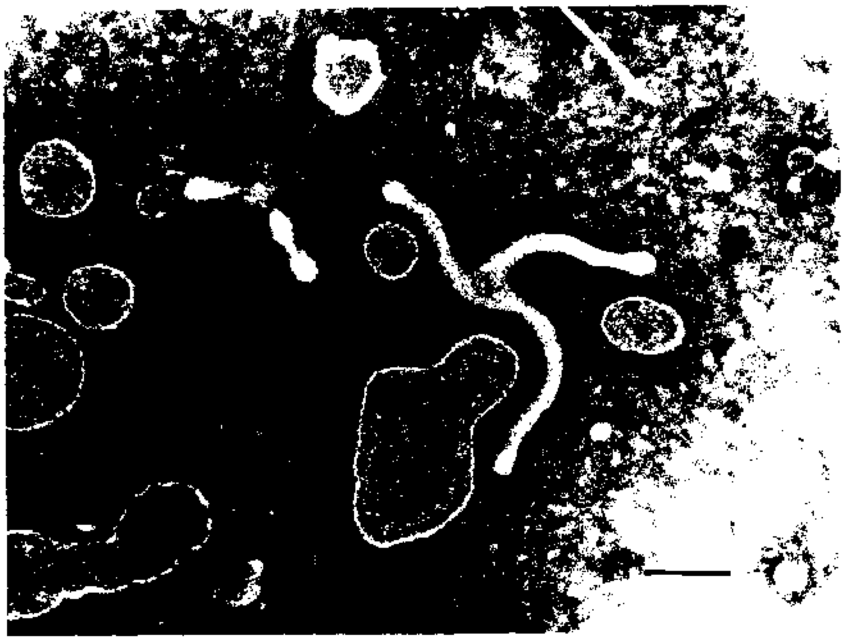

Fig. 5 Mycoplasm from Nile crocodile faeces, bar 200nm.

In the absence of a suitable host system for the isolation of crocodile viruses, TEM examination of negative stained crocodile faeces should form part of routine investigations of mortality. This technique has been used successfully to identify viruses in both mammalian and avian faeces and will, in future, lead to the discovery of more gastro-intestinal and other viruses of the crocodile and help in the understanding and management of mortality outbreaks.

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A survey of parasites and pathology of African dwarf crocodiles *Osteolaemus tetraspis* in the Congo Republic

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Wild-caught African dwarf crocodiles *Osteolaemus tetraspis* are regularly brought to markets in Brazzaville, where they are slaughtered for their meat (Behra, 1990), which is regarded as a delicacy by the local population. As wild crocodiles are not easily accessible to the parasitologist or pathologist, their availability was regarded as a singular opportunity. In this paper we report the findings of the sampling and examination of 23 crocodiles carried out during a two week period in May 1993.

During this time markets in Brazzaville were visited daily. When crocodiles were brought for slaughter, their length was measured, at slaughter a blood smear and a blood sample were taken and then the inner organs were purchased and taken to the State Veterinary Laboratory for further sampling and examination. After a while the internal organs became unaffordably expensive, which forced us to send an assistant to the market, solely to purchase the inners. Consequently we could not measure the length of these last crocodiles nor take their blood samples. The blood smears in these cases were taken from heart blood.

In the laboratory the organs were separated, lungs , stomach and intestine were dissected carefully and searched for parasites which were preserved in glycerine alcohol. Faecal samples were taken for bacteriological and virological examination and preserved frozen. Hearts (the 2 ventricles only), spleens, fat bodies and kidneys were weighed for morphometric analysis, the stomach pH measured with the help of indicator strips and samples of all organs fixed in 10% formol saline for histopathological examination. Due to the dressing procedure adopted by the market vendors, the kidneys were mostly cut in halves and often missing completely. We were also not able to sample any brain or other nervous tissue. The blood samples were allowed to clot and then the serum poured off and frozen; the blood smears were fixed with May Gruenwald Giemsa solution.

After the return of the senior author to South Africa the tissue samples were processed routinely, sectioned and stained with haematoxylin eosin for histopathological examination, the blood smears stained with Giemsa stain, the faeces samples were given to Dr G.H. Gerdes for negative staining and transmission electron microscopy (TEM) and to Dr M. H. Henton for bacteriological examination. The parasites were counted and distributed for detailed identification as follows: The pentastomes went to Dr J. Riley, Dundee, the ascaridoids and the trematodes to Dr L. Khalil, London and the blood smears containing blood parasites to Dr M. A. Peirce, London.

The length of 13 crocodiles ranged from 90 - 147cm, all 23 crocodiles were sexually mature, with a male to female ratio of 13:10. The mean spleen/heart ratio of 21 individuals was 0,83 (±0,22), while the fat body/heart ratio of 19 animals ranged from 0,09 to 11,72. Only 3 kidneys could be weighed, with kidney/heart ratios ranging from 0,89 to 1,77. In 21 of the crocodiles the stomach pH ranged from 2 to 4 and only 2 animals showed high values, pH 6 and 7 respectively.

Gross pathology was found in 10 of the crocodiles, consisting of verminous stomach ulcers (9), pleuritis (1) and obstruction of the stomach with large feathers (1).

Histopathological examination revealed inflammatory lesions in the following organs: Duodenum (8), fat body (2), heart (1), jejunum (7), kidney (5), liver (18), lung (21), mesentery (4), oesophagus (1), oviduct (2), pancreas (6), stomach (21) and thyroid (2). Some of the above figures do not include parasites which were present in sections of the duodenum (3: Hepatozoon schizonts, trematode attached to villi), jejunum (1: Hepatozoon schizonts), kidney (1: nematode larvae in a granuloma), liver (2: sporulated coccidial oocysts in a granuloma and nematode larvae in a granuloma), lung (2: Hepatozoon schizonts, granuloma with nematode remains), mesentery (1: nematode eggs in a granuloma), pancreas (1: coccidial sporocysts in a granuloma) and stomach (17: Hepatozoon schizonts 2 and verminous gastritis 17). Trauma was found in the mesentery (1) and stomach (5). Degeneration affected the following organs: Adrenals (7), fat body (4), ovary (3), parathyroids (6), testicle (7), thymus (11) and thyroid (6).

Parasites: Pentastomes of the genera Alofia and Sebekia were found in the lungs of 21 and in the body cavity of 6 crocodiles. Ascaridoids were present in the stomach of 15 crocodiles, mostly associated with macroscopically visible ulcers, in the intestine of 7 and in the cloaca of 3 crocodiles, while trematodes, all identified as Pseudoneodiplostomum bifurcatum, occurred in the intestine of 21 animals. Blood stages of Hepatozoon were found in 21 blood smears and schizonts in histopathological sections of the mucosa of duodenum, jejunum and stomach as well as in the lung of one animal and in a second crocodile in the stomach mucosa only. Coccidial sporocysts were found in tissue sections of pancreas and liver of one crocodile.

The bacteriological examination of 21 faecal samples yielded on average 3 bacterial and 3 fungal species per sample. The bacteria isolated are presented in Table 1 and the fungi in Table 2. No viral particles were detected by TEM in any of the samples.

The sizes of the crocodiles in this study were similar to those observed by Behra (1990), but the sex ratio was not shifted quite as strongly towards the male side as found by that author. The spleen/heart ratios were relatively high in comparison to normal Nile crocodiles (Huchzermeyer, 1994), which seems to fit in with the found prevalence of inflammatory lesions in many organs apparently caused by septicaemia. The fat body/heart ratios are indicators of the state of nutrition. In 6 animals they were below 1, indicating an exhaustion of energy reserves. It was 0,40 in the animal, whose stomach was obstructed by long wing feathers. The wide range of the few kidney/heart ratios may have been due to prolonged water deprivation, but falls within the range of normal distribution found in Nile crocodiles (Huchermeyer, 1994). High stomach pH values have also been found in farmed Nile crocodiles, which died after long illness (Huchzermeyer, 1994).

Table 1: Bacteria isolated from intestinal contents of 21 African dwarf crocodiles

Genus	Species	No. isolates
Bacillus	*cereus, coagulans*, sp.	11
Enterococcus	*faecium*	9
Enterobacter	*agglomerans, faecium*, sp.	8
Escherichia	*coli* 051:K23, rough	6
Proteus	*mirabilis*	6
Micrococcus	*luteus*, sp.	4
Citrobacter	*amalonaticus, freundii*	3
Salmonella	*wangata, yoruba*, III b30:K:enx	3
Klebsiella	*oxytoca* capsule types 44 and 60	2
Flavobacterium	*balustinum*	1
Lactobacillus	sp.	1

Table 2: Fungi isolated from intestinal contents of 21 African dwarf crocodiles

Genus	Species	No. isolates
Aspergillus	*clavatus, flavus, niger*, sp.	8
Penicillium	sp.	7
Cryptococcus	*lipolytica, luteolus*	4
Beauveria	sp.	3
Candida	*guilliermondii, krusei*	3
Chrysosporium	sp.	3
Trichosporon	*beigellii, capitum*	3
Paecilomyces	sp.	2
Acremonium	sp.	1
Arthrinium	sp.	1
Curvularia	sp.	1
Phoma	sp.	1
Serratia	*odorifera*	1
Streptomyces	sp.	1

Except for the presence of nematodes in the present cases, the histopathology of the stomach ulcers was very similar to that described in stomach ulcers of Nile crocodiles, particularly with regard to the severe vascular and perivascular reactions (Huchzermeyer and Penrith, 1992).

Gastric ulcers without nematodes were found in a zoo specimen of O. tetraspis (Heard, Jacobson, Clemmons and Campbell, 1988).

In a number of cases trauma had been caused by long thorns penetrating internal organs. These thorns were found pointing cranially and inwards, as if the animal had backed into them. They are presumed to be part of a traditional type of trap and may have been the cause of at least some of the many lesions of sepsis in a variety of internal organs, rendering at least some of the meat unfit for human consumption by universally eccepted standards. Contributing to this are the degenerative lesions found in many organs which doubtless are due to the severe stress of captivity and transport, the estimated average time lapse between capture and slaughter being 30 days. An interesting finding was the presence of active thymuses in sexually mature animals. Thymic necrosis similar to that described in Nile crocodiles (Huchzermeyer and Penrith, 1992; Penrith and Huchzermeyer, 1993) was found in 11 out of 16 animals and in theses cases can also be regarded as having been caused by stress.

Fishes are presumed to be the intermediate hosts of the pentastomes, ascaridoids and trematodes of O. tetraspis. It would be interesting to determine these by studying the feeding habits of the crocodiles and by the dissection of their prey. Only sequestered coccidial stages were found in the present material. All active stages would have been eliminated during the long confinement in captivity.

The bacterial and fungal intestinal flora of African dwarf crocodiles has not been investigated previously. Citrobacter freundii was isolated from the tank water of a zoo specimen (Kennedy, 1973). Edwardsiella tarda which commonly occurs in farmed Nile crocodiles in South Africa, was not isolated from our specimens. It must be pointed out, however, that the findings presented in this paper are from severely stressed animals.

This study should should be extended to sampling crocodiles closer to the point and time of capture. It should further encompass all aspects of capture, transport and marketing, leading to a better understanding of the particular situation of the exploitation of this species and consequently to the formulation of effective conservation measures.

The Director of the Onderstepoort Veterinary Institute is thanked for the generous financial support of this project, Director and staff of the State Veterinary Laboratory in Brazzaville for permitting the use of their facilities and Drs M.H.Henton and G.H.Gerdes for their part in the bacteriological and virological examinations.

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CONDITION FACTOR OF *Caiman crocodilus yacare* IN DIFFERENT HABITATS OF PANTANAL MATO-GROSSENSE

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INTRODUCTION

The condition factor is used as an index of the relative fatness of animals in nature. According to Taylor (1979), the condition factor is a measure of how well the animal is coping with the environment.

The *Caiman crododilus yacare* is found in several habitats of Pantanal such as rivers, ponds natural and artificial and marshes. A wide variety of prey species ingested by caimans is thought to be related not only to the habitat in which they are living, but also to their size. Thus, this study was carried out to determine the relationships between the condition factor of animals of different body size classes and types of habitat.

STUDY AREA

The Mato-Grossense Pantanal is situated in the centerwest region of Brazil, between 16 and 22° lat. South and 55 and 58° long. west. The region is a wide plain of alluvial accumulation, with average altitude 120 m above sea level, and it has marked rainy and dry seasons that vary in intensity and geographic extension, according to the annual climatic and hydrologic characteristics (Brazil, 1974). The interaction between climatic, hydrologic, geologic and geomorphologic factors is associated with a large complexity of habitats and biodiversity.

A total of 190 caimans were caught during the dry season (sept, through nov.) from different habitats of Pantanal as follows: fresh water ponds, temporary channels and the Negro river in the Nhecolandia region; fresh water ponds and artificial roadside ponds in the Abobral region; and Miranda river in Miranda region of Pantanal of Mato Grosso do Sul, Brazil.

METHODS

The caimans caught were classifed according to their snout vent length (SVL) as follows: 1 - Young, having less than 50 cm SVL; 2 - Sub-adult, having 51 to 70 cm SVL; and 3 - Adult, having more than 71 cm SVL.

The condition of caimans was measured by relative condition proposed by Le Cren (1951). The relationships between length of *C.c.yacare* from different habitats and size classes were examined by analysis of covariance. The relationship is of the form: $W = aL^b$, where w is body weight in grams and L is snout - vent length of the individual in centimetres. Coefficients *a* and *b* were calculated by linear regression after logarithmic transformation of raw data. The individual's relative condition factor (ai) was calculated from the formula $ai = 10^3 (Wi \times Li^{-b})$, where *b* is the exponent derived from the population. Comparisons between *ai* were made by analysis of Variance using the Duncan test.

RESULTS

The relationships between length and weight of caimans did not differ significantly ($P > 0.05$) between habitats and animal size classes, so the value of *b* was calculated for the whole population. Individual relative condition factors for each caiman were calculated from: $ai = 10^3 (peso \times CFC^{-3.06})$.

Condition factors of caimans differed significantly between habitats ($P < 0.05$). Caimans from "Miranda" river had higher condition factors than those in the other habitats, but differed significantly only from temporary channels and ponds of Abobral (Tab.I). Condition factors did not differ significantly among size classes, but the interaction habitat and size class was significant ($P < 0.05$)

The young caimans showed highest condition factor in salt water ponds and the big caimans in "Miranda" river and artificial roadside ponds (Table I).

Table I - Mean relative condition factor (CF) of *C. c. yacare* in different habitats and size classes during the dry season, in the Pantanal Mato-Grossense, Brazil.

HABITATS	SIZE CLASSES						All individual	
	Young		Sub-Adult		Adult			
	n	$CF.10^{-3}$	n	$CF.10^{-3}$	n	$CF.10^{-3}$	n	$CF.10^{-3}$
"Miranda" river	3	2.06^{ab}	11	1.81^{b}	17	2.26^{a}	31	2.07A
Artificial roadside ponds	4	1.80^{b}	4	1.96^{b}	2	2.38^{a}	10	2.00AB
Salt water ponds	30	2.20^{a}	11	1.74^{b}	24	1.66^{b}	65	1.92AB
"Negro" river	5	2.00^{a}	1	1.69^{a}	4	1.70^{a}	10	1.86AB
Ponds of Nhecolandia	8	1.81^{a}	1	1.56^{a}	12	1.89^{a}	21	1.85AB
Temporary channels	20	1.80^{a}	13	1.87^{a}	7	1.63^{a}	40	1.79B
Ponds of Abobral	7	1.61^{a}	3	1.95^{a}	3	1.86^{a}	13	1.75B
TOTAL	77	1.96^{a}	44	1.88^{a}	69	1.83^{a}		

a, b Different superscript between colunnas indicate a significant ($P < 0.05$) difference due to size classes.
A, B Different superscript between rows for sums for all individuals indicate a significant ($P < 0.05$) difference due to habitat.

DISCUSSION

Variation in diet may be related to habitat occupied, prey species encountered, prey vulnerability, prey size suitability, and animal size (Delany and Abercrombie, 1986). In this study, differences in condition factor are most likely to be related to availability of prey in different habitats and the relationship between prey size and animal size.

In the salt water ponds of the Pantanal, the most frequent food sources were Hemiptera (Belostomatidae and Naucoridae), Coleoptera and larve of insects (odonata) and sometimes anphibians (Uetanabaro, 1989;

Santos et al., unpublished data). Considering that young crocodilians ate mainly insects (Taylor, 1979, Webb et al., 1982, Magnusson, 1986, Uetanabaro, 1989), the highest condition factor of young caiman in this environment may be due to the higher incidence of insects. Santos et al. (unpublished data) evaluated the values of crude protein for Hemiptera (Belostomatidae), Coleoptera (Hidrofilidae) and larve of insects (odonata) and found 64,1, 65,4 and 61,1%, respectively, which is considered high.

According to Magnusson (1986) larger crocodilians may or may not continue to eat invertebrates, but the mayority supplement their diets with vertebrates, depending on the habitat. In the Pantanal, fish are the most common food supply for adult caimans because they abound in rivers, artificial ponds and several natural ponds in the region (Santos et al., unpublished data). This fact should explain the higher condition factor values found for big caimans in the "Miranda" river and artificial roadside ponds.

It is important to point out that data for some habitats are too few for a valid comparison and further research should be conducted before from conclusions are drawn.

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SCANNING ELECTRON MICROSCOPY STUDY OF FUNGAL INFECTION IN EGGS OF FARMED *CROCODYLUS POROSUS*.

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Abstract

An ubiquitous fungus, *Fusarium solani* has been frequently isolated, both superficially and systemically, from juvenile farmed crocodiles, *Crocodylus porosus*. Other fungi isolated with less frequency are *Paecilomyces lilacinus* and *Aspergillus sp.*

Infection rates at a commercial farm had reached epidemic proportions with mortality and morbidity in excess of 50% of each year's hatchlings and eggs. Contamination of freshly laid eggs by the pathogen has been determined as the probable primary cause of infection, along with subsequent trauma in juveniles.

Scanning Electron Microscopy was used in this study to determine the method of access of the fungi into the eggs.

Aim

To investigate fungal infection in the shell of eggs of farmed estuarine crocodiles, *Crocodylus porosus*, using Scanning Electron Microscopy.

Introduction

Fungal disease in hatchling *Crocodylus porosus* has been documented in previous reports (Hibberd & Harrower, 1991, 1993a). As a result of work to date, hatchling survivorship to the end of the first year has been increased to more acceptable levels (Hibberd 1993b). Recurrent fungal infections in eggs and subsequent high embryo mortality have led to this study.

Methods and materials

Shells from infertile and fertile eggs of *Crocodylus porosus* were collected during incubation and at hatching. Samples were taken for culture, following standard mycological procedures. Randomly selected segments of shell (less than 1 sq cm) were stored in 70% Ethanol. These were later air dried, attached to aluminium stubs using adhesive tabs and silver DAG, then gold coated to a thickness of 15 nanometres in a Polaron SC515 Evaporation Plant. These were examined using a Jeol JSM-5300LV Scanning Electron Microscope, in high vacuum mode, with secondary electron images recorded on 35mm black and white film.

Results

Shell pore size varied (100 to 500 microns). Pores and cracks were frequently plugged with hyphal elements and organic debris. Spores and hyphae were visible on the shell surface and in the pore proper. Fungal colonies also proliferated along cracks in the shell. Photographic evidence showed the spores, conidiophores and hyphae of different fungal species. An unidentified species of mite was also present (body width less than 100 microns). *Aspergillus sp* and *Fusarium solani* were identified from culture.

Conclusions

The pore size of *Crocodylus porosus* eggs allowed the easy passage of fungal spores and hyphal elements through the shell. Hyphae were able to penetrate the shell layers. An unidentified species of mite was also able to gain entry through the pores and cracks, and may also be a contributing source of fungal contamination of the eggs.

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My thanks are extended to Vince McCafferty for instruction and supervision in the use of the SEM, and to Doug Steley and Paula McDonald for photographic assistance.

List of photographs used on poster.

Fig. 1 External surface of egg shell of *Crocodylus porosus* showing pore size and structure. (Bar = 500μ)

Fig. 2 Enlargement of Fig. 1, top centre open pore. (Bar = 100μ)

Fig. 3 Enlargement of Fig. 2, conidia arrowed. (Bar = 50μ)

Fig. 4 Enlargement of Fig. 3, conidia arrowed. (Bar = 10μ)

Fig. 5 Enlargement of Fig. 4, conidium of similar size and shape to that of *Fusarium solani*. (Bar = 1μ)

Fig. 6 External surface of egg shell of *Crocodylus porosus* showing pore size and structure. (Bar = 500μ).

Fig. 7 Enlargement of Fig. 6, lower centre open pore, note arrowed area. (Bar = 100μ)

Fig. 8 Enlargement of Fig. 7, fungus arrowed. (Bar = 10μ)

Fig. 9 Enlargement of Fig. 8, hyphae (h) and conidiophore (arrowed) with phialides, of similar size and shape to those of *Aspergillus sp.* (Bar = 1μ)

Fig. 10 Branching septate hyphae on egg surface. (Bar = 5μ)

Fig. 11 Partially occluded pore. (Bar = 50μ)

Fig. 12 Almost totally occluded pore. (Bar = 100μ)

Fig. 13 Surface view into crack in shell, debris and hyphae visible. (Bar = 50μ)

Fig. 14 Enlargement of Fig. 13, hyphae extending from between calcite layers of shell. (Bar = 10μ)

Fig. 15 Portion of shell with occluded pore, (P), and sporodochia, arrowed. (Bar = 500μ)

Fig. 16 Enlargement of Fig. 15, mycelial mass in occluded pore, (Bar = 100μ)

Fig. 17 Enlargement of Fig. 16, mycelial mass showing thin walled hyphae, and thin branching hyphae. (Bar = 10μ)

Fig. 18 Enlargement of Fig. 15, sporodochia. (Bar = 100μ)

Fig. 19 Enlargement of Fig. 18, hyphae. (Bar = 10μ)

Fig. 20 Sporodochia. (Bar = 50μ)

Fig. 21 Sporodochia. (Bar = 10μ)

Fig. 22 Internal surface of shell, hyphae arrowed. (Bar = 500μ)

Fig. 23 Enlargement of Fig. 22, central area, hyphae and mites. (Bar = 100μ)

Fig. 24 Internal surface of shell, Mite trapped by hyphae. (Bar = 50μ)

SYSTEMIC MYCOTIC DISEASE IN JUVENILE FARMED CROCODILES, *CROCODYLUS POROSUS*.

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The 12th Working Meeting of the IUCN Crocodile Specialist Group, Pattaya, Thailand, 2-6 May 1994.

Abstract

An ubiquitous fungus, *Fusarium solani* has been frequently isolated, both superficially and systemically, from juvenile farmed crocodiles, *Crocodylus porosus*. Infection rates at a commercial farm had reached epidemic proportions with mortality and morbidity in excess of 50% of each year's hatchlings and eggs. Contamination of freshly laid eggs by the pathogen has been determined as the probable primary cause of infection, along with subsequent trauma in juveniles.

The pathogen is widely distributed in the farm environment. Treatments of diseased animals have met with varying degrees of success, however, attempts have been made to control the incidence of the disease by modifying husbandry practices. Hatchling survival at one year has been improved to above 65%.

Other fungi isolated with less frequency are *Paecilomyces lilacinus* and *Aspergillus* sp.

Aim

To investigate the epidemiology of fungal disease in farmed saltwater crocodiles, *Crocodylus porosus*.

Introduction

The history of a fungal disease at a commercial farm has been reported previously (Hibberd & Harrower, 1991). A comprehensive literature survey has been carried out and is the subject of a separate report in preparation. Work by Muir & Cunningham (1990) and Buenviaje (1991) has fuelled speculation that fungal disease, both superficial and systemic, is more prevalent than previously reported.

Methods and materials

Animals, facilities and staff support are provided by Koorana Crocodile Farm. Laboratory work is carried out in the Biology Dept. at the CQU, following standard histological and mycological procedures, as taught in the department.

Treatments of eggs and hatchlings have been attempted (Hibberd & Harrower, 1993), and changes to farming practices have been instigated after investigation of environmental parameters.

Results as at 31 Dec 1993

Year	Hatchling Survival		
	30 June	31 Dec	31 Dec excluding unrelated deaths
1989		53.1%	
1990		40.8%	
1991		44.1%	
1992		66.6%	77.4%
1993	88.8%	73.6%	78.9%

The survival rate of hatchlings has been increased, however more work is required to increase the hatching success of viable eggs. This will be the major objective of the 1993/1994 breeding season.

Conclusions

Fungal disease in farmed crocodiles is more common than first thought. Establishing a cure is difficult due to both the resistance of the pathogen and the highly stress sensitive nature of the host. However, preventative measures may lead to reducing infection rates to an acceptable level. There is no reason to believe that eggs and hatchlings produced in the wild do not succumb to fungal disease as do farm reared stock, given that the natural habitat of the crocodile host and the fungal pathogen are so similar.

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Acknowledgments

This research into mycoses in crocodiles forms the basis of a Master of Applied Science program by the Author at the University of Central Queensland. The work has the approval of the UCQ Animal Experimentation Ethics Committee, and operates under the relevant Queensland National Parks and Wildlife Service Permits to Take and Keep. It is jointly sponsored by the Biology Department at the UCQ and Koorana Crocodile Farm and has been supported by UCQ Research Grants for 1992, 1993 and 1994.

List of photographs used on poster.

Fig. 1 *C. porosus* adult female defending her nest. These warm humid nests made of soil, leaf litter and other plant debris, are ideal for the incubation of fungi as well as crocodile eggs. Naturally occurring fungal spores in the nesting material readily adhere to the sticky mucous layer on freshly laid eggs.

Fig. 2 *C. porosus* eggs. Fungal colonies can be seen on the shell of both eggs, and in particular, along the crack in the second. Hyphae may penetrate the shell via the pores, and also via the cracks which are sometimes caused by the female during the laying process.

Fig. 3 Cross section of *C. porosus* egg shell (s) with membrane layer (m) attached. Hyphae (arrowed) can be seen in the air space which has formed between the two layers.

Fig. 4 Developing *C. porosus* egg with fungal colonies of *Fusarium solani* visible as white cottony areas (arrowed). The crocodile embryo can be seen through the membrane layer.

Fig. 5 *C. porosus* embryo at a later developmental stage. The fungal contamination has progressed deeper inside the egg through and from the membrane layer.

Fig. 6 Healthy two year old *C. porosus* juveniles. These animals have progressed from indoor pens with heated air and water, to unheated external pens. Daily winter temperatures at this latitude may range from around 5°C minimum to 25°C maximum.

Fig. 7 *C. porosus* hatchling showing external lesions.

Fig. 8 General dissection of specimen from Fig. 7, note infection in liver.

Fig. 9 *C. porosus* lung showing multiple fungal granuloma. (Bar = 100μ)

Fig. 10 Enlargement of Fig. 9, lower right portion. (Bar = 50μ)

Fig. 11 Enlargement of Fig. 10, showing hyphal elements in the lung tissue. (Bar = 10μ)

Figs. 9, 10, & 11 all stained by the Periodic Acid Schiff method.

Fig. 12 Half strength Potato Dextrose Agar (HPDA) slopes and sterile wooden swab sticks used for environmental sampling, and the scraping of lesions on live animals. Cultures are of *Fusarium solani*.

Fig. 13 HPDA plate with aluminium ring, used for obtaining purified mycelial cultures from post-mortem crocodile tissue samples. (Harrower 1989). This culture is of *Aspergillus sp* obtained from a cross section of a *C. porosus* hatchling's trachea.

Fig. 14 *F. solani* hyphae, macroconidia, and microconidia. (Bar = 10µ)

Fig. 15 *F. solani* chlamydospores. (Bar = 10µ)

Fig. 16 *Aspergillus sp.* conidiophores, phialides, and conidia. (Bar = 5µ)

Fig. 17 *Paecilomyces lilacinus* hyphae, tapered phialides, and conidia. (Bar = 10µ)

Figs. 14, 15, 16, & 17. These slide preparations are stained with Acid Fuchsin in Lactic Acid.

Fig. 18 The Author and *C. porosus* juvenile, with adult breeding pair in the background.

Figures 1 to 17 inclusive were photographed by the Author using a Canon AE1 Program camera with a variety of lenses and microscope attachments.

Assessment of Cox Lagoon, Belize, Central America as a Morelet's Crocodile Sanctuary

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ABSTRACT

Cox Lagoon is located on the 14,600 ha Sing Tut Big Falls Farm, 45 km west of Belize City, Belize, Central America. Because of the value of Cox Lagoon as a wildlife resource, the property is being managed as a private sanctuary featuring Morelet's crocodiles, *Crocodylus moreletii*. From 12 February to 5 March, 1993 and from 24 February to 9 March, 1994, a total of 23 surveys were conducted in the fresh water lagoon. In 1993, 413 sightings of crocodiles were recorded ($\bar{x}$=37.6 SD=4.6). In 1994, 225 sightings were recorded ($\bar{x}$=18.8, SD=8.9). There was a significant relationship between water depth and number of crocodiles sighted with sightings increasing as water level decreased.

INTRODUCTION

Cox Lagoon, on the 14,600 ha Sing Tut Big Falls Farm (STBFF), is located approximately 45 km west of Belize City, Belize, Central America. With a dry season from December to May, average annual rainfall in the region is 1300-2000 mm; soils are composed of siliceous limestone with flints and characteristically have low fertility and slow internal drainage; STBFF is in the subtropical moist forest life zone and supports mahogany caoba, sapote, sapodilla, breadnut, allspice, chicle, bullhoof, ironwood, cohune and nargusta (Hartshorn et al., 1984). Cox Lagoon is a 5 km extension of Cox Creek; the open freshwater of Cox Lagoon is surrounded by swamp forest and on the western shore contains a large expanse of marsh dominated by Eleocharis and various grasses.

Historically, Cox Lagoon has been identified as a critical wetland. Abercrombie (1980) reported that in 1978, 1979 and 1980 he observed 27,60 and 38 _C. moreletii_ respectively in Cox Lagoon and he recommended that the area be designated a crocodile preserve. The entire Mussel Creek drainage including Cox Lagoon was proposed as a preserve for rare birds and crocodiles (Hartshorn et al., 1984). Cox Lagoon has been listed as a site of nature conservation interest (Zisman, 1989) and in 1993 was listed by the Belize Ministry of Agriculture in a regulation establishing sanctuaries for the hickety, _Dermatemys mawii_. Because of the diversity of wildlife including a significant population of _C. moreletii_ inhabiting Cox Lagoon, we recommended to the Belize Ministry of Tourism and Natural Resources that 13000 ha of STBFF be designated a nature preserve for crocodiles (Hunt and Tamarack, 1992). In 1994 Dora Weyer presented another proposal for a Mussel Creek preserve to the prime minister of Belize. Fortunately, the owners of STBFF have agreed to manage Cox Lagoon as a private crocodile sanctuary. To assist them in assessing the wildlife value of their property, we conducted crocodile surveys in Cox Lagoon.

METHODS

From 12 February to 5 March 1993 and from 24 February to 9 March, 1994, surveys were conducted in Cox Lagoon. The survey distance was 5.5 km from Mussel Creek (17°28'25" N, 88°31'45"W) to Cox Creek (17°25'50"N, 88°33'20"W). Before each survey environmental parameters including the depth of water at the Cox Creek bridge were recorded. With an observer at the bow, a 5.2 m canoe was paddled by one person at the stern. In spotting crocodiles, head lamps powered by 6 and 12 volt batteries were used. Crocodiles were approached until they submerged. Either the total length (TL) was estimated or it was classified eyes only (EO).

To estimate the population size, $P=1^2-s^2m$ can be used where P=sighting fraction for an average survey, s= standard deviation of the census total and m=mean census value; if there is great variation between surveys and data on total numbers do not fit a binomial distribution $P=\bar{x}/m$ can be used where $\bar{x}$=mean census value and m=the maximum number seen during one survey (Messel et al, 1976, King et al, 1990). With the sighting fraction known, the unseen crocodiles can be added to the census for an estimate of the total population.

RESULTS

In 1993, 11 surveys were conducted (Fig.1, Table 1); a total of 413 sightings of *C. moreletii* was recorded ($\bar{x}$=37.6 SD=4.6). Crocodiles <0.6 m(TL) were 27% of the total (Fig.2). To determine the sighting fraction P=1-21.2/37.6 and P=.44 for an unseen fraction of 56%.

In 1994, 12 surveys were conducted (Fig.3, Table 2) and a total of 225 sightings of *C. moreletii* was recorded ($\bar{x}$=18.8, SD=8.9). With 41% of the total, crocodiles <0.6 m(TL) were the most numerous size class; crocodiles >2 m(TL) represented 2 % of the total (Fig.4). Because the number of crocodiles sighted varied so greatly between surveys, P=18.8/41 had to be used and the sighting fraction was .43.

Water level in the 1993 survey period remained consistently low ($\bar{x}$=122 cm, SD=3.7) but water level in the 1994 survey period was atypically high ($\bar{x}$=183 cm, SD=14.7) with a mean daily decrease in water level of 4.3 cm. With a water level of 156 cm during the last survey of 1994, 41 crocodiles were sighted. The total 23 surveys show a significant relationship between water depth and number of crocodiles sighted; as water level decreased, sightings of crocodiles increased (R^2=0.6027, F=31.86, P<0.0001).

In the survey area we identified 124 species of birds, 23 species of mammals and 14 species of reptiles. Egg deposition sites of *Dermatemys mawi* occurred on high banks. During four surveys we observed tapirs, *Tapirus bairdii*. In 1994, four groups of howler monkeys, *Alouatta pigra* inhabited forest near Cox Lagoon. Tracks of jaguar, *Panthera onca*, ocelot *Felis pardalis* and margay, *Felis wiedii* were identified on the STBFF road near Cox Creek. Jabiru storks, *Jabiru mycteria* foraged in Cox Lagoon, Mussel Creek and the cultivated rice fields of STBFF.

STATUS AND MANAGEMENT OF COX LAGOON

Agricultural activities are restricted to the cleared land covering 24% of STBFF. Currently, rice is being grown on 250 ha and will increase to 800 ha. The farm will also produce sheep, goats, pigs, chickens and cattle. There are 1300 cattle on STBFF. The owners have been carefully monitoring the use of herbicides,pesticides and fertilizer. Irrigation water for the rice crop is pumped from the Belize River and is recirculated in the fields. It is expected that effluent will not affect Cox Lagoon and the Mussel Creek drainage.

The owners of STBFF have agreed to manage Cox Lagoon as a private sanctuary for crocodiles. Soon after their purchase of STBFF in 1992, the owners learned of plans by the ministry of development to build a bridge across the Belize River which would link the STBFF road intersecting the Western Highway. This public road would have made it impossible to protect Cox Lagoon from intruders. Fortunately, the plan for the bridge seems to have been defeated. During the past 18 months, most of the significantly destructive poachers and squatters were excluded from STBFF. During the same time, educators, researchers and naturalists have been encouraged to use Cox Lagoon as a wildlife resource. In night and day canoe trips into Cox Lagoon, we escorted Paul Tut,STBFF; Dora Weyer, University of Arkansas and Matthew Miller, Monkey Bay Sanctuary.

In discussions with owners of STBFF we advised them of the following:

1. A sign describing the sanctuary status of Cox Lagoon should be posted at the Cox Creek bridge.
2. Access to Cox Lagoon should be limited to canoes. Dredging a wider channel in Cox Creek would permit the passage of larger boats but could affect drainage. Clearing a road to Cox Lagoon would be intrusive and would affect the wilderness character of the wetland.
3. A canoe shuttle between Monkey Bay Sanctuary and STBFF could provide visitor access to Cox Lagoon. Night canoe trips offer excellent opportunities for seeing tapirs and crocodiles. Matthew Miller at Monkey Bay Sanctuary is interested in taking his biology students to Cox Lagoon.
4. Local people often walk down Cox Creek to catch fish on line and hook but fishermen possessing nets, traps or firearms should not be permitted.

5. To monitor trespassing, a canoe patrol should be periodically conducted; hunting camps on high ground are easily seen from Cox Lagoon. In 1994, we examined one abandoned camp which had a large holding pen for *Dermatemys mawii*.

DISCUSSION

According to Abercrombie (1986), many areas containing habitat for crocodiles are inaccessible by road and historically, this factor has helped preserve *C. moreletii* in Belize. Crocodiles, however, are difficult to find near areas of human settlement and large crocodiles are scarce in all but the most inaccessible habitat (Abercrombie, et al 1980).

Our study indicates that Cox Lagoon still contains a viable population of *C. moreletii*. The decrease in number of crocodiles sighted in 1994 was caused by high water. Although only one nest has been found (Platt,1992), 41% of sightings in 1994 were crocodiles <0.6 m (TL) and significant nesting probably occurs near Cox Lagoon. In addition to *C. moreletii*, Cox Lagoon supports a diversity of other wildlife and in the Mussel Creek drainage 31 species of mammals, 44 species of reptiles and 314 species of birds have been recorded (Weyer,1994). As an attraction for wildlife watchers, Cox Lagoon is strategically located near the western highway between Belize City and Belmopan. Other important attractions near Cox Lagoon include the Monkey Bay Sanctuary, the Belize Zoo and the Baboon Sanctuary. In world conservation strategies, ecotourism can provide income and employment (Munro and Holdgate,1991); ecotourism in Belize can be an important source of revenue (Bruner,1993) and can justify the preservation of a Cox Lagoon Crocodile Sanctuary.

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Table 1. Surveys of Morelet's Crocodiles in Cox Lagoon

Survey No.	EO	< 0.6 m	0.6-0.9 m	0.9-1.2 m	1.2-1.5 m	1.5-1.8 m	1.8-2.1 m	> 2.1 m	Total
1	7	6	10	1	3	1	1	2	31
2	14	11	7	1	3		2	1	39
3	6	11	6	4	3	1	3	1	35
4	8	12	6	5	4	4			39
5	7	8	9	2	6	4	2	1	39
6	10	11	7	6	5	1	1		41
7	5	7	4	17	4	1	2		40
8	3	13	5	15	5	2	2		45
9	2	12	3	12	9	1	1		40
10	3	11	4	10	5	3			36
11		9	2	14	3				28
Average/survey	5.9	10.1	5.7	7.9	4.6	1.6	1.3	0.5	37.6
Totals	65	111	63	87	50	18	14	5	413
Totals (%)	15.7	26.9	15.3	21.1	12.1	4.4	3.4	1.2	

Table 2. Surveys of Morelet's Crocodiles in Cox Lagoon

Survey No.	EO	< 0.6 m	0.6-0.9 m	0.9-1.2 m	1.2-1.5 m	1.5-1.8 m	1.8-2.1 m	> 2.1 m	Total
1	1	3	2	1	4	2		1	14
2	5	16	2	3	1		3	2	32
3	3	10	1		3	1	2		20
4	5	11	1	1	1				19
5	2	4		2	2	1	2		13
6	2	7		1	2		2		14
7	2	4		1		1	1		9
8	3	10		1	2	1	1	1	19
9	2	4		1	1		1		9
10	2	8		2	3	1	1		17
11	3	7	1	2	1	1	2	1	18
12	4	9	4	6	9	7	2		41
Average/survey	2.8	7.8	0.9	1.8	2.4	1.3	1.4	0.4	18.8
Totals	34	93	11	21	29	15	17	5	225
Totals (%)	15.1	41.3	4.9	9.3	12.9	6.7	7.6	2.2	

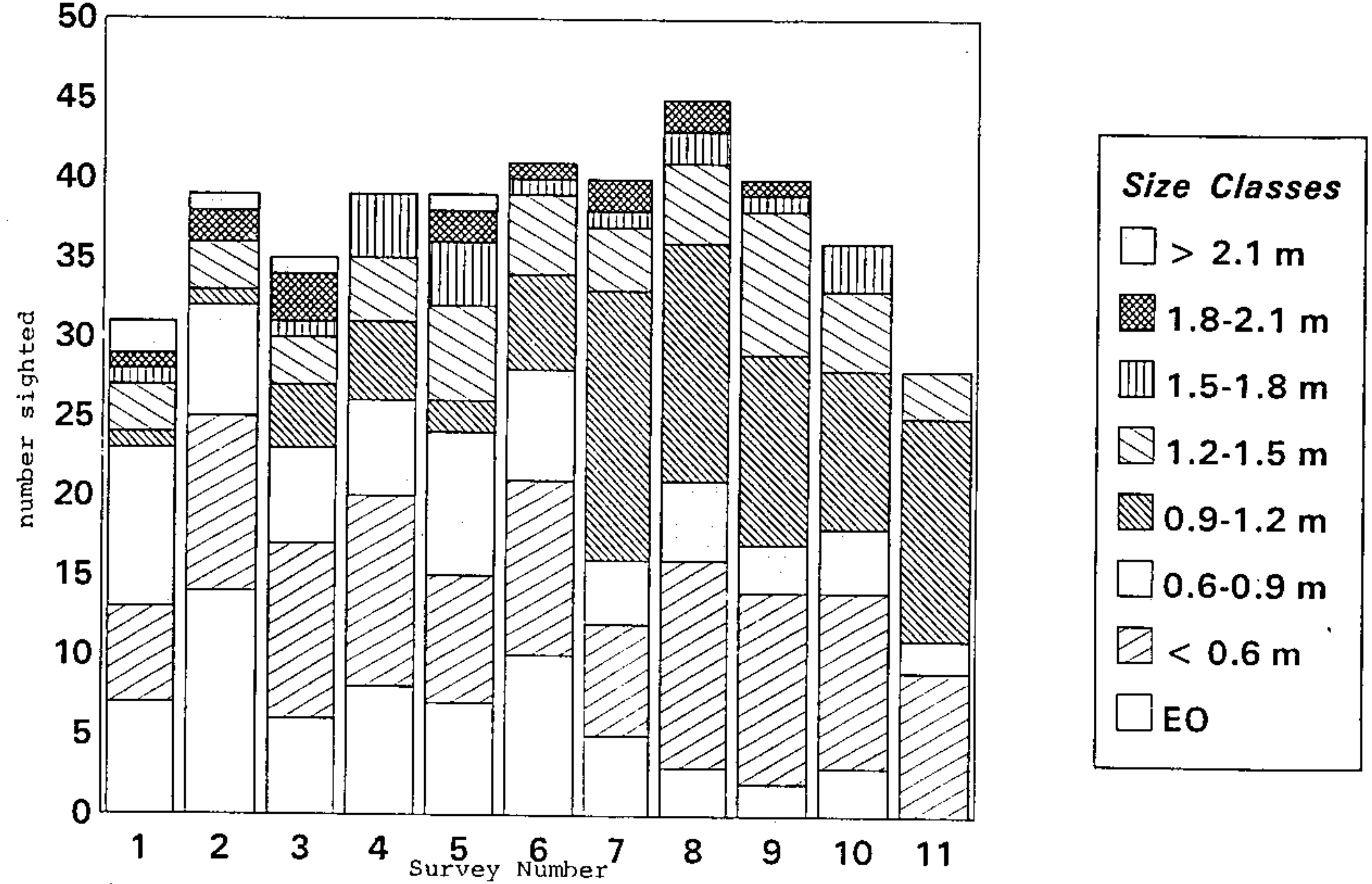

Figure 1. Surveys of Morelet's crocodiles In Cox Lagoon

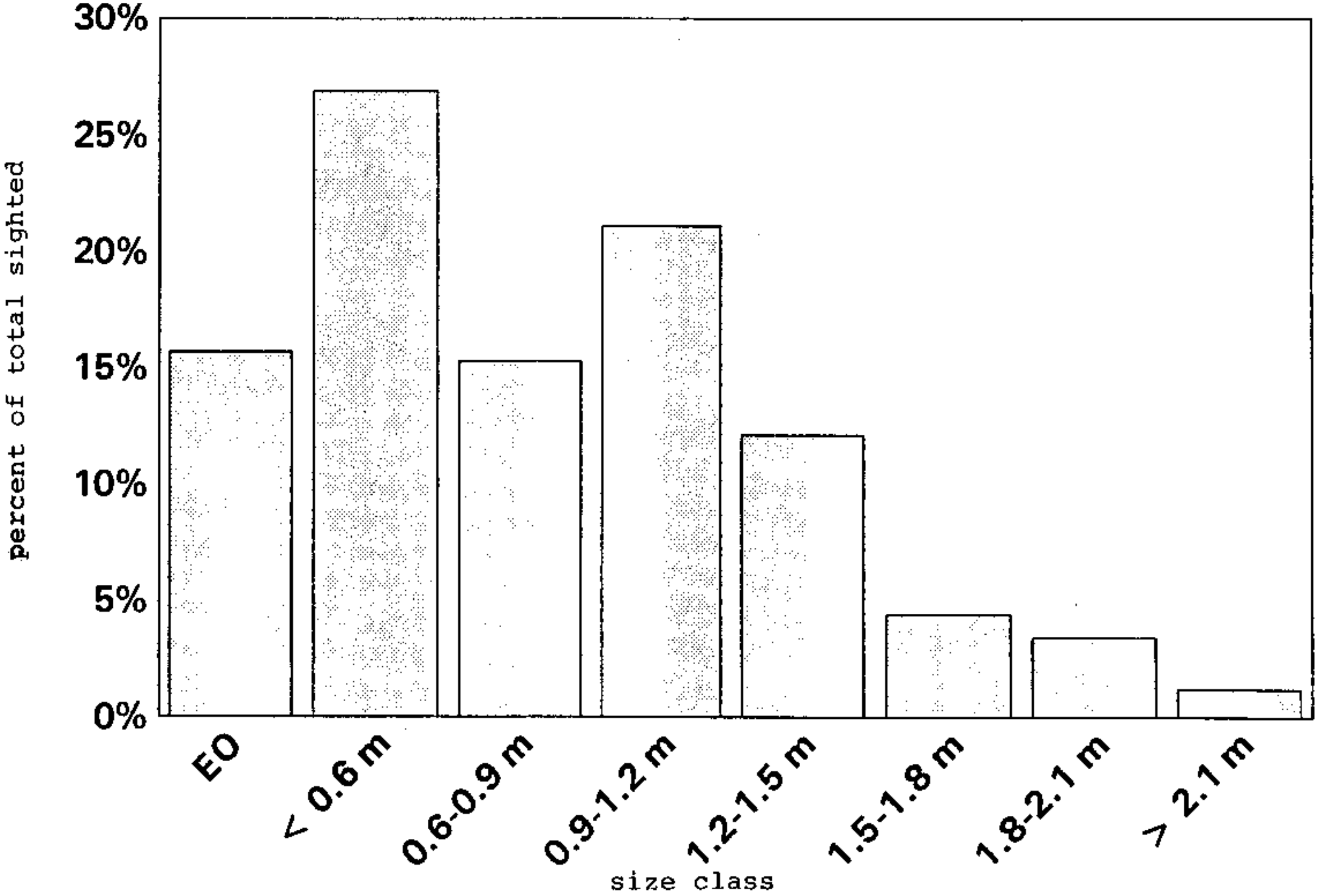

Figure 2. Total of 11 surveys in 1993 in Cox Lagoon

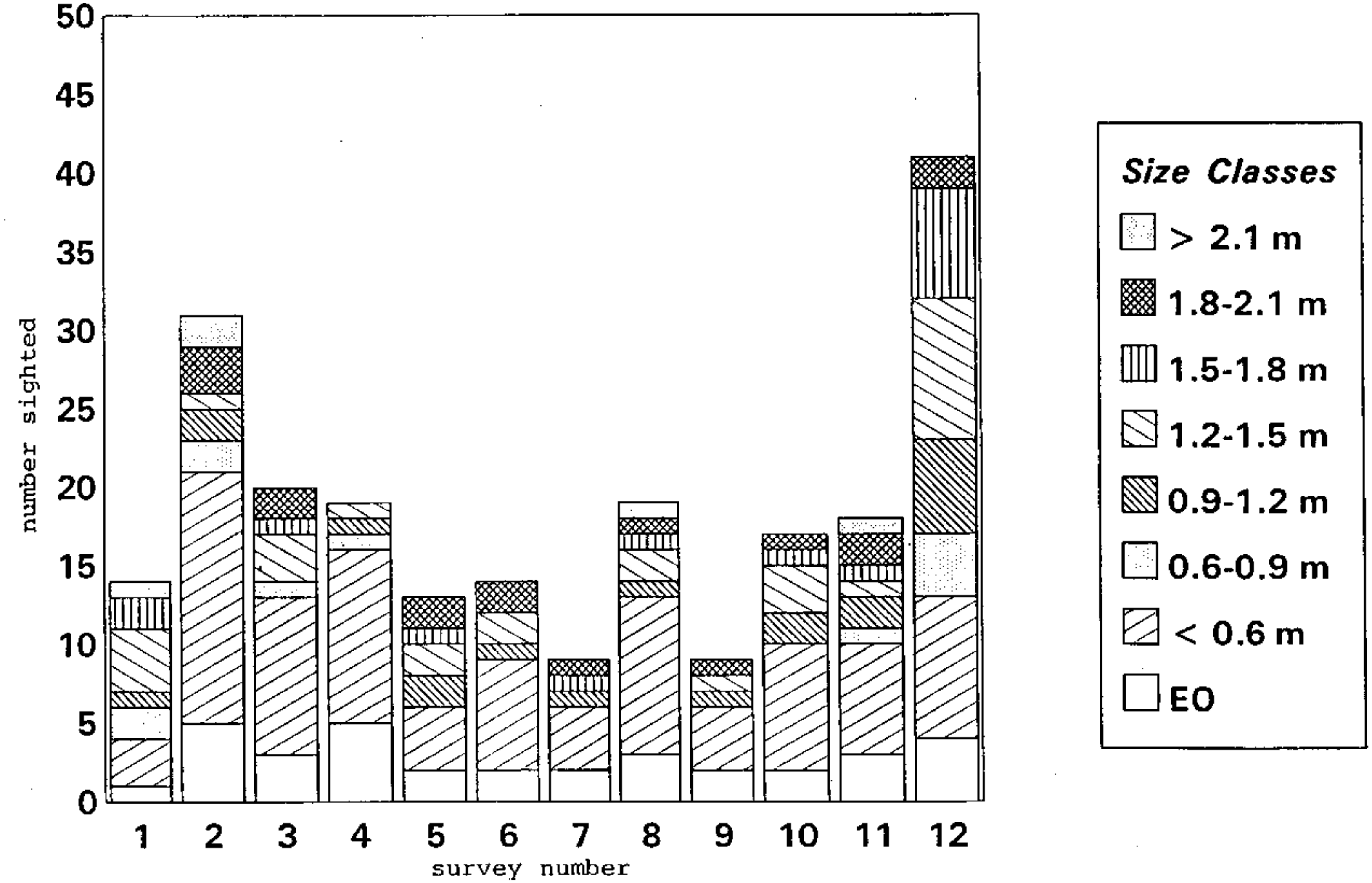

Figure 3. Surveys of Morelet's crocodiles in Cox Lagoon

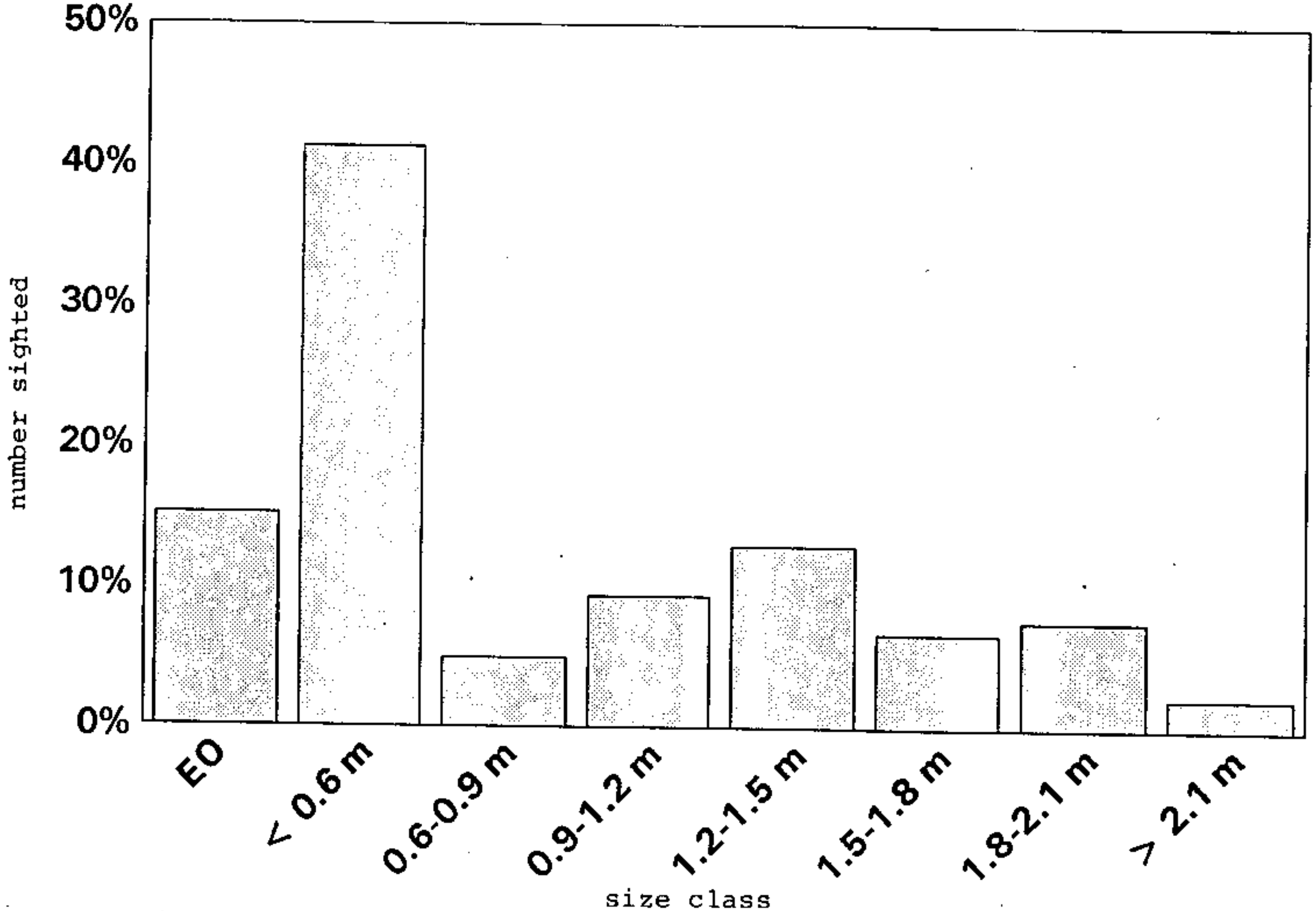

Figure 4. Total of 12 surveys in 1994 in Cox Lagoon