TECHNIQUES OF SURVEYING FOR CROCODILIANS

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INTRODUCTION

A great number of techniques have been developed for surveying crocodilians, and these vary with regard to the situations in which they are applicable and the type of data they produce. When planning a survey, the first, most important and often the most difficult stage is to link a method of data collection with a method of analysis that will allow a definitive answer to the question being asked. Some questions may not be amenable to study with the time and resources available, and it is best to be aware of this at the start of the study. Two common and important uses of survey techniques are to establish the status or the maximum sustainable yield (MSY) of a population. As many studies to determine the status or maximal permissible levels of exploitation for a population are based on one survey, their titles are probably misleading. Neither the status, nor the maximum sustained yeild of a population can be determined from a single survey. One survey can at best determine that: (1) the species was very difficult to observe; or (2) large numbers of animals were seen in the area. Result (1) translates into: the species requires urgent study (conservation organization) or the species is too rare to consider for exploitation (management authority). Result (2) translates into: in the absence of other information the species can be given low priority for research in comparison with other species (conservation organization), or the species <u>may</u> be sufficiently common to support some form of exploitation (management authority).

These results are very general and in most instances could have been predicted before the survey. Fairly obviously, if surveys are to be cost-effective, they must recognize the dynamic aspect of the population under study. This is not to say that a survey to investigate the status of a population should be undertaken only if money is guaranteed for future surveys. Rather, care must be taken to ensure that the results are collected in such a way that will allow comparisons if and when the opportunity for follow-up studies occurs. In the case of attempts to take sustained yields from populations the situation is stated clearly by Caughley (1977): "The calculation of an MSY must be treated as a first approximation and the effect of the harvesting must be followed carefully to allow fine adjustment towards the optimum."

All too often the results of a survey are presented as the number seen, or sometimes, more ambitiously, as the absolute number of animals present. Even if the results are taken at face value, their significance is likely to be hotly debated. Except in the case of extremes (e.g. none or millions), we need more basic biological information in order to make informed decisions:

(1) population age/size structure;
(2) distribution of population, stratified by size and sex, amongst habitats;
(3) distribution of habitats in the area surveyed.

When the biology of the species is already fairly well known we can sometimes streamline the follow-up surveys by concentration on a critical, or representative, segment of the population. This can be useful as it may allow us to use artifacts (such as nests or tracks) to monitor the population, so reducing interference and/or expense. In general, the collection of additional biological information adds very little cost to the survey (often as little as extra ink and a few notebook pages) but may be critical to the interpretation of results. Consider the case of an isolated population occupying only one hectare. The population is considered endangered and a proposal to create a 10,000 hectare reserve for the species is made. It may be that the population was limited by lack of a particular resource, perhaps habitat with cover for juveniles. In that case a 10,000 hectare reserve not containing more of the resource would have only half the potential for recovery as a 10,001 hectare reserve that contained an additional one hectare of the resource. Alternatively, a 5 hectare reserve of a different shape might be equally effective and more likely to gain legislative approval.

Basic to any sampling program is that surveys be objective, unbiased, and replicated. Objective means as independent of the observer as possible. Unbiased means not subject to systematic error. Replicated indicates that a variance estimate can be made. In reality no system of survey is totally objective or unbiased, and it is often difficult to achieve sufficient replication, especially when it is necessary to stratify by habitat. Nevertheless, a little thought at the planning stage can save a lot of headaches later on and greatly increase the utility of the results.

In the following section I will review most of the techniques that have been used in surveying for crocodilians. None is necessarily better than the others, though some are applicable over a wider range of conditions. The would-be surveyor needs to look for similarities between his situation and that described in terms of habitat, resources, and the biology of the species. A more general discussion of planning the survey is given in the final section.

METHODS OF SURVEY

Interviews and Opportune Personal Observations

Interviews and opportune personal observations are usually the least preferred methods of obtaining information, as both methods are likely to be subjective, biased, and unreplicable. However, they are cheap and are frequently used by biologists to obtain information while visiting an area for other reasons (Moore 1953; Charnock-Wilson 1970; Abercrombie 1978; Whitaker and Whitaker 1978) or to augment more detailed studies (Parker and Watson 1970). Sometimes the results are so dramatically obvious that decisions can be based directly on them. Joanen (1974) was able to establish the general distribution and trends in numbers of alligators in the southern U.S.A. from a detailed questionnaire sent to all wildlife agencies in the area; Morgan and Patton (1979) established, on the basis of lack of records, that *C. acutus* had been extirpated from the Cayman Islands; and the staff of the Madras Snake Park were able to show by 5000 miles of survey (interviews and opportune observations) which revealed only 6 animals that the gharial had been reduced to critical levels (Whitaker 1975). Often interviews are useful to expose public attitudes to crocodilians and have been used solely for this purpose (Hines and Scheaffer 1977).

Whatever their merits as survey techniques in some situations, interviews and opportune personal observations will generally be used by researchers addressing a specific problem only as a means to identify appropriate study areas in preparation for the use of one of the following, more detailed, techniques.

Daylight Ground Counts

Daylight ground (foot, boat, or car) surveys of crocodilians generally reveal only a small percentage of the population (Graham 1968). Chapman (1970) has estimated that percentage as 20-50% for *Crocodylus niloticus*, but there have been no detailed studies and it will surely vary between species and habitats. In general such techniques are used only when some aspect of the biology of the animal makes the population, or a subset of the population, abnormally indifferent to exposure. *C. niloticus* in some areas is exceptionally easy to count during the breeding season, as all mature adults congregate on a few beaches. Modha (1967) gave details of nesting congregations on Central Island, Lake Rudolf, and Pooley (1969) described the concentration of mature crocodiles in Lake St. Lucia (45 miles long) onto 1 1/2 miles of nesting beaches. Inchaustegui et al. (1980) reported similar breeding aggregations of *C. acutus* in the Dominican Republic. Thompson and Gidden (1972) counted *Alligator mississippiensis* basking during the first spring warm spell in northern Florida. Cott (1968) reported ground counts of nesting *C. niloticus* but presented data that indicate counts from the air (fixed-wing aircraft) reveal a greater proportion of the population. The only carefully controlled daylight ground surveys of crocodilians repeated over a number of years seem to be those of Pooley (1969) in Ndumu Game Reserve between the years 1962 and 1968. His data also demonstrated the importance of taking the biology of the species into account during such surveys. Counts during winter when a greater proportion of the crocodiles were basking on mud banks were consistently much higher than those undertaken during summer.

In summary, daylight ground counts generally reveal only a fraction of the population, but may be used effectively by a biologist who already has a fairly intimate knowledge of the biology of the species.

Daylight Surveys from Aircraft

Most of the same comments apply to this technique as to daylight ground surveys. The technique has its greatest value in habitats without tall vegetation that hides crocodilians from view. The only direct comparison of daylight ground counts with counts from the air seems to be that of Cott (1968) which indicates that aerial counts are more effective. Where applicable, aerial counts would probably always be preferable because of their speed and replicability. Data from Graham (1968) and Parker and Watson (1970) indicate that daylight counts from aircraft record only a small proportion of the animals that are revealed by night spotlight counts,and that the daylight counts from aircraft are strongly biased against small animals. Graham attempted to use aerial photography to census but found that suitable weather conditions were not sufficiently frequent to justify its use. Parker and Watson (1970) successfully surveyed part of the Victoria Nile using aerial photography and by use of standardized length markers anchored near shore were able to estimate the sizes of the crocodiles appearing in the photographs. Unfortunately there was an obviously very large, but unmeasurable, bias against some size classes, making their postulated size structure of the population so hypothetical as to be of little practical use.

The choice between use of a helicopter or a fixed, high-wing aircraft largely depends on cost. One would expect to see more animals at slower speeds but this must be weighed against the more frequent maintenance, less personal safety, and higher operational costs in a helicopter. In any case Parker and Watson (1970) reported no significant differences in the counts obtained from light aircraft and from helicopters surveying the same areas for *C. niloticus*. General aeronautical aspects of survey by fixed-wing aircraft have been reviewed by Grigg (1979).

Night Counts

Counting at night, usually from a boat, with the aid of a spotlight is the most widely used method of censusing crocodilians. The reflective tapetum of a crocodilian's eye glows red in a spotlight and can be seen for a considerable distance. This is the method most commonly used for intensive poaching, and therefore the method directly measures the hunted population. The biases due to animals learning to avoid the spotlight under heavy hunting pressure may reduce the number seen, but this is important mainly with older, more experienced, age groups.

The method frequently has been used to monitor hunted populations (e.g. Chabreck 1976; Onions this volume) and for surveys of status (e.g. Campbell 1972; Graham 1968; Messel et al. 1978; Parker and Watson 1970; Pernetta and Burgin 1980). The proportion seen varies with habitat, water level, and weather conditions. Messel et al. (in press) estimated 60-70% for tidal river systems in northern Australia, but frequently the researcher "feels" that he is seeing a very high percentage (e.g. Graham 1968; Chapman 1970). For some age groups and some situations the percentage seen may be very high (e.g. Staton and Dixon 1975; Magnusson 1981), but generally it is safer to assume that a significant proportion is being missed and to try to keep this constant by standardizing procedures (e.g. Chabreck 1966; 1977). Mark-recapture techniques are likely to be of use only in limited circumstances (Chabreck 1966). Messel et al. (1978) discussed factors affecting the sightability of *Crocodylus porosus* in tidal rivers of northern Australia, and Woodward and Marion (1979) evaluated the factors affecting night counts of *Alligator mississippiensis* in lakes in Florida, U.S.A. Different methods of survey are applicable in different areas. Magnusson (1979) and Staton and Dixon (1975) used foot rather than boat surveys, and Parker and Watson (1970) surveyed areas of thick papyrus at night from a helicopter. Whatever the mode of transport, the northern Australian and Florida studies give the factors most likely to bias the results.

Surveys for Artifacts

The two most obvious artifacts that crocodilians leave are marks in the mud or sand and nests. Some species, notably *A. mississippiensis*, call during the breeding season, and on those occasions when the animal is not seen the call also can be regarded as an artifact.

Estimates of numbers and sizes of crocodilians can be made from footprints (Mitchell 1969; Joanen 1969) and tail scute marks (Bustard and Singh 1977), but the utility of these methods is limited. The proportion of animals basking on a suitable substrate, the effects of season and disturbance on basking behavior, and the number of times and places an animal will leave the water on a given day are largely unknown for most species. The greatest use of the method is in determining the presence (but not absence) of a particular individual or class of individuals which are not amenable to other methods of survey. Obvious examples are large "light shy" animals. Webb et al. (1977) used tracks to infer the presence of an attendant adult with a group of hatchlings even though the adult was not actually seen with the young.

Chabreck (1966) suggested that calls of male A. mississippiensis could be used to give an index of population density but this technique does not seem to have been used extensively. Probably, calls, like tracks, are most useful to indicate the presence of large animals that cannot be surveyed by other means.

In contrast to marks on the bank, nests of mound nesting species are easy to see and in some circumstances can be related to a known or estimated proportion of the population. Ogden (1978) estimated the number of C. acutus in Florida Bay, U.S.A., from the known number or nests that had been located over a number of years. Chabreck (1966) estimated the number of A. mississippiensis on Rockfeller Refuge, Louisiana, from the number of nests found during 1966. Probably the main advantage of nest counts is that for some species, in some habitats, they can be done from the air (e.g. Chabreck 1966; Joanen 1969; Goodwin and Marion 1978; Kushlan and Kushlan, 1981). In many cases surveying for nests may be the only feasible method of monitoring the population (Kwapena and Bolton this volume). It is possible to estimate the absolute number of nests in an area by various statistical methods even when sightablility is not 100% (e.g. Magnusson et al. 1978), but it is unlikely that this information is normally required. The number seen may be used as a minimum number present but in any case allows trends in the breeding section of the population to be monitored. The timing and intensity of nesting may vary between years, depending on the weather (McNease and Joanen 1978), and allowance must be made for this in the evaluation of long term trends in population size. To date the only application of the technique for direct management has been the monitoring of alligator populations in the Louisiana marshes (Chabreck 1966; Palmisano et al. 1973; McNease and Joanen 1978).

Biological Data That Can Be Collected During Surveys

Except in the case of total absence it is often very difficult to interpret the significance of numbers of crocodilians without further information. One of the simplest and most important pieces of information that can be taken during surveys is the size distribution of the population. Most experienced biologists feel that they can estimate sizes of crocodilians with about 90% accuracy (Chapman 1970), but this is experience and species specific. Various rules of thumb have been put forward for estimating sizes of crocodilians, such as that the distance from the eye to the snout in inches equals the length in feet (Chabreck 1966), but in reality most biologists probably estimate sizes from some "Gestalt" combination of size and shape. Only experience allows accurate estimation for each species. Nonetheless, most relatively naive observers can group crocodilians as being hatchling, small, and large (Messel et al. 1978), hatchling, small, medium, and large (Pernetta and Burgin 1980), or young, juvenile, and adult (Woodward and Marion 1979). The hatchling-medium boundary is reasonably easy to determine but the medium-large boundary will vary with species. It is best to place it at lower breeding size for females of the species being investigated if this is known. Data from Pooley (1969) illustrate the importance of size stratification in determining the effect of hunting on a population. The drastic decline he demonstrates in the larger size classes would have been masked considerably if he had lumped all sizes together. Magnusson (1979) reported large numbers of *Paleosuchus trigonatus* in a number of habitats sampled, but examination of the size frequency distribution revealed a total lack of animals less than one year old. This apparently healthy population therefore probably lacked some resource essential for breeding or for growth of young and was maintained by recruitment from elsewhere. The relative proportions of animals of each size also can be important for estimating population sizes from surveys of particular segments of the population, such as nesting females (Chabreck 1966; Palmisano et al. 1973; Nichols et al. 1976).

Another aspect that may be important is the distribution of sexes. Joanen and McNease (1972), McNease and Joanen (1974), and Goodwin and Marion (1978) discussed sex-related differences in movements of alligators, and Palmisano et al. (1973) discussed how this relates to possible strategies of harvesting. Webb and Messel (1978a) discussed sex-related differences in movement of *C. porosus* in northern Australia. Unfortunately, crocodilians usually have to be captured to be sexed. This takes the exercise from a pure survey into a long-term study. Chabreck (1963) and Webb and Messel (1977a) gave details of various capture methods that have been developed for crocodilians. It is well to remember that different species vary in their habitat preferences, behavior, and temperment. Methods used for capturing one species may well be useless for another. Loveridge (1979) reviewed methods of immobilizing crocodilians with drugs if this is necessary (it rarely is in the context of surveys). The crocodilian can then be sexed by methods described by Brazaitis (1968), Chabreck (1963), or Joanen and McNease (1978). Most crocodilians older than six months can be sexed with a fair degree of accuracy, but *A. mississippiensis* may not be sexually differentiated until more than 12 months old (Joanen and McNease 1978; Nichols and Chabreck 1980). The most effective method is direct observation of the penis or clitoris by gently opening the cloaca, though inserting a finger and feeling for the penis is reliable for larger animals.

Once the animal is in hand it is worthwhile to weigh, measure,and mark it, and hence increase its value if caught again. Webb and Messel (1978b) discussed morphometric data that are commonly taken,and Chabreck (1963) and Whitaker (1978) discussed marking techniques. It may even be considered worthwhile to take other biological data, such as stomach contents (Taylor et al. 1978), record marks and injuries (e.g. Webb and Messel 1977b), and external parasites.

While capture of animals under survey conditions is difficult and hence subsequent data difficult to obtain, making estimates of sizes is not. It is difficult to see how not making size estimates during surveys could be justified as the potential gains are so great.

Habitat Data

Details of habitat are easy to record and may be critical to the interpretation of results. Differential use of habitat by particular sexes and ages has already been discussed (Parker and Watson 1970; McNease and Joanen 1978; Webb and Messel 1978a). Sometimes a detailed habitat description will allow the area to be recognized on future surveys, and presentation of results stratified by area and habitat allows more detailed analysis (Graham 1968; Parker and Watson 1970) as well as facilitating comparison with follow-up surveys (see Pernetta and Burgin 1980 for an excellent presentation of survey data).

Sometimes a detailed knowledge of habitat use by a species may allow information to be gained from a survey of that habitat alone. Hines (1979) discussed the extent of habitat suitable for *A. mississippiensis* in Florida, and McNease and Joanen (1978) established the relative suitability of various marsh types for alligator nesting in Louisiana. Their study formed the basis of population estimates for alligators in Louisiana and their subsequent harvest (Palmisano et al. 1973). Magnusson (1980) established the suitability of a range of habitats for nesting by *Crocodylus porosus* in Arnhem Land, Northern Australia, and this formed the basis of aerial surveys of suitable nesting habitat in Arnhem Land (Magnusson et al. 1978), Cape York Peninsular (Magnusson et al. 1980), and the Alligator Rivers region (Grigg and Taylor 1980).

PLANNING A SURVEY

There is no single survey plan applicable to all species and conditions. If there were, the variety of techniques alluded to in the foregoing sections would not have been developed. However, there are a number of basic aspects that will enter into all surveys:

1. Know your animal.-- Despite the method used, the basic truth is that the quality of the survey is directly proportional to the experience of the researcher. If planning a survey and lacking a great deal of experience with the animal in question, try to spend some time with another researcher who has experience with similar species in similar habitats. This may avoid repetition of a lot of mistakes that have been made before.

2. Use local knowledge with care.-- A researcher arriving in a new area is usually impressed with the detailed knowledge of the local people,

and rightly so. The problem lies in translating this knowldge into data interpretable by the researcher. For example, initial studies on crocodile nesting habitat in northern Australia indicated a strong preference by crocodiles for a particular grass, Ischaemum australe. Most nests were located by aboriginal hunters with detailed knowledge of the area. It was only in the second year of the study that the hunters realized the researchers were interested as much in the range of habitats used as in the number of nests found and demonstrated that the crocodiles use a range of habitats in proportion to their availability (Magnusson 1980). While accepting the extent of the local peoples' knowledge, researchers should always question their interpretations of what they are being shown.

3. Research the history of the population to be studied.-- Before commencing try to deterimine historical, present, and predicted land use patterns in the area, the past and present levels of exploitation of crocodilians, and what research has already been carried out on the species which might allow special types of survey.

4. Be familiar with the geography of the area.-- Determine the amount and distribution of the various habitats that the crocodilians might be using and do replicate sampling in each, even if this reduces the number of crocodiles seen. Try to cover as representative a number of areas as possible and avoid the common tendency of concentrating on areas in which it is easy to find animals. Detailed maps or aerial photographs are invaluable.

5. Collect data on population structure.-- A minimum requisite for interpretation of results is the size structure of the population, stratified by area and habitat. If necessary, practice making size estimates on zoo animals.

6. Decide how to analyze the results before starting.-- How, where, and when to collect data will depend on what the study is attempting to demonstrate. Be sure the question or premise is clear before starting. Treat all surveys as if they were the first of a series, whether funds are presently available for repeat surveys or not. Any elementary statistics book will give a range of analyses for making tests for differences between areas and/or surveys. Be sure that data are collected in such a way that they can be plugged into some such test. Basic requirements for all analyses are replication and stratification.

7. Standardize conditions as far as practicable.-- It is not always possible to standardize all factors, but be aware of the probable causes of bias and record enough data regarding them that sensible decisions can be made as to their probable effect on the final results.

8. Allow sufficient time for the survey.-- How much time is required will vary according to the area to be covered, the researcher's previous experience, and the support facilities. In developing countries it is well to allow one week of dealing with the bureaucracy for each two weeks

of attempted survey, and, to expect one week of ineffectual survey (transport, equipment difficulties) for each week of effective survey. Most people unfamiliar with an area underestimate the time required to survey. Even a small area usually requires several months (or several years of experience leading to several weeks of survey). Often a biologist visits a country for several weeks and produces a "status report." In fact such studies do not give data on the status, they establish the urgency (priority) for determining the status of the population. A true status report for even a tiny country requires many months, if not years of work. For this reason the advantage of persons resident, or with regular access to the area, being included in the survey team cannot be overestimated.

The following people are experienced in crocodilian surveys and are currently working in the field:

Alistair Graham - C. niloticus, C. noveaguinae, C. porosus (Papua New Guinea)

Gordon Grigg - C. porosus (aerial survey of habitat, Australia)

Ted Joanen and Larry McNease - A. mississippiensis (Louisiana)
James Kushlan - A. mississippiensis, C. acutus (Florida)

William Magnusson - C. porosus (Australia), M. niger, C. crocodilus, P. palpebrosus, P. trigonatus (Brazil)

Harry Messel - C. porosus (Australia)

Tony Pooley - C. niloticus (South Africa)

Grahame Webb - C. johnsoni (Australia)

Alan Woodward and Tommy Hines - A. mississippiensis (Florida)

The following people can give details of monitoring programs now in effect:

Tommy Hines, Florida, U.S.A.
Sixto Ichaustegui, Dominican Republic
Robert Jenkins, Australia
Ted Joanen, Louisiana, U.S.A.
Navu Kwapena, Papua New Guinea
Tony Pooley, South Africa
Romulus Whitaker, India

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