Monitoring the Recovery of Siamese Crocodiles in Wetlands of the Xe Champhone Ramsar Site, Savannakhet Province, Lao, PDR

Steven G. Platt
Wildlife Conservation Society
Myanmar Program

Report to:
Wildlife Conservation Society
P.O. Box 6712
Vientiane, Lao PDR

7 May 2021

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Acknowledgements

This report benefited from discussions with Thomas Rainwater, Lonnie McCaskill, Sitha Som, and Lewis Medlock. Cassandra Paul, Ruth Elsey, and Thomas Rainwater provided critical literature references. Lonnie McCaskill, Thomas Rainwater, and Lewis Medlock are thanked for allowing use of their photographs. An early draft of this report benefited from the review of Lewis Medlock.

Cover photograph: Collecting eggs from a Siamese crocodile nest near Tan Soum Village in the Xe Champhone Ramsar Site.

I. Introduction

Monitoring of animal populations is defined as the estimation of absolute or relative abundance for the purpose of drawing inferences about variation in abundance over time and/or space (Nichols and Karanth 2012). Unlike a survey which determines conditions at a single point in time, monitoring tracks changes over time, and if properly conducted, can determine if wildlife populations are increasing, decreasing or stable (Kremen et al. 1994). Such data are essential for establishing appropriate conservation objectives, evaluating the effectiveness of management interventions and policy decisions, assessing the impact of threats, and informing stakeholders (Hedges 2012). Most importantly, long-term monitoring can ultimately develop a body of empirical knowledge with the potential to improve the predictive capacity of managers to deal with novel situations, thereby increasing the effectiveness of conservation strategies (Hedges 2012). As such, population monitoring should be a key component of any long-term conservation plan (Kremen et al. 1994).

Developing effective methodologies for monitoring Siamese crocodile (*Crocodylus siamensis*) populations in the Xe Champhone wetlands (now Xe Champhone Ramsar Site) was accorded high priority in the long-term recovery plan prepared by Wildlife Conservation for this flagship species (Hedemark et al. 2009; Platt 2012). Successful monitoring of Siamese crocodiles in the Xe Champhone wetlands will allow conservation actions to be assessed in an adaptive management context (e.g., Walters 1986). Ideally the methodology used by Village Conservation Teams (VCTs) should be relatively simple, inexpensive to implement, and yield an index of relative abundance that accurately reflects changes in crocodile populations over time. Herein I review and evaluate four potential methodologies (nocturnal spotlight counts, camera trapping, track and sign surveys, and nest counts) proposed for monitoring Siamese crocodile populations in the Xe Champhone wetlands (Platt et al. 2014), and make recommendations based on that assessment.

II. Review of Monitoring Methods

Nocturnal spotlight counts

Nocturnal spotlight counts (Figure 1) are used to census crocodilian populations worldwide and a variety of other population estimation techniques (e.g., mark-recapture) have confirmed the accuracy of this methodology (Bayliss 1987; Hutton and Woolhouse1989; King et al. 1990). Spotlight surveys are generally conducted from a boat (Bayliss 1987; Fukuda et al. 2013), but can also be done from land (Subalusky et al. 2009); headlamps are used to search for the reflective eyeshines of crocodilians along transects, often defined by the shoreline of rivers or lakes (Chabreck 1966; Bayliss 1987). Spotlight counts are used to calculate an encounter rate (crocodiles observed/km of survey route), which serves as index of relative abundance because not all crocodiles present are observed during a survey (Bayliss 1987). The relationship between the spotlight count and actual population size is assumed to remain constant over time, such

Figure 1: Nocturnal spotlight counts are used to survey and monitor crocodilian populations throughout the world. Spotlight surveys are most effective in rivers, creeks, and open lacustrine habitats, but unsuited for use in the densely vegetated swamps and marshes of the Xe Champhone Ramsar Site. (Photographs by Lewis Medlock).

that any change in the encounter rate should reflect a proportional change in the total population (Bayliss 1987; Nichols 1987). An important, although often unstated assumption of relative indices is that detectability remains constant across space and time (Nichols 1987; Subalusky et al. 2009). Relative indices are powerful tools for monitoring population trends when survey techniques are standardized (Bayliss 1987). Sighting probabilities can also be calculated from repeated spotlight counts, which allow calculation of a "sighting fraction", i.e., the proportion of the population observed during a single survey. The absolute population size can then be estimated if the sighting fraction is known (King et al. 1990).

Our previous fieldwork (2011-213) found that nocturnal spotlight counts were an ineffective monitoring tool for Siamese crocodiles in the Xe Champhone wetlands owing to the dense aquatic and shoreline vegetation that 1) precluded boat access to many areas inhabited by crocodiles and 2) provided excellent concealment for crocodiles (Platt et al. 2014). Our spotlight counts failed to detect crocodiles even in areas where tracks, scats, and nesting activity indicated crocodiles were present. These results are unsurprising as spotlight counts are most effective in open lacustrine and riverine habitats where the likelihood of detecting crocodilians is generally high. In marshes and swamps, detectability can be severely curtailed by aquatic vegetation that obstructs viewing and provides concealment for crocodiles (Webb 2000; Platt et al. 2004; Subalusky et al. 2009). Similar to our results, Bezuijen et al. (2013) observed few crocodiles during spotlight counts of other comparable habitats in Lao, and concluded this methodology was ill-suited for use in densely vegetated wetlands, particularly at sites harboring low numbers of crocodiles. Furthermore, because individual sighting probabilities are usually low even where crocodilians are abundant (9-25%; Taylor and Neal 1984; Woodward et al. 1996), spotlight counts have limited utility for monitoring low density populations such as those in Xe Champhone wetlands. When individual sighting probabilities are depressed, the effort required to detect crocodiles becomes prohibitively high (Bezuijen et al., 2013). For these reasons, we regard spotlight counts as an inappropriate methodology for long-term monitoring of Siamese crocodile population trends in the Xe Champhone Ramsar Site and associated wetlands.

Camera trapping

Camera trapping is a particularly effective tool for monitoring large mammals (Swann et al. 2004), but has also been used successfully with smaller mammals, birds, and on occasion reptiles, including crocodilians (Thorbjarnarson et al. 2000; Platt et al. 2002; Charruau and Hénaut 2012; McGrath et al. 2012; Chowfin 2013). During our earlier efforts (2012-13), we assessed the use of camera traps to detect Siamese crocodiles in the Xe Champhone wetlands (Platt et al. 2014). We deployed Reconyx®

Figure 2: Camera traps are best deployed at active crocodilian nests. This image records nest visitation by a female American alligator (*Alligator mississippiensis*) in South Carolina, USA (Photograph courtesy of Thomas R. Rainwater).

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camera traps at bait stations consisting of a domestic chicken carcass suspended above the water at locations where tracks, scats, and local reports indicated crocodiles were likely to be found. We positioned camera traps to cover the bait as well as the probable avenue of approach. When triggered, cameras took three photographs with a two second interval between exposures. Camera traps (N = 19) were deployed in late February and recovered in early May. Trapping effort (trap nights) was calculated for each site as the number of nights each camera was deployed multiplied by the total number of cameras deployed at a site (Trap Nights = 1294). We also placed camera traps (N = 4) near active nests during May-June 2012 and 2013 in an attempt to photograph attending female crocodiles. Cameras were mounted on trees near the nest, or if suitable trees were unavailable, a small wooden frame was constructed approximately 3-4 m from the nest mound.

Our camera trapping at bait stations yielded no photorecords of crocodiles, although various birds and small mammals were detected. Crocodiles apparently failed to respond to the bait we provided, which was somewhat surprising given that carrion is usually quickly consumed when available (Atwell 1959). That said, we cannot rule out the possibility that crocodiles approached our bait stations, but failed to trigger cameras. Merchant et al. (2012) found that motion-sensitive infrared cameras were unable to consistently make photo-captures of American alligators (*Alligator mississippiensis*) under captive conditions, and suggested a number of technical modifications to improve the likelihood of successfully photographing crocodilians. Based on our results, camera trapping was deemed an unsuitable tool for monitoring crocodiles in the Xe Champhone wetlands (Platt et al. 2014).

Our efforts to photograph crocodiles at active nests proved somewhat more successful, although we experienced technical problems with the equipment, visitation by females was infrequent, and properly positioning cameras was difficult owing to multiple avenues of approach that needed to be covered (Platt et al. 2014). Nonetheless, camera traps placed on two nests in 2012 and again in 2013, yielded a series of poor-quality images of an adult crocodile (presumably the attending female) taken at Kout Mark Peo in June 2013. Small rodents (potential predators of crocodile eggs) were also occasionally photographed at crocodile nests. In summary, camera trapping appears to be a suitable technique for monitoring nest attendance by female Siamese crocodiles (Figure 2). Performance can be enhanced and detectability of crocodiles improved by programming camera traps to take photographs at intervals of 1-5 minutes rather than relying on the motion and infrared sensors to trigger the units (Rainwater, unpubl. data).

Track and sign surveys

Track and sign (scats, basking sites, drags) surveys require minimal training, are relatively inexpensive to implement, and except for the wettest months, can be conducted at frequent intervals throughout most of the year (Figure 3). However, based our past experience track and sign surveys are unsuitable for long-term population monitoring because survey results are highly variable and difficult to interpret, and probably depend on poorly understood intrinsic and extrinsic factors such as substrate condition, water levels, and social interactions between crocodiles (e.g., large crocodiles could control access to basking sites). Nonetheless, track and sign surveys are useful for determining the presence/absence of crocodiles at a site, provide crude estimates of the minimum number of crocodiles inhabiting a wetland, and might be useful in determining approximate size-class distributions (Platt et al. 1990; Wilkinson and Rice 2000; Simpson 2006; Platt et al. 2009). Despite the limited utility of the data collected, track and sign surveys also serve to actively engage villagers in crocodile conservation efforts, maintain a team presence in the field that can discourage poaching and other illegal activities, and instill a sense of community involvement and pride in the conservation project (Platt et al. 2014).

Nest counts

Nest counts are a valuable tool in crocodilian managements programs and have been successfully employed to monitor populations of both hole- and mound-nesting species (McNease et al. 1994; Rainwater and Platt, 2009). Trends in nest count data provide a statistically rigorous means to assess the numerical response of populations over time (Nichols 1987; McNease et al. 1994). Furthermore, if the proportional representation of sexually mature females in the population can be determined, nest counts can also be used to estimate population size (Chabreck 1966; Nichols 1987; Webb et al. 1989). This method is most applicable to crocodilians that construct conspicuous nests in open habitats (e.g., *Alligator mississippiensis*) or in the case of hole-nesting species,

Figure 3: Crocodile scat found at wetlands in the Xe Champhone Ramsar Site. Track and sign surveys can be used to determine presence/absence of crocodiles, but are unsuitable for long-term population monitoring.

concentrate at specific sites each year to deposit eggs (e.g., *Crocodylus acutus*). A number of crocodilian management programs employ aerial surveys to quantify annual nesting effort because even in densely vegetated habitats inaccessible to boats where spotlight counts are infeasible, nests are often readily detectable from unmanned aerial vehicles (drones), helicopters, or low-flying fixed wing aircraft (McNease et al. 1994; Elsey and Trosclair 2016). Moreover, because many species exhibit strong interannual nest-site fidelity (Elsey et al. 2008; Platt et al. 2008), once these sites have been identified, searching tends to become increasingly efficient over time. Long-term population trends can be determined by regressing annual nesting effort (y) against year (x) (McNease et al. 1994). The average rate of population change can then be calculated from the slope of the linear relationship between annual nesting effort and year (Bayliss et al. 1989).

Given the difficulty of detecting crocodiles during nocturnal spotlight counts in heavily vegetated habitats, and the limitations of camera trapping and track and sign surveys, annual nest counts appear to be the most appropriate method for monitoring long-term population trends of Siamese crocodiles and evaluating the success of our conservation actions in the Xe Champhone wetlands (Platt 2021; Platt et al. 2014). Because linear regressions require at least five data points for meaningful interpretation (Zar 1996), a minimum of five years of nest count data must be accrued before population trends can be statistically detected.

Several additional considerations are important when using nest counts to monitor the recovery of Siamese crocodile populations. First, the Champhone River corridor provides connectivity between wetlands and crocodiles inhabiting these sites are interacting as a single metapopulation. Thus, population trends should be analyzed by pooling nest count data across all sites. Second, given the small number of crocodiles present at each conservation site, trends may – at least initially - be masked by annual variability in reproductive effort (Webb et al. 1989). Third, a considerable lag between population recovery and an increase in the number of nests can be expected owing to the time required for young crocodiles to attain sexual maturity and enter the pool of reproductive adults. Thus, several years may elapse before an actual population increase is reflected in nest count data. The number of viable eggs must also be taken into account when evaluating population recovery. If significant numbers of non-viable eggs are being produced by females, other management options (e.g., release of adult males) should be considered. Lastly, it must be recognized that on occasion, a nest will escape detection. In that case, reports of hatchlings encountered by villagers should serve as a proxy for an actual nest in the annual count, i.e., a group of neonate crocodiles should be scored as a single nest when determining trends over time. Below, specific recommendations are provided for conducting an annual hard-target search for Siamese crocodile nests in the Xe Champhone Ramsar Site.

III. Protocol for Annual Hard-Target Nest Searches

Objectives

Our objectives are two-fold: 1) Obtain Siamese crocodile eggs for incubation at village facilities. Head-started crocodiles will eventually be released in local wetlands to augment the existing population and increase the trajectory of population recovery. 2) Quantify annual nesting effort and ultimately determine the long-term trend of the Siamese crocodile population in the Xe Champhone Ramsar Site.

Timing

The reproductive phenology of *C. siamensis* in Lao appears to vary somewhat between populations in neighboring Thailand and Cambodia (Platt et al. 2014). In Lao, our experience suggests a close correlation between crocodile nesting activity and the annual monsoonal cycle. To briefly summarize, courtship and mating probably occur during March and April, followed by nest construction and clutch deposition in mid-May and early June. Eggs incubate through July and hatching occurs in August and September after a period of about 75 -80 days (Brazaitis and Watanabe 1983; Platt et al. 2011). Given this reproductive phenology, nest searches are best conducted in mid- to late June. Postponing nest searches until late June or early July increases the likelihood that clutches will be lost due to monsoonal flooding.

Searching

Locating Siamese crocodile nests can be challenging. Siamese crocodiles construct typical mound nests composed of vegetation, soil, and woody debris. Nests are large mounds (ca. 1.5 m wide and 0.75 m high) that can be conspicuous when constructed at an open microsite. However, females often conceal nests in thickets of tangled vegetation or beneath a dense tree canopy. Nests in the Xe Champhone wetlands are usually positioned along the shoreline in close proximity to water and on floating mats of vegetation. Two methods should be used when searching for crocodile nests. First, intensive foot searches should be repeatedly conducted during the nesting season (mid-May through June) by VCTs in their assigned Area of Responsibility (AOR). This AOR will consist of village wetlands of which the VCT is intimately familiar owing to their life-long association with these habitats. Given the high degree of site fidelity exhibited by reproductive female crocodilians, particular attention should be devoted to searching locations where crocodiles have nested in previous years. Repeated searches (at least once every two weeks) are necessary because nest construction by individual females is staggered throughout May and June; i.e., a single search will fail to detect nests constructed later in the season. Searching skills of VCTs are expected to improve over time.

Floating mats of vegetation are a favored site for crocodile nest construction in the Xe Champhone Ramsar Site, but an especially difficult habitat to search on foot. We therefore recommend that search effort by VCTs be supplemented with reconnaissance flights by unmanned aerial vehicles (UAV) operated by an individual skilled at identifying crocodile nest mounds. Both fixed-wing and rotary UAVs have been successfully employed to search for crocodilian nests (e.g., Elsey and Trosclair 2016; Scarpa and Pina 2019), although the latter are preferred (Figure 4). Specific models for consideration include the Mavic 2 and Autel 2 6K. UAV surveys should be conducted in late June, at which time nest construction and egg-laying by female crocodiles is expected to be completed. Regardless of whether or not eggs will be collected, each nest should be inspected and opened to determine the clutch size and confirm the presence of viable eggs (see below). Both clutch size and egg viability rates are essential demographic parameters for measuring population recovery.

Egg collection

Except in the event of unforeseen and extenuating circumstances, crocodile eggs should only be collected by VCTs operating under the direct supervision of WCS personnel. The latter should be immediately notified when an active nest is discovered and arrangements made to recover the clutch as quickly as possible. Upon arriving at the nest, GPS coordinates should be recorded and multiple photographs taken of the nest and surrounding habitat from different angles. Before opening the nest, the width and height of the mound should be measured (in cm), distance to the nearest water determined (in meters, preferably along the route used by female), and tree canopy cover directly above the nest estimated (in increments of 20%). The top of the nest mound should then be carefully opened to expose the clutch. Each egg should be gently removed from the nest and the dorsal surface marked with a pencil to maintain the proper orientation during handling (rotation of the egg can result in embryo death). The length and width of each egg should be measured (in mm) with a dial caliper, egg mass determined (in grams) with a Pesola spring balance or digital scales, and the presence (or absence) of an opaque band noted. Photographs should be taken of the opaque bands from a series of eggs (N = 10); these can be used later to estimate the date of clutch deposition. After processing, eggs should be securely packed in a Styrofoam box containing natural nesting material and transported to a designated incubation facility. Care must be taken to minimize jarring and vibration while the eggs are being transported. Once at the facility, eggs should be placed in McCaskill Chambers for artificial incubation.

Measuring population trends

Long-term population trends can be determined by regressing annual nesting effort (y) against year (x) (McNease et al. 1994). The average rate of population change can then be calculated from the slope of the linear relationship between annual nesting effort and year (Bayliss et al. 1989).

Figure 4: American alligator nests photographed from an unmanned aerial vehicle (drone) in Florida, USA. Note well-worn trails surrounding nest and the head of an attending female alligator at the 5 o'clock position (top photograph). Female alligator in lower photograph is visible at 10 o'clock position (Photographs courtesy of Lonnie McCaskill).

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