Movement of captive-reared Siamese crocodiles *Crocodylus siamensis* released in the Southern Cardamom National Park, Cambodia

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មូលន័យសង្ខេប

ធ្លាប់តែមានរបាយធំទូលាយនៅអាស៊ីអាគ្នេយ៍ ក្រពើភ្នំ(*Crocodylus siamensis*) បច្ចុប្បន្នជាប្រភេទជិតផុតពូជធ្ងន់ធ្ងរបំផុតជាសកលនៅក្នុងចំណោមពពួកក្រពើទាំងអស់។ គេជឿជាក់ថាប្រទេសកម្ពុជាជាជម្រកដ៏ធំជាងគេបំផុតនៃប៉ូពុយឡាស្សុងព្រៃដែលនៅសេសសល់នេះ ដូច្នេះការពង្រឹងការអភិរក្សក្រពើភ្នំក្នុងប្រទេសកម្ពុជា ជាការងារអាទិភាពបំផុត។ ការសិក្សានេះមានគោលបំណងស្វែងយល់ពីបំលាស់ទីនិងការរស់នៅរបស់ក្រពើភ្នំដែលបានលែងទៅក្នុងព្រៃធម្មជាតិ ដែលជាកម្មវិធីថ្នាក់ជាតិស្តីពីការស្តារក្រពើភ្នំឡើងវិញ។ នៅក្នុងការសិក្សានេះ ក្រពើភ្នំមានចំនួន១៥ក្បាលត្រូវបានបំពាក់ឧបករណ៍វិទ្យុទាក់ទងនិងតាមដានរយៈពេល១៨ខែ បន្ទាប់ពីបានលែងទៅក្នុងឧទ្យានជាតិជូរភ្នំក្រវាញខាងត្បូង ប៉ែកនិរតីនៃប្រទេសកម្ពុជា។ ក្រពើភ្នំចំនួន១៣ក្បាលបានផ្លាស់ទីប្រមាណ ៧០០មពីទីកន្លែងលែង ក្នុងអំឡុងពេលតាមដាន (ការតាមដានប្រព្រឹត្តទៅនៅរដូវប្រាំង)។ លទ្ធផលនេះ បង្ហាញថាអាកប្បកិរិយារបស់ក្រពើភ្នំភាគច្រើនមិនផ្លាស់ទីឆ្ងាយពីកន្លែងលែងទេ ដែលត្រូវគ្នាទៅនឹងការសិក្សាកន្លងមកលើក្រពើភ្នំធម្មជាតិនៅក្នុងតំបន់ជូរភ្នំក្រវាញ។ ការរស់នៅជិតកន្លែងលែងអាចជាប្រយោជន៍ចំពោះខ្លួនវា ព្រោះវាបន្តយឱកាសក្នុងការខិតជិតជាយជម្រកឬតំបន់ដែលបង្កឲ្យពួកវាមានជម្លោះជាមួយមនុស្ស។

Abstract

Once widely distributed throughout Southeast Asia, the Siamese crocodile *Crocodylus siamensis* is currently one of the world's most Critically Endangered crocodilian species. Because Cambodia is home to the largest remaining wild population, conservation efforts within the country should be considered of upmost importance. This study was aimed to understand the movement and survival of captive-reared Siamese crocodiles released as a part of a national reintroduction and reinforcement programme. In the study, 15 juvenile and sub-adult crocodiles fitted with VHF radio transmitters were monitored for up to 18 months after release in the Southern Cardamom National Park, southwestern Cambodia. Thirteen of the crocodiles were detected within 700 m of the release site during monitoring, which occurred mostly during the dry season. Their sedentary behaviour was consistent with previous studies of young Siamese crocodiles in the Cardamom Mountains. Remaining close to release sites may be beneficial for crocodiles by reducing chances of their moving to more marginal habitats or areas where conflict could potentially occur with people.

Keywords

Movement patterns, radio-tracking, reintroduction, Siamese crocodile.

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Introduction

The Siamese crocodile *Crocodylus siamensis* is considered one of the world's most Critically Endangered crocodilian species (IUCN, 2015), and is one of the least studied in the wild. The species was once widely distributed throughout Southeast Asia, specifically in Indonesia, Malaysia, Thailand, Laos, Cambodia, Vietnam and possibly Myanmar and Brunei (Ross, 1998). By the early 1990s, Siamese crocodile was reported to be effectively extinct in the wild, but scattered populations have since been discovered in Cambodia, Laos and Indonesia (Kalimantan) (Daltry & Chheang, 2000; Kurniati *et al.*, 2005; Platt *et al.*, 2006; Simpson *et al.*, 2006). Cambodia has the largest remaining wild population, but this is widely fragmented across the country and very few nests are recorded annually (Bezuijen *et al.*, 2006; Sam *et al.*, 2015).

Populations of the Siamese crocodile have been greatly depleted and fragmented in Cambodia by illegal poaching for the skin trade, live capture for stock farms, egg-collection, and hunting for meat (Nao & Tana, 1994; Thorbjarnarson, 1999). Additionally, crocodile farms frequently hybridize Siamese crocodile with Cuban crocodile *C. rhombifer* and saltwater crocodile *C. porosus*, and there is at risk of such hybrids escaping or being released into the wild (Simpson & Bezuijen, 2010; Starr *et al.*, 2010; Daltry *et al.*, 2016). Although the threat of hunting and wild capture has reduced in Cambodia, recovery of wild populations is still impeded by poor reproductive rates, habitat conversion and degradation, and incidental deaths from drowning in fishing gear (Simpson & Sam, 2004). Furthermore, the chances of unaided population recovery are reduced by the small and scattered nature of existing populations in the wild.

Although Siamese crocodile was originally described over 200 years ago, very little is known about ecology and biology of the species in the wild (Simpson & Sam, 2004). The few studies published indicate that the species inhabits a wide range of freshwater habitats including slow-moving rivers, streams, oxbow lakes, seasonal lakes, marshes, and swamps up to 730 m a.s.l. (Daltry *et al.*, 2003; Simpson *et al.*, 2006). Studies conducted during the dry season (December–April) in the Cardamom Mountains of southwestern Cambodia have found wild crocodiles to be highly sedentary, typically remaining within a lake or short length of river (Simpson *et al.*, 2006). Conversely, during the wet season (May–November) adult Siamese crocodiles have been recorded dispersing up to 25 km before returning to a dry season site (Simpson *et al.*, 2006).

Because remaining populations of the species are small and fragmented, reintroduction and/or reinforcement via the release of captive-bred animals into secure natural habitats is an important strategy to recover wild populations (Thorbjarnarson, 1992; National Crocodile Conservation Network, 2012). Understanding how released animals adapt to their new environment is critical to the success of any reintroduction or reinforcement programme. We present the results of radio-tracking conducted on 15 captive-reared Siamese crocodiles that were released in the Southern Cardamom National Park in 2012 (n=10) and 2014 (n=5). The aim of our study was to understand the movements and survival of crocodiles taken from captivity and released into the wild.

Methods

Study site

The crocodiles were released in one of eight sites identified by the Cambodia Crocodile Conservation Programme for reintroduction and reinforcement of Siamese crocodile in the Cardamom Mountains (National Crocodile Conservation Network, 2012) (Fig. 1). The site is located in Srae Ambel District, Koh Kong Province within the Southern Cardamom National Park and comprises hill evergreen forest, semi-evergreen forest and open forest and grassland, with an elevation range of 10–600 m a.s.l.

Names of localities and landscape features at the release site are not provided in this paper to protect the crocodiles. The release site comprised a section of river located at an elevation of 70 m a.s.l., approximately 5 km from its headwaters. The nearest village was located 12 km downstream. The width of the river ranged from 30 to 50 m, and riverine habitats included a mixture of rocks, sandbars, and vegetation in the water, with rapids separating deepwater sections (*anlong* in Khmer) which have an average minimum dry season depth of 4.39 m (± 1.95m SD) and length of 300–1,000 m.

Release procedures

Release of the crocodiles followed protocols given in the *Siamese Crocodile Reintroduction and Reinforcement Strategy and Action Plan* (National Crocodile Conservation Network, 2012). Prior to release, all of the crocodiles in this study were cared for at the Phnom Tamao Wildlife Rescue Centre (PTWRC), and originated from confiscations made by law enforcement officials and donations from other captive facilities. All of the animals were identified as 'purebred' Siamese crocodiles through DNA testing (Starr *et al.*, 2010). They were also medically cleared by veterinarians belonging to the Wildlife

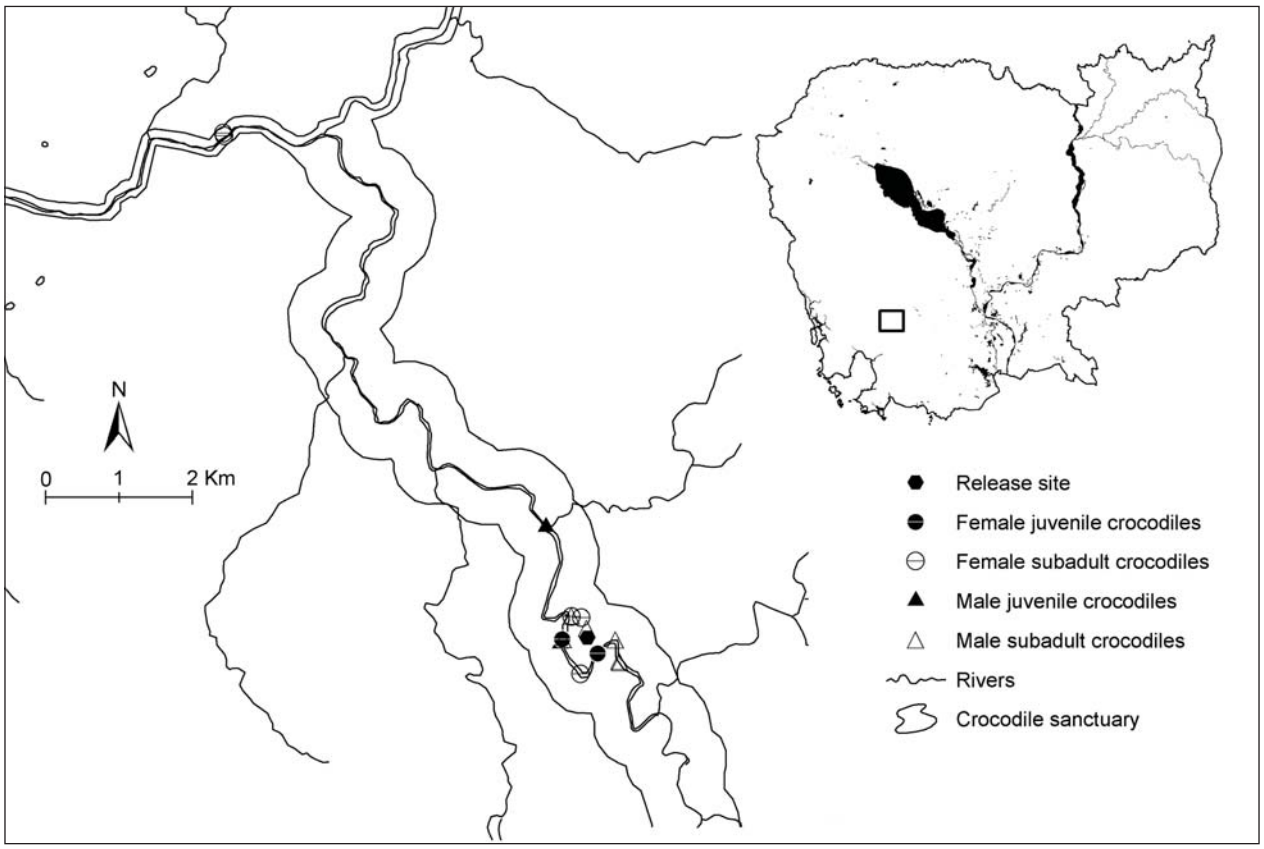

Fig. 1 General location of Siamese crocodile release area in Cambodia and last recorded locations of crocodiles.

Conservation Society to ensure they were in good health before release.

A temporary enclosure (5 m x 8 m) was constructed on the river bank at the release site which extended four metres into the river. The crocodiles were kept in the enclosure for about one week to allow them to recover from the journey from PTWRC and to monitor their condition and ensure they were ready for release. Eighteen crocodiles were released in the project site in 2012 and eight in 2014. Ten and five of these, respectively, were fitted with VHF radio-transmitters (150 MHz, Sirtrack Ltd, New Zealand) (Table 1). Small radio-transmitters (weighing ca. 40 g) with expected battery life of 13 months were attached to the dorsal base of the tail of four juvenile animals (ranging from 132 to 149 cm in total length). Larger radio-transmitters (weighing ca. 50 g) with expected battery life of 18 months were attached to the same part of 11 sub-adult crocodiles (ranging from 155 to 183 cm in total length).

Data collection and analysis

Radio-telemetry of the 15 crocodiles was undertaken for a total of 282 days from December 2012 to June 2015. Because the release site and surrounding area were inaccessible in July–October due to the wet season, all data collection was conducted during the dry season. Monitoring was conducted for 5–7 days every month when the site was accessible (specifically November–June). Observations were carried out on boat or on foot using a portable 3-element Yagi antenna attached to a 16-channel receiver (Advanced Telemetry Systems, USA). Signals could usually be detected from distances up to 500 m and 5–10 m in depth and crocodile locations were registered using hand-held GPS receivers. A 9-km stretch of river was surveyed (comprising 2 km upstream and 7 km downstream of the release site) for five days during each survey. If crocodiles were not located during this period, one to two additional days were devoted to surveying areas beyond the aforementioned stretch of river.

The mean minimum daily distance travelled by individual crocodiles was calculated using location data from successive days and calculating Euclidean distances between points. The release site was used as the reference point to determine average distances that crocodiles travelled from the release site. ArcGIS (vers. 10.2.2) and MS Excel were used for calculations.

Results

The number of times each crocodile was detected after release varied greatly. One individual (M11) was detected only once, three days after release; five (M1, F2, M8, M12 & F13) were detected less than six months after release; and five (M3, F4, F6, M9 & F14) were found six to seven months after release. Four crocodiles (M5, M7, F10 & F15) were detected after one year and the latest detection occurred 18 months after release (Table 1). None of crocodiles released were found or reported dead.

Thirteen of the 15 crocodiles remained within 700 m of the release site during the survey period. The two exceptions were sub-adult females (F6 and F15; Table 1) whose final detections were in the same *anlong* ca. 10 km downstream of the release site and ca. 3 km upstream of the nearest village (Fig. 5). The mean minimum distance travelled by crocodiles per day was 280.91 m (SD = 189.87) and the mean minimum distance crocodiles were located from the release site was 741.12 m (SD = 1,095.28) (Table 1).

There was little difference between the distances travelled by male and female crocodiles. On average, females (n=7) travelled 349.56 m/day (SD = 250.86), whereas males (n=8) travelled 220.84 m/day (SD = 96.55 m/day) (Fig. 2). Mean distances from the release site recorded for female crocodiles were 1,138 m (SD = 1561.71) and 393.28 m (SD = 111.37) for males (Fig. 3). However, the figures for females are likely distorted by the two individuals that travelled 10 km downstream of the release site, while the remaining five females travelled a minimum distance of 435 m (SD = 234.09) from the release site.

Juvenile crocodiles (n=4) appeared to move less than sub-adult crocodiles (n=11), travelling 171.68 m/day (SD = 32.12) and 320.63 m/day (SD = 208.93) on average, respectively (Fig. 4). Juveniles were located 368.87 m (SD = 169.85) from the release site on average, whereas the equivalent figure for sub-adults was 876.49 m (SD = 1,263.03) (Fig. 5). Again however, the latter figures are likely distorted by the two individuals that travelled 10 km downstream from the release site.

Table 1 Siamese crocodiles released and monitored in southwestern Cambodia from 2012 to 2015.

Code name	Status	Total length (cm)	Start date	End date	No. of times recorded	Mean minimum distance (m) travelled per day	Mean distance from release site (m)
M1	Juvenile	132	13 December 2012	27 February 2013	19	203.33	388.64
F2	Sub-adult	156	13 December 2012	30 January 2013	11	260.36	161.44
M3	Sub-adult	176	13 December 2012	12 June 2014	20	327.66	609.98
F4	Juvenile	144	13 December 2012	19 January 2014	31	134.38	596.12
M5	Sub-adult	183	13 December 2012	10 May 2014	40	138.68	282.33
F6	Sub-adult	160	13 December 2012	21 May 2013	28	330.46	1,201.67
M7	Sub-adult	163	13 December 2012	12 June 2014	43	175.71	430.39
M8	Sub-adult	168	13 December 2012	26 February 2013	6	319.98	329.07
M9	Juvenile	148	13 December 2012	12 June 2014	17	193.03	290.15
F10	Juvenile	149	13 December 2012	12 June 2014	39	155.98	200.58
M11	Sub-adult	173	17 January 2014	20 January 2014	1	333.79	333.79
M12	Sub-adult	172	26 February 2014	20 March 2014	5	74.56	481.94
F13	Sub-adult	173	27 February 2014	12 June 2014	9	732.12	648.28
F14	Sub-adult	155	26 February 2014	12 June 2014	10	671.88	569.05
F15	Sub-adult	155	19 January 2014	25 April 2015	4	161.77	4,593.49

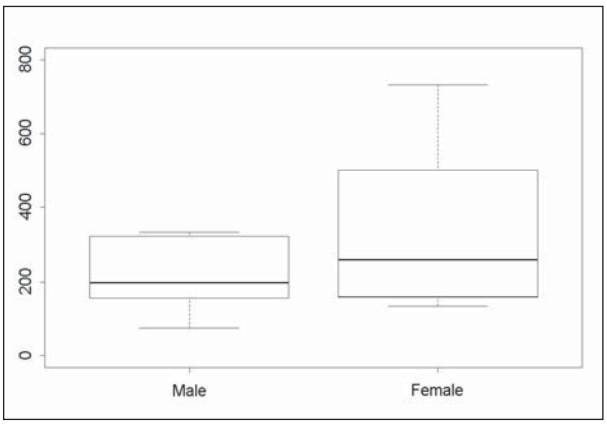

Fig. 2 Mean minimum daily distances (m) travelled by eight male and seven female Siamese crocodiles in southwestern Cambodia. Bold lines represent mean values, whiskers represent minimum and maximum values and boxes respresent lower and upper quartiles.

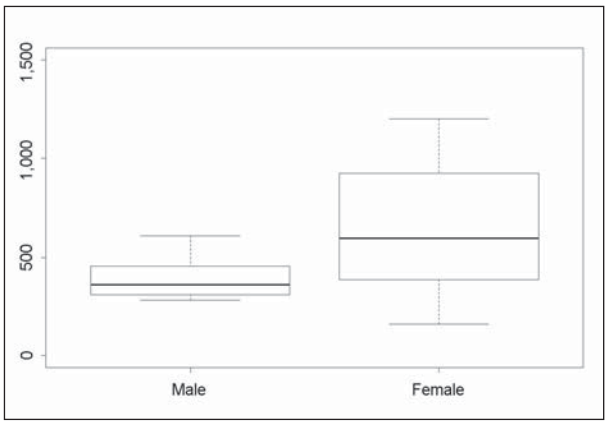

Fig. 3 Mean minimum distances (m) travelled from release site by eight male and seven female Siamese crocodiles in southwestern Cambodia. Bold lines represent mean values, whiskers represent minimum and maximum values and boxes respresent lower and upper quartiles.

Fig. 4 Mean minimum daily distances (m) travelled by four juvenile and eleven sub-adult Siamese crocodiles in southwestern Cambodia. Bold lines represent mean values, whiskers represent minimum and maximum values and boxes respresent lower and upper quartiles.

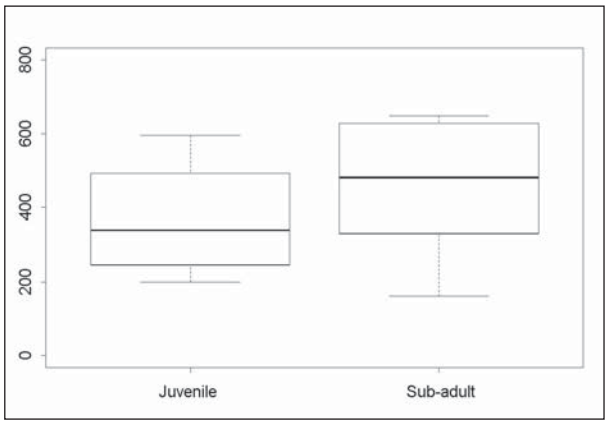

Fig. 5 Mean minimum distances (m) travelled from release site by four juvenile and eleven sub-adult Siamese crocodiles in southwestern Cambodia. Bold lines represent mean values, whiskers represent minimum and maximum values and boxes respresent lower and upper quartiles.

Discussion

Few studies have monitored the movements of captive-reared Siamese crocodiles released as part of a reintroduction programme, although similar releases have been undertaken e.g., Cat Tien National Park in Vietnam (Polet *et al.*, 2002). Our study suggests that captive-reared juvenile and sub-adult Siamese crocodiles released into novel environments show site fidelity during the dry season, at least for the first year after release. This suggests that such animals may have good prospects for surviving at suitable release sites.

Because visual sightings of the released crocodiles were rare due to their wariness, the fate of those not observed could not be confirmed. More than half of our study animals could not be located after six months, but no dead crocodiles were found or reported by local communities. The lack of observations in these cases could be due to other factors, such as equipment failure. For instance, Strauss *et al.* (2008) found that only 50% of batteries in VHF transmitters affixed to Nile crocodiles lasted longer than six months. Other crocodile release programmes have also experienced similarly high rates

of 'disappearance' (e.g., Ballouard *et al.*, 2010), but without direct evidence of mortality, it is difficult to know if this might be due to batteries expiring, device failure, or dispersal beyond detection range and/or death of crocodiles outside of the study area. Because no evidence of mortality was observed or reported during the study period, we suspect that most, if not all, of our study crocodiles survived.

Previous studies of Siamese crocodile movements during the wet season reveal that the species can travel further than our study animals did during the dry season. Simpson *et al.* (2006) recorded a juvenile female moving 2–4 km across flooded forests and between the Areng River (southwestern Cambodia) and oxbow lakes from March to September. They also monitored an adult male which moved up to 11.9 km along the same river over three and a half months during the dry season. Studies on saltwater crocodiles *Crocodylus porosus* in Australia have demonstrated that the linear range of the species varies from 1.3 ± 0.9 km during the dry season to 62 km in the wet season (Kay, 2005). On release, captive-bred gharials *Gavialis gangeticus* also varied greatly in their movements, with some remaining close to the release site and others settling up to 40 km away (Ballouard *et al.*, 2010). Because habitat quality is likely a driver of site fidelity among released crocodiles (van Weerd *et al.*, 2011), the fact that most of our crocodiles stayed near the release site could indicate its habitat quality was good. However, the real measure of success for reintroduction and reinforcement programmes is breeding success. As the first animals we released in 2012 will take at least five years to reach sexual maturity, further surveys should be conducted to search for evidence of nests and juveniles.

With fewer than three wild nests reported each year for Siamese crocodiles in Cambodia, existing populations are too small and fragmented to recover in the absence of reintroduction and reinforcement efforts. This study is part of ongoing efforts to establish viable populations of the species in the country, and our discovery that young crocodiles typically remain near release sites during the dry season is encouraging because it suggests the risk of crocodiles straying from release sites into areas with less suitable habitat or greater risk from people may be low. Our release of captive-reared animals follows a decade of conservation work to determine the distribution and natural history of Siamese crocodiles (Sam *et al.*, 2015) and secure key areas as sanctuaries. It was of course critical to understand the historical distribution and habitat needs of this species before any sort of reintroduction, and to eliminate the reasons it was extirpated in the first place. Another critical step was to engage with the communities to garner support for the recovery of an animal that has the potential for conflict with humans.

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