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POPULATION STATUS AND CONSERVATION OF WILD SIAMESE CROCODILES *(CROCODYLUS SIAMENSIS)* IN THE TONLE SAP BIOSPHERE RESERVE, CAMBODIA

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ABSTRACT

We investigated the conservation status of the Siamese crocodile *(Crocodylus siamensis)* in the Tonle Sap Biosphere Reserve (TSBR), Cambodia, from June 2000 through September 2001 using a combination of daylight surveys, nocturnal spotlight surveys, and interviews of knowledgeable persons. Our results indicate that small numbers of *C. siamensis* persist in several areas of TSBR, although the viability of these populations is questionable. We found nothing to suggest that crocodilians other than *C. siamensis* currently inhabit TSBR. Anecdotal evidence indicates that significant population declines have occurred throughout TSBR, which we attribute to chronic over-harvesting to stock crocodile farms. Although illegal, this practice continues, and market demand provides a strong incentive for villagers to harvest the last remaining wild crocodiles. We therefore recommend careful oversight of the farming industry coupled with *in situ* protection of wild populations in TSBR. If adequate protection can be achieved, reintroduction into secure areas of TSBR is warranted. Finally, a rigorous monitoring program should be implemented to evaluate recovery efforts and detect future population trends.

Key words: Cambodia, conservation, crocodile farming, *Crocodylus siamensis*, folk taxonomy, Siamese crocodile, Tonle Sap Biosphere Reserve

INTRODUCTION

The Siamese crocodile (*Crocodylus siamensis*) is considered one of the least studied and most critically endangered crocodilians in the world (THORBJARNARSON, 1992; ROSS, 1998; IUCN, 2003). Virtually nothing is known concerning the ecology of *C. siamensis* in the wild, and populations throughout Southeast Asia have declined precipitously as a result of habitat destruction, collecting to stock crocodile farms, and illegal hunting (THORBJARNARSON, 1992; ROSS, 1998). Although *C. siamensis* was recently reintroduced into Cat Tien National Park (FITZSIMMONS *ET AL.*, 2002; POLET, 2002), extant wild

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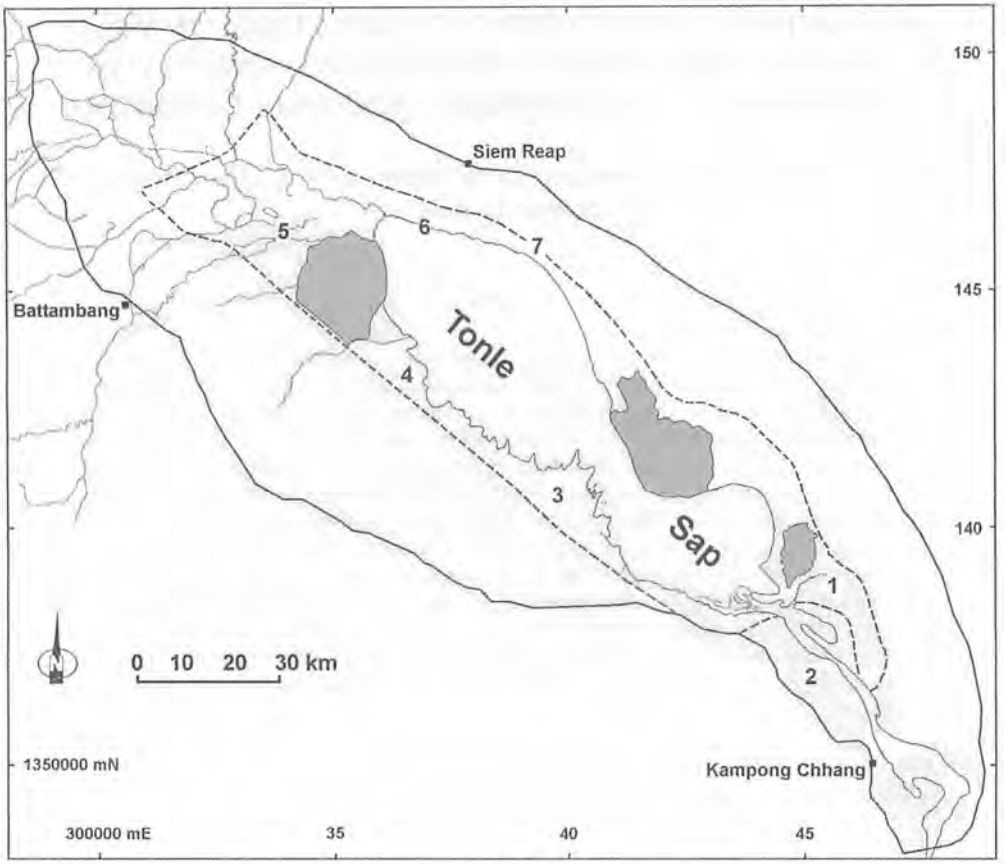

Figure 1. Map of Tonle Sap Biosphere Reserve, Cambodia. Solid line denotes boundary of Transition Zone, Buffer Zone encompassed by dashed line, and Core Areas are shaded. Numbers correspond to locations in Table 2.

populations no longer occur in Vietnam (PLATT & TRI, 2000; STUART *ET AL.*, 2002), and there is little information available from either Indonesia or Malaysia (COX *ET AL.*, 1993; ROSS, 1998). Remnant populations of questionable viability persist at several localities in Thailand (KREETIYUTANONT, 1993; RATANAKORN *ET AL.*, 1994; PLATT *ET AL.*, 2002a) and Laos (SAWATHVONG, 1994; STUART & PLATT, 2000; BAIRD, 2001; MATEUS, 2001; THORBJARNARSON, 2003).

Although historically widespread and abundant in Cambodia (CAMPBELL, 1860; SMITH, 1931; KIMURA, 1969; THUOK & TANA, 1994; THUOK, 1998), the current distribution and status of *C. siamensis* in the country are poorly known. Surveys were accorded high priority by the IUCN Crocodile Specialist Group (THORBJARNARSON, 1992; ROSS, 1998), but security concerns seriously limited field investigations until recently (THUOK, 1998). An improved political situation now makes fieldwork possible and populations of *C. siamensis* were recently found in the Cardamom Mountains (DALTRY & CHHEANG, 2000; BARR, 2002) and along the Sre Ambel River (PLATT *ET AL.*, 2002b). Additionally, it has been widely suggested that the Tonle Sap (Great Lake) and surrounding wetlands harbor

significant numbers of *C. siamensis* (SCOTT & POOLE, 1989; SALTER, 1993; THUOK & TANA, 1994; WOODSWORTH, 1995; CITES Management Authority of Cambodia, 1998; DOROSHENKO *ET AL.*, 1998; GUM, 1998; THUOK, 1998); however, survey data are lacking and the basis for these reports is unclear (ROSS, 1998). Populations of 100 to 2,000 wild crocodiles reportedly occur at specific localities around the lake (THUOK & TANA, 1994; CITES Management Authority of Cambodia, 1998; THUOK, 1998), but ROSS (1998) and THUOK (1998) caution that these estimates are largely speculative and field surveys are required for confirmation. We here present the results of an investigation into the population status of *C. siamensis* in the Tonle Sap Biosphere Reserve (TSBR). Our objectives were to determine if viable populations of *C. siamensis* remain in TSBR, assess the impact of crocodile farming on wild populations, and provide conservation recommendations based on these findings.

STUDY AREA

Tonle Sap (Fig. 1), located in the central plain of Cambodia, is the largest permanent freshwater lake in Southeast Asia (MUNSON *ET AL.*, 1968; SCOTT, 1989). The Tonle Sap floodplain (defined as that area within the 10-m asl contour line and encompassing Tonle Sap and surrounding wetlands; GIESEN, 1998) extends approximately 250 km from northwest to southeast and is up to 100 km wide (SCOTT, 1989). The Tonle Sap River connects Tonle Sap with the Mekong River near Phnom Penh. The region experiences a tropical monsoonal climate with a pronounced wet season between May and November; peak monthly rainfall (ca. 270 mm) occurs in September and October (GIESEN, 1998). During the dry season (December to mid-May) Tonle Sap covers an area of 250,000 to 300,000 ha and has a mean depth of <1 m. At the onset of the wet season the Tonle Sap River reverses flow and carries water from the Mekong into Tonle Sap, resulting in widespread inundation of the surrounding floodplain (Fig. 2). Tonle Sap expands to approximately 1.3 million ha and mean water depth increases to 8–10 m at the height of the wet season (SCOTT, 1989). Floodwaters begin to recede in November and the lowest water levels occur during April and early May (SCOTT, 1989).

Tonle Sap is surrounded by extensive seasonally flooded wetlands. In general the stature of the vegetation decreases as distance from the lake increases and duration of flooding decreases (MCDONALD *ET AL.*, 1997). Approximately 80% of the floodplain is covered by semi-continuous stands of trees and shrubs up to 4 m in height characterized by *Homalium brevidans, Hydrocarpus anthelmintica, Terminalia cambodiana, Vitex* spp. and *Gmelina asiatica* (SCOTT, 1989; MCDONALD *ET AL.*, 1997; GIESEN, 1998). Gallery forests (*sensu* MCDONALD *ET AL.*, 1997) consisting of trees 7 to 15 m tall cover <10% of the floodplain, occur primarily along the lakeshore and riverbanks, and remain flooded for up to 8 months. Gallery forests are dominated by *Barringtonia acutangula, Diospyros cambodiana,* and a diverse assemblage of woody creepers (SCOTT, 1989; MCDONALD *ET AL.*, 1997; GIESEN, 1998). Patches of emergent (e.g., *Cyperus* spp., *Rhynchospora* spp., *Nelumbo nucifera, Echinochloa stagnina*) and floating (e.g., *Achyranthes aquatica, Eichhornia crassipes, Pistia stratiotes, Salvinia* sp.) vegetation are scattered throughout the floodplain (MCDONALD *ET AL.*, 1997). Significant areas of natural vegetation have been destroyed by fuelwood cutting and conversion to ricefields (GIESEN, 1998). WOODSWORTH

Figures 2,3. Two views of an elevated structure (ca. 10 m high) in Prek Toal Village illustrating the dramatic seasonal variation in water levels of Tonle Sap. Structure in late February when water levels are declining (left). Same structure in September as water levels approach annual maximum (right).

Figure 4. An adult male Siamese crocodile *(Crocodylus siamensis)* photographed on a crocodile farm in Siem Reap, Cambodia that was reportedly captured in the Prek Toal Core Area of Tonle Sap Biosphere Reserve during 2001.

(1995) estimates that the area of natural vegetation declined from approximately 1,000,000 ha in the 1960s to 564,000 ha in the 1980s. By the late 1990s, approximately 361,000 ha of natural forest and 157,000 ha of degraded forest remained (GIESEN, 1998).

One hundred and sixty communes inhabited by an estimated 1.02 million people are located on the periphery of Tonle Sap. In addition, about 170 floating villages ranging in size from 2 to over 100 households occur on the lake and move in accordance with seasonally fluctuating water levels (GIESEN, 1998). Rice farming, fuelwood collection, fish culture, and subsistence and commercial fishing are the principal economic activities in Tonle Sap communities (GIESEN, 1998; GUM, 1998). Commercial fishing is concentrated in 57 administrative fishing lots, which encompass extensive areas of the lake and surrounding wetlands (GIESEN, 1998). Fishing lots are enclosed with bamboo fences that extend for many kilometers and lot operators strictly control access for the duration of the fishing season (October through May).

In 1997 Tonle Sap was designated a Biosphere Reserve in UNESCO's Man and the Biosphere Program (UNESCO, 2003). Biosphere Reserves consist of strictly protected, inviolate core areas surrounded by buffer and transitional zones where sustainable resource extraction and human occupancy is permitted (HOUGH, 1988). Three core areas were established in TSBR: Prek Toal (31,282 ha), Moat Khla–Boeng Chhmar (32,969 ha), and Stoeng Sen (6,586 ha) (GIESEN, 1998; Ministry of the Environment, Phnom Penh, unpubl. data). In contrast to the standard UNESCO model, subsistence and commercial fishing are permitted in TSBR core areas. The three core areas are surrounded by a buffer zone of approximately 510,768 ha. The remainder of the floodplain and some adjacent agricultural lands are encompassed by the transition zone (899,600 ha), which is bordered by National Routes 5 and 6 (GUM, 1998; Ministry of the Environment, unpubl. data).

METHODS

We investigated the status of *C. siamensis* in TSBR from June 2000 to September 2001 using a combination of daylight surveys, nocturnal spotlight surveys, and village interviews. We conducted spotlight surveys (BAYLISS, 1987) in TSBR core areas during the late dry season of 2001 (March to June). In general, crocodile densities vary as water levels fluctuate between wet and dry seasons, but the likelihood of detection is greatest when crocodiles become concentrated by receding water levels during the dry season (RAINWATER *ET AL.*, 1998). We conducted most spotlight surveys from 8-m wooden fishing boats equipped with long-shaft diesel outboard motors, although small (5-m) oar-propelled wooden boats were employed when shallow water precluded using the larger craft. A 400,000 candlepower Q-beam spotlight, 12-volt headlights, and Maglite® flashlights were used to search for crocodile eyeshines during spotlight surveys. Potential survey routes were traversed during the day to assess habitat and navigability, and search for crocodile sign (e.g., tracks, slides, dragmarks, and nests). The coordinates of the beginning and endpoint of each survey were determined with a Garmin® 48 Global Positioning System (GPS). Boat speed was measured with the GPS and used to determine the distance traversed in each survey. Survey routes were calculated as midstream length in linear habitats such as creeks and rivers, or shoreline distance in lagoons (KING *ET AL.*, 1990). Each survey route is described in field notes archived at the Campbell Museum, Clemson University,

Clemson, South Carolina, USA. Additionally, we sought out knowledgeable individuals and conducted interviews of villagers, fishermen, hunters, and crocodile farmers throughout the study area during 2000 and 2001. Individuals were questioned regarding crocodile sightings, hunting and collecting practices, past and present trade, and general knowledge of crocodiles. Such individuals are typically an excellent source of information regarding the local occurrence of wildlife, especially culturally or economically important species (FOGERTY, 2001).

RESULTS AND DISCUSSION

Population Surveys

We conducted spotlight surveys along 168.6 km of waterways in the Prek Toal (50.4 km), Stoeng Sen (25.1 km), and Moat Khla-Boeng Chhmar (93.1 km) core areas of TSBR (Table 1). A greater distance was covered during daylight surveys, but not quantified. No wild crocodiles or crocodile sign were encountered during daylight or spotlight surveys. Some habitat proved inaccessible during our survey; fishing lot operators denied access to leased areas fearing we would disrupt fishing activities, and shallow water precluded boat

Table 1. Spotlight surveys conducted for crocodiles in core areas of the Tonle Sap Biosphere Reserve, Cambodia during 2001.

Location	Date	Km surveyed
Prek Toal Core Area		
Prek Das	3 March	15.6
Prek Preas	22 March	16.8
Prek Spot	23 March	6.3
Prek Das	26 May	11.7
Stoeng Sen Core Area		
Tvear Boeng	9 March	5.2
Prek Kaz	10 March	6.5
Plov Lorb Trail	10 March	1.4
Stoeng Sen River	21 June	12.0
Moat Khla–Boeng Chhmar Core Area		
Stoeng Stong	22 June	25.0
Prek Balote	24 June	16.5
Prek Tahoursaw	25 June	15.0
Prek Bayarp	27 June	10.0
Prek Tvang Bra	28 June	20.6
Prek Tachang Klong	29 June	6.0

access to other areas. Most importantly we were unable to survey interior floodplain wetlands, which are potentially important dry season refugia for crocodiles; these habitats become isolated as floodwaters recede and cannot be reached by boat. Demonstrating that a species no longer occurs in an area is almost impossible (BROCKE & VAN DYKE, 1985; GUYNN *ET AL.*, 1985; BRUSSARD, 1986). Therefore our data should not be interpreted as a complete absence of crocodiles from TSBR core areas, but instead suggest that densities are so low that the likelihood of detecting crocodiles during a survey is very small (GUYNN *ET AL.*, 1985; LAZELL, 1986).

In addition to field surveys, we interviewed numerous people concerning the occurrence of crocodiles in TSBR (Table 2). Interviews were often conducted in a large group format so it was difficult to determine the number of respondents; however, they totaled over 300. Respondents reported encountering crocodiles or finding crocodile sign since the early 1980's at widely scattered localities throughout TSBR (Table 2; Fig. 1). The majority of recent sightings occurred in the three TSBR core areas, Day Roneath Wetlands, and the flooded forests of Battambang Province adjacent to the Prek Toal Core Area. Although the last crocodile nest was reportedly found in 1996 (Stoeng Sen Core Area), the recent (1999-2001) collection of hatchlings from Moat Khla–Boeng Chhmar and Prek Toal core areas, the flooded forest adjacent to the Prek Toal Core Area, and the Dey Roneath Wetlands indicates that reproduction is occurring in these areas. Additionally hunters maintained that at least three nesting females remained in Prek Toal Core Area. However, given the large number of man-hours collectively accrued by our informants in the field, most of whom spend each day working in potential crocodile habitat, the small number of crocodiles reportedly encountered during recent years suggests that at best low density populations persist in TSBR. Neither our field survey or interview data indicate that TSBR harbors large populations of *C. siamensis* as others have speculated.

Species Diversity

Based on local reports, GIESEN (1998) suggested that as many as four species of crocodilians occur or formerly occurred in the Tonle Sap ecosystem, including *C. siamensis*, estuarine crocodiles *(C. porosus)*, gharials *(Gavialis gangeticus)*, and Tomistoma *(Tomistoma schlegelii)*. Historically, *C. porosus* inhabited the Mekong Delta (CUC, 1994; CAO & JENKINS, 1998; STUART *ET AL.*, 2002) and may have occurred as far upstream as Tonle Sap, although we are unaware of any confirmed records. However, a Chinese diplomat living in Angkor during the 13th century mentions exceptionally large crocodiles inhabiting Tonle Sap (CHOU, 1987), and THORBJARNARSON (2001) notes that Bas-reliefs at the Angkor ruins depict crocodiles attacking humans, a behavior more likely associated with *C. porosus* (PLATT *ET AL.*, 2001 and references therein) than *C. siamensis*. Furthermore, a number of persons we interviewed stated that a large, aggressive crocodile, known locally as *krapear* (sea crocodile), formerly inhabited Tonle Sap, but disappeared many years ago, possibly a reference to *C. porosus*. Although the ecological relationship between *C. siamensis* and *C. porosus* is unknown, elsewhere (Australia, India, New Guinea, Philippines) in its extensive distribution *C. porosus* inhabits inland freshwater wetlands in sympatry with a congener (THORBJARNARSON, 1992).

We regard the recent occurrence of either *T. schlegelii* or *G. gangeticus* in TSBR as highly improbable. The only populations of *T. schlegelii* found on mainland Southeast Asia

Table 2. Summary of interview data obtained from local respondents concerning the status of crocodiles in the Tonle Sap Biosphere Reserve, Cambodia. Numbers in parentheses correspond to locations in Figure 1. TL = total length.

Location	Year	Comments
Moat Khla–Boeng Chhmar Core Area	1997	Approximately 40 hatchlings captured and sold to farms in Siem Reap.
	1999	Hunter found skeleton of adult crocodile and heard hatchlings vocalizing.
	2000	Crocodile tracks found in dry season and two large adults observed during August. Hunter found two dead adult crocodiles in October that appeared to have been engaged in combat; one crocodile possibly an escapee from farm.
	2001	One adult and several hatchlings observed during July–August.
Prek Toal Core Area	1982–93	At least 47 adult crocodiles captured and sold to farms.
	1982–2000	One hunter captured and sold about 10 hatchlings each year.
	1987	24 hatchlings and two adults captured by fisherman.
	1990	One juvenile captured in fish trap.
	1995	Eight hatchlings captured during July–August.
	1996	Six hatchlings and one adult captured and sold to farm in Prek Toal Village.
	1997	Large (TL ca. 4 m) adult crocodile observed.
	1998	Seven hatchlings captured during July–August.
	1999	Two adult crocodiles encountered in August; juvenile captured.
	2000	Juvenile captured in March; nesting female and three hatchlings captured in June; 15 hatchlings captured July–August; adult observed in September.
	2001	Two adult crocodiles captured and sold to farms in Prek Toal Village; six adults we examined on farms in Siem Reap were said to have been recently captured in Prek Toal Core Area; 42

Location	Year	Comments
		hatchlings captured in wetlands along Prek Das River and sold to farmers in Prek Toal Village during September; two adults observed (February and August); hunters believed at least three breeding females remain in core area.
Stoeng Sen Core Area	1982–96	Hunters captured and sold one to four adult crocodiles each year; catch was primarily nesting females.
	1998	Two adult crocodiles captured and sold.
	1999	Adult crocodile observed during wet season.
	2000	Crocodile tracks observed in dry season; adult encountered during August.
	2001	Adult encountered during November; small numbers of crocodiles, including nesting females are said to remain in this area.
Wetlands north of Tonle Sap River, Kampong Thom Province (1)	1987–88	20 crocodiles (TL to 1.2 m) taken by one hunter; few crocodiles believed to remain in this area.
Wetlands south of Tonle Sap River, Kampong Chhnang Province (2)	1991	Female captured at nest containing 30 eggs.
	1998	Two adults and a juvenile observed; juvenile captured in fishing net.
	2000	Two adult crocodiles observed in November.
Fishing Lot 6 (3)	2000	Crocodile tracks found in March; dense vegetation in this area makes hunting difficult; some crocodiles thought to persist.
Dey Roneath Wetlands (4)	1982	15 hatchlings captured.
	1983–84	Three adult and "many" juvenile crocodiles captured.
	1985–90	Numerous crocodiles captured.
	1990	Three nesting females and 60 hatchlings captured.
	2000	One adult and four hatchlings captured July–August; tracks of an adult found in dry season.
	2001	Three adult crocodiles at farm in Siem Reap reportedly captured in this area

Location	Year	Comments
		during the dry season; hunters claim small numbers of crocodiles remain in remote wetlands.
Flooded forest–Battambang Province (5)	1985–93	One hunter captured 10 to 15 nesting females and about 150 hatchlings each year.
	1990	Nest containing 32 eggs collected in May; four hatchlings caught in bamboo fish trap during August–September; juvenile (TL ca. 1.0 m) crocodile caught in fishing net.
	1991	Juvenile crocodile captured in bamboo fish trap.
	1993	Adult female captured at nest.
	1997	Large adult (TL ca. 4 m) observed in wet season.
	1998	21 hatchlings captured.
	1999	22 hatchlings captured in wet season; large adult observed in December.
	2000	Three adult crocodiles encountered August–September; many hatchlings heard vocalizing.
Choeng Khneas (6)	1997	Juvenile (TL ca. 1.2 m) caught in fishing net.
	1999	Juvenile (TL ca. 1.0 m) crossing road; possibly escaped from nearby crocodile farm.
Fishing Lot 5 (7)	1999	Skeleton of adult crocodile found during dry season; adult crocodile observed in October.

occur in extreme southern Thailand and peninsular Malaysia (THORBJARNARSON, 1992). Moreover, *T. schlegelii* is restricted to heavily vegetated peat swamps throughout much of its range (SEBASTIAN, 1994; BEZUIJEN *ET AL.*, 2001), a habitat lacking in TSBR. Finally, the *T. schlegelii* supposedly on exhibit at the Phnom Tamao Zoological Garden near Phnom Penh (GIESEN 1998) is nothing more than a misidentified *C. siamensis* (S. PLATT & H. SOVANNARA, personal observations). Likewise, with the exception of an enigmatic specimen collected in Burma (Myanmar) during the 1920s (BARTON, 1928), *G. gangeticus* is known only from the Indian subcontinent where it inhabits deep, fast-flowing rivers with exposed sandbanks for nesting (WHITAKER & BASU, 1983). Given the distance to known populations and the lacustrine environment of Tonle Sap, it is doubtful that *G. gangeticus* occurs in TSBR.

We found nothing to suggest that any species besides *C. siamensis* currently inhabits TSBR, and speculate that the conclusions of GIESEN (1998) regarding crocodilian diversity

are due to the assumption that vernacular names correspond to biological species. During our interviews, villagers consistently described three folk taxa (*sensu* BERLIN *ET AL.*, 1966) of crocodiles inhabiting TSBR: *krapeu kongkep* (frog crocodile), krapeu khmao (black crocodile), and *krapeu krahorm* (red crocodile). Crocodile farmers in Prek Toal Village and Siem Reap showed us numerous examples of each, which we identified as *C. siamensis* on the basis of post-occipital, nuchal, and ventral scalation (BRAZAITIS 1973a & b). The local folk taxonomy appears to be based largely on behavioral disposition and skin pigmentation, the latter a trait that is highly variable among individuals and determined by incubation temperature (DEEMING & FERGUSON, 1989), and is over-differentiated, whereby a single biological species is represented by three nonsynonymous folk species. Over-differentiation of economically or culturally important species is common among traditional societies (DWYER, 1976; HUNN, 1977; FLECK *ET AL.*, 1999; WILKIE & SARIDAN, 1999), and our interviews highlight the danger of uncritically assuming that vernacular names provided by informants can be equated with scientifically recognized taxa.

Exploitation

Crocodiles in Tonle Sap have long been harvested for skins and to stock crocodile farms. Commercial skin hunting was banned by the French colonial administration in 1945, and protection continued during the post-colonial reign of King Sihanouk (THUOK & TANA, 1994). Declining populations spurred the development of farms in the late 1940's and harvesting wild crocodiles to stock these farms soon supplanted the direct harvest for skins (KIMURA, 1969; THUOK & TANA, 1994). Protection was abolished by the Khmer Rouge (1975–79), but later reinstated under Article 18 of the Fishery Law of 1987, which "forbids the catching, selling, and transportation of ...[wild] crocodiles..." (THUOK & TANA, 1994). Private crocodile farms were likewise disbanded by the Khmer Rouge, but reestablished in the early 1980s (THUOK & TANA, 1994).

Crocodile farming is now a major economic activity in the provinces surrounding Tonle Sap where 396 farms held over 20,000 crocodiles in 1998 (THUOK & TANA, 1994; CITES Management Authority of Cambodia, 1998; THUOK, 1998). Additionally, large numbers of crocodiles have been exported from Cambodia since the mid-1980's to stock commercial farms in Thailand, Vietnam, and China (THORBJARNARSON, 2001). Farm stock commanded extremely high prices from the early 1980's to mid-1990's (US$ 300 for a hatchling and up to US$ 7,000 for an adult female; Chhin Sokun Theary, pers. comm.), primarily as a result of market demand from Thailand. Prices have since declined, but remained relatively high during our survey (US$ 25-30 for a hatchling and US$ 700 for an adult female), now fueled by an increasing demand from China (THORBJARNARSON, 2001).

Despite legal protection, a profitable market has existed for the capture and sale of wild crocodiles to farms since the early 1980s (THORBJARNARSON, 2001). SALTER (1993) noted that wild hatchlings were captured and sold to farms, GIESEN (1998) reported that farmers in Prek Toal Village purchased wild crocodiles, and according to BRADLEY-MARTIN & PHIPPS (1996), the breeding stock of a farm in Phnom Penh consisted solely of wild-caught adults taken from Siem Reap and Battambang Provinces. Our interviews indicate that this practice continues, and the high prices (often the equivalent of several months income) paid to hunters provides a strong economic incentive for exploiting the remaining

wild populations in TSBR. Crocodile farmers in Prek Toal Village and Siem Reap stated they occasionally purchase wild crocodiles, and we examined 10 adults at farms in Siem Reap that were reportedly captured in 2001 from Pursat and Battambang Provinces (Fig. 3). Indeed, several farmers indicated that wild crocodiles are preferred as farm stock because purchasing them from fishermen is less expensive than obtaining stock from other farmers, and wild crocodiles are reputed to grow faster and produce larger clutches than crocodiles reared in captivity. Due to the clandestine nature of this trade, most farmers appeared reluctant to discuss purchasing wild crocodiles, and we suspect the practice is more widespread than suggested by our interviews.

A variety of techniques are employed by hunters to capture wild crocodiles. Hunters locate nests by following tracks through the mud of drying ponds, capture females at the nest site, and then monitor the nest and collect neonates upon hatching. Cassette recordings of juvenile distress calls are used to elicit vocalizations from small crocodiles, which are found with the aid of a headlight and captured by hand. Larger crocodiles are located with headlights and taken with wire snares mounted on bamboo poles. Drying ponds known to be inhabited by crocodiles are sometimes enclosed by bamboo fences built with frequent gaps into which cone-shaped bamboo traps are placed. Hunters then wade through the shallow water driving the crocodiles before them, which become trapped while attempting to escape through the gaps in the fence. All size classes are taken opportunistically in bamboo fish traps and nets. Interestingly, KIMURA (1969) noted that hunters frequently captured *C. siamensis* that were "sleeping" in dried mud, a behavior suggestive of aestivation (dormancy in response to dry conditions). While at least 10 species of crocodilians are known to aestivate (TAPLIN, 1988), this behavior has not been otherwise reported in *C. siamensis*.

Until the late 1990s crocodile hunting was a specialized activity conducted by organized teams of hunters during the dry season. These teams have since disbanded, in part due to the scarcity of wild crocodiles. Moreover, fishing lot operators now control access to most crocodile habitat and deny entry to hunting parties. While villagers continue to opportunistically harvest wild crocodiles, organized hunting now appears to be primarily conducted by employees of fishing lot operators.

Conservation Status and Recommendations

The results of our investigation strongly suggest that small numbers of *C. siamensis* persist in several areas of TSBR. Assessing long-term population trends is difficult given the lack of baseline data, but anecdotal evidence indicates that a significant decline has occurred during the last 40 years. As recently as the late 1960s KIMURA (1969) noted that crocodiles remained common in the flooded forests of Battambang and Siem Reap Provinces, and were especially abundant along the Prek Das River, an area now encompassed by the Prek Toal Core Area. Additionally, the local inhabitants we interviewed unanimously agreed that crocodiles were much more abundant 20 years ago than today.

We attribute this population decline to the chronic over-harvesting of wild crocodiles to stock farms. In contrast to ranching programs that depend on healthy natural populations as a source of eggs and neonates, the maintenance of viable wild populations is irrelevant to crocodile farms where stock is produced by captive adults in closed-cycle breeding operations (THORBJARNARSON, 1992, 1999). Indeed, the existence of a large, unregulated

farming industry in Cambodia provides a strong economic incentive for local villagers to collect and sell the few remaining wild crocodiles to farmers. Habitat destruction appears to have contributed little to the decline of *C. siamensis* in TSBR. Although significant areas of wetland have been destroyed by human activities (WOODSWORTH, 1995; GIESEN, 1998), adequate habitat remains, but is currently devoid of crocodiles.

The viability of *C. siamensis* populations remaining in TSBR is questionable. Recent nesting activity appears rare, and exploitation of the few remaining crocodiles continues. Significantly, adult females are preferentially targeted by hunters owing to the high prices paid by farmers for breeding stock, and nest defense behavior renders them particularly vulnerable to capture. The loss of even a few individuals, especially breeding females can be expected to have significant negative demographic consequences in small populations (GILPIN & SOULÉ, 1986).

Harvesting wild crocodiles to stock farms is undoubtedly the greatest threat to the continued survival of *C. siamensis* in TSBR, and addressing this issue should be foremost in any conservation plan. To this end the farming industry will require careful oversight by the Fisheries Department to insure that wild crocodiles are not being laundered through captive stocks. This could be most readily achieved by the institution of a national program whereby all crocodiles currently held in captivity are marked with a unique permanent number and annual production is carefully monitored. Similar programs have proven successful in deterring the illegal harvesting of crocodilians in other countries (CHILDS, 1987).

Regulation of the crocodile farming industry should be coupled with increased *in situ* protection of wild *C. siamensis* remaining in TSBR. We recommend that protection efforts be focused on TSBR core areas, which appear to harbor remnant populations. In keeping with the traditional UNESCO Biosphere Reserve model, core areas should be protected from all extractive enterprise. The limited number of navigable waterways entering the core areas offer excellent prospects for controlling access during the dry season when crocodiles are most vulnerable to capture. In addition to protecting crocodiles, inviolate core areas will probably benefit commercial fish stocks and other wildlife as well. Given time, the network of core areas may begin to function as a source-sink system (HANSKI & SIMBERLOFF, 1997) in which fish and wildlife produced in the core area (source) disperse into the buffer and transitional zones (sink) where sustainable harvest is permitted (HOUGH, 1988).

If effective protection can be achieved, we concur with GIESEN (1998) and recommend that serious consideration be given to reintroducing C. siamensis into all three TSBR core areas. Crocodile farms in and around TSBR are a potential source of animals for reintroduction as in accordance with IUCN/SSC guidelines (IUCN/SSC, 2003), the founding stock of these farms is most likely of local provenance. Using such animals minimizes the probability of disrupting locally adapted gene complexes through outbreeding depression (STORFER, 1999). As FITZSIMMONS *ET AL.* (2002) note, outbreeding depression is an inherent problem for crocodilian reintroduction programs using farm stock because these animals often originate from widely scattered source populations. While hybridization of *C. siamensis* with Cuban crocodiles *(C. rhombifer)* and *C. porosus* appears limited in comparison to farms in Thailand and Vietnam, it nevertheless does occur in Cambodia (THORBJARNARSON, 2001). Therefore it is essential to genetically ascertain (FITZSIMMONS *ET AL.*, 2002) that individuals selected for reintroduction are pure *C. siamensis* and not hybrids.

Reintroduction of *C. siamensis* should be followed by a rigorous monitoring program to evaluate recovery and detect future population trends in TSBR (DODD & SEIGEL, 1991). However, spotlight surveys may not be the most appropriate monitoring technique for TSBR. Although boat access is virtually unlimited during the wet season, crocodiles are widely dispersed and concealed in flooded vegetation, and therefore unlikely to be detected. Even in high density populations detection probabilities are depressed during high water periods (MONTAGUE, 1983; HOLLANDS, 1987; RAINWATER *ET AL.*, 1998). Conversely, during the dry season crocodiles retreat into isolated floodplain wetlands that are inaccessible to boats. Thus we recommend that dry season aerial surveys be evaluated as a technique to monitor crocodile populations in TSBR. Aerial surveys are less time consuming and provide a population index that is statistically comparable to spotlight surveys (BAYLISS, 1987). Furthermore, even in heavily vegetated swamps crocodile nests are often visible to low-flying aircraft and nest counts may prove a more useful indicator of population trends than spotlight surveys (CHABRECK, 1966; HOLLANDS, 1987; PLATT *ET AL.*, 1995).

Finally, hydrological changes resulting from dam construction on the upper Mekong and its major tributaries (OSBORNE, 2000; HOGAN ET AL., 2004) could alter prospects for the future recovery of *C. siamensis* in TSBR. Predicted impacts of dam construction include wetland loss, and an altered flooding cycle with a dry season flow 50% greater than under natural conditions (CHAPMAN & HE, 1996; DUDGEON, 2000; LAMBERTS, 2001). Although somewhat speculative, these changes could negatively affect crocodile populations through habitat loss (DUDGEON, 2000), a reduction in the availability of fish and other prey (ROBERTS, 1993; LAMBERTS, 2001; HOGAN *ET AL.*, 2004), and an increased loss of nests to flooding (KUSHLAN & JACOBSEN, 1990).

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