นิเวศวิทยาประชากรและการอนุรักษ์เต่ากระอาน
Batagur baksa (GRAY, 1831) ในประเทศเมียนมาร์ ไทย และมาเลเซีย

กัลยา

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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POPULATION ECOLOGY AND CONSERVATION OF THE RIVER TERRAPIN,
Batagur baksa (GRAY, 1831) IN MYANMAR, THAILAND AND MALAYSIA

MISS KALYAR

A Dissertation Submitted in Partial Fulfillment of the Requirements
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กัลยา: นิเวศวิทยาประชากรและการอนุรักษ์เต่ากระอาน *Batagur baska* (Gray, 1831) ในประเทศเมียนมาร์ ไทย และมาเลเซีย (POPULATION ECOLOGY AND CONSERVATION OF THE RIVER TERRAPIN, *Batagur baska* (Gray, 1831) IN MYANMAR, THAILAND AND MALAYSIA)

อ. ที่ปรึกษา: ผู้ช่วยศาสตราจารย์ ดร. กำธร ธีรคุปต์, อ. ที่ปรึกษาร่วม : ดร. จอห์น ธอร์ปจานาร์ซั่น, 116 หน้า.

การศึกษานี้ยืนยันว่ายังคงมีประชากรกลุ่มเล็กๆ ของเต่ากระอาน *Batagur baska* อยู่ในบริเวณชายฝั่งของรัฐมอญ รัฐยะไข่ เขตอิรวดี และเขตตะนาวศรี ในประเทศเมียนมาร์ อันเป็นผลมาจากความเชื่อทางศาสนาของคนท้องถิ่นรวมกับความขัดแย้งของกองกำลังติดอาวุธในพื้นที่ จึงเป็นการปกป้องประชากรเต่ากระอานได้ในระดับหนึ่ง ในส่วนของพื้นที่ชายฝั่งทางคาบสมุทรของมาลายาซึ่งเป็นพื้นที่สำคัญแห่งสุดท้ายของเต่ากระอาน การประเมินประชากรของการศึกษาครั้งนี้บ่งชี้ว่าเหลือเต่าเพศเมียในวัยเจริญพันธุ์น้อยกว่า 50 ตัวในแม่น้ำเปรัคของมาเลเซีย นอกจากนี้พบว่ายังคงมีเต่ากระอานจำนวนหนึ่งอาศัยอยู่ในคลองละงู จังหวัดสตูลของประเทศไทย และได้จดบันทึกรังที่วางไข่ในธรรมชาติจำนวน 3 รังรวมทั้งหาดทรายตามแนวลำคลองที่มีศักยภาพเป็นแหล่งทำรังวางไข่

ภายในสถานเพาะเลี้ยงที่สถานีประมงน้ำจืดจังหวัดสตูล เต่าเริ่มจับคู่และผสมพันธุ์ระหว่างเดือนตุลาคมถึงพฤศจิกายนและเริ่มทำรังวางไข่ในเดือนธันวาคมและมกราคม จำนวนไข่เต่าเฉลี่ยต่อรัง ($n = 14$) เท่ากับ 21.7 ± 5.6 ฟอง ระยะการฟักตั้งแต่ 74 ถึง 110 วันขึ้นอยู่กับวิธีที่ใช้ในการฟัก อัตราการฟักเป็นตัวตั้งแต่ 40.8% - 58.1% ขึ้นอยู่กับวิธีที่ใช้ในการฟักไข่ ที่สถานเพาะฟักโบตา กานัน ประเทศมาเลเซีย การจับคู่และผสมพันธุ์เริ่มตั้งแต่เดือนสิงหาคมไปจนถึงเดือนธันวาคม ขณะที่การทำรังวางไข่เริ่มตั้งแต่เดือนตุลาคม โดยมีจำนวนสูงสุดในเดือนมกราคมและต่อเนื่องไปจนถึงกลางเดือนมีนาคม จำนวนไข่เต่าเฉลี่ยต่อรังเท่ากับ15.2 ± 5.7 ฟอง ($n = 10$) ตั้งแต่ปี ค.ศ.1993 ถึง 2005 สถานีเพาะฟักโบตา กานันสามารถผลิตไข่ได้ถึง 1524 รัง โดยมีอัตราการฟักเป็นตัวตั้งแต่ 27.5% - 60.5% ระยะการฟักตั้งแต่ 71 ถึง 92 วัน

จากการวิเคราะห์เต่าเพศเมียจำนวน 79 ตัวและเต่าเพศผู้ 50 ตัวพบว่าไม่มีความแตกต่างทางรูปร่างลักษณะอย่างมีนัยสำคัญระหว่างเต่ากระอานกลุ่มต่างๆ และสามารถสรุปได้เพียงว่าเต่ากระอานเพศผู้มีความกว้างของกระดองส่วนบนแคบกว่า กระดองตื้นกว่า กระดองส่วนล่างสั้นกว่า และน้ำหนักตัวน้อยกว่าตัวเมียอย่างมีนัยสำคัญในทุกพื้นที่

ประชากรเต่ากระอานเผชิญกับภัยคุกคามมากมายตั้งแต่การล่า การถูกจับโดยบังเอิญจากกิจกรรมประมง การสูญเสียถิ่นที่อยู่อาศัย การล่าเต่าและเก็บไข่เต่าทั้งเพื่อการดำรงชีพและเพื่อการค้า มลภาวะในสิ่งแวดล้อม ไปจนถึงการเปลี่ยนแปลงสภาพภูมิอากาศโลก การลดลงอย่างรวดเร็วของประชากรเต่ากระอานในธรรมชาติทำให้จำเป็นต้องมีการจัดการอนุรักษ์อย่างเร่งด่วน

สาขาวิชา ....วิทยาศาสตร์ชีวภาพ..................	ลายมือชื่อนิสิต................................
ปีการศึกษา ...... 2549..................................	ลายมือชื่ออาจารย์ที่ปรึกษา....................
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KALYAR: POPULATION ECOLOGY AND CONSERVATION OF THE RIVER TERRAPIN, *Batagur baska* (Gray, 1831) IN MYANMAR, THAILAND AND MALAYSIA. THESIS ADVISOR: ASST. PROF. KUMTHORN THIRAKHUPT, Ph.D., THESIS CO-ADVISOR JOHN THORBJARNARSON, Ph.D., 116 pp.

This study confirmed that *Batagur baska* small populations still persists in coastal regions of Mon and Rakhine States and Ayeyarwady and Tanintharyi Division in Myanmar where a combination of local religious beliefs and areas of armed conflict confer some degree of protection. Peninsular Malaysia represents the last stronghold of *B.baska* and this study estimates indicate that less than 50 breeding females remain in Perak River, Malaysia. A small numbers of *B. baska* still inhabited in Langu Canal in Satun Province, Thailand and also documented the occurrence of three wild nests and other potential nesting beaches along the river.

In Satun Inland Fishery Station, under captive condition, courtship and mating took place during October and November, followed by nesting in December and January. Mean clutch size among females ($n = 14$) was 21.7 ± 5.6 eggs (range = 18 to 25 eggs). Incubation periods ranged from 74 to 110 days depending on the method of incubation. Hatching success ranged from 40.8% to 58.1% depending on incubation method. In Bota Kanan Hatchery, courtship and mating takes place from August through December, while nesting and clutch deposition occurs as early as October, with a peak in January, and continues until mid-March. Clutch size produced by captive female averaged 15.2 ± 5.7 eggs ($n = 10$; range = 6-20). From 1993 to 2005, 1524 clutches were produced by adults maintained at BKH with hatching success ranging from 27.5 to 60.5%. Incubation periods ranged from 71 to 92 days.

Based on 79 females and 50 males, the analysis indicates that there is no significant morphological difference between *B.baska* among isolated populations and it could only be concluded that *B. baska* males had significantly narrower carapace width, shallower shells, shorter plastrons, and lighter body weight than those in females at all locations.

Batagur baska populations face a variety of threats including predation, incidental capture as a result of fishing activity, habitat loss, subsistence and commercial harvest of eggs and turtles, exposure to environmental pollutants, and global climate change. Due to rapid decline of the wild population of *B.baska*, the conservation management is urgently needed.

Field of study……Biological Sciences....... Student's signature....Kalyar....

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This work is dedicated to the memory of my mother from whom I inherited my love to animals.

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Chapter 1

Introduction

There are 59 turtle species in the family Bataguridae throughout Asia. The River terrapin, *Batagur baska* is one of the largest emydid turtle reaching a carapace length of at least 60cm. River terrapins inhabit coastal estuaries and mangrove swamps from eastern India and Bangladesh, west to Myanmar, southern Thailand, Cambodia, southern Vietnam, and south to peninsular Malaysia and Sumatra, Indonesia (Bourret, 1941; Ernst and Barbour, 1989; Iverson, 1992). Populations throughout this range have drastically declined or been extirpated from their historical range by a combination of habitat destruction and chronic over harvesting of eggs and adult turtles (Wirot, 1979; Moll, 1980; Groombridge, 1982; Tikadar and Sharma, 1985; Thirakupt and Vandijk, 1994; Bupathy, 1997; Das, 1997; Platt et al., 2000). Therefore population ecology and conservation status studies in respective areas should be conducted to estimate the current situation.

Batagur baska is listed as Critically Endangered by the World Conservation Union (IUCN) and is listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Very little information is known about the morphological and genetic variability of the species, and this could play an important role in its conservation management. This research will have an emphasis on the ecology and conservation biology of *B.baska*. Data on species relative density, habitat preference, morphology, diet and threat will be compiled and analyzed. Data will be mapped using Global Information System (GIS) to show the distribution of this species in three different countries.

Objectives

1. To study the morphological characteristics, distribution, population status, sex ratio, habitat characteristics, breeding season, breeding behavior and nesting site characteristics of *Batagur baska* in Myanmar, Thailand and Malaysia.
2. To study the factors resulting in the decline of *Batagur baska* in the wild such as predators, destruction of nesting beaches by sand mining, creation of dams and destruction of mangrove forests.
3. To evaluate the conservation efforts in captive breeding center in Satun Inland Fishery, Thailand and Bota Kanan Hatchery, Malaysia.

Anticipated Benefit

This systematic survey will be very useful to determine the current conservation status for these critically endangered species. The knowledge of the natural history and current population status can provide useful information for the conservation and management.

Chapter 2

Literature Review

Distinguishing Characteristics

Batagur baska is among the world's largest freshwater turtles; males are somewhat smaller than females, which may attain a carapace length (CL) of 60 cm and weigh up to 35 kg. The olive brown to olive gray carapace is domed with smooth scutes, and posterior serrations are lacking in adults. The carapace of hatchlings and small juveniles is armed with spines that disappear with age and are thought to deter predators. The well-developed, uniformly yellowish or cream colored plastron is extensively sutured to the carapace, with a small anal notch. The plastral scute formula is abdominal > pectoral >< femoral > humeral > anal > gular. The head is small to moderately sized for such a large turtle, with a characteristic upturned snout and a notched, serrated jaw. The head is olive gray dorsally, but lighter gray laterally and ventrally with light-colored jaws. Juveniles are drably colored. The stout forelimbs are somewhat paddle-shaped with four claws. The skin is olive gray and occasionally darker. The sexes are strongly dichromatic during the breeding season; the skin on the head, neck, and legs of the male turns dark black and iris color changes from yellowish to pure white, while females remain drably colored. The iris of the female is black. Even when not breeding, males tend to be somewhat darker than females. The sexes can also be distinguished on the basis of tail characteristics; males have longer, thicker tails than females (Moll, 1978; Moll, 1980; Ernst and Barbour, 1989).

Geographic variation in the coloration of *B. baska* is not well described. Anderson (1879) noted that the head and forelimbs of males from Burma or India turned bright red during the reproductive season, a condition not observed elsewhere (Moll, 1980); however, this may have been the result of confusion with sympatric species of *Kachuga*. Although less pronounced, Moll (1980) likewise observed differences in coloration between populations of *B. baska* on the east and west coast of Peninsular Malaysia.

Reproduction

Reproduction of *B. baska* has been well-studied in Malaysia (Moll, 1978; 1980), Myanmar (Maxwell, 1911), and to a lesser extent in India (Bhupathy, 1995, 1997; Ghosh and Mandal, 1990) and Cambodia (Platt et al., 2003). Reproductive data from wild populations elsewhere are unavailable.

Size and age at sexual maturity vary according to sex; males exhibit secondary sexual characteristics and females begin nesting upon attaining a CL of 400 and 450 mm, respectively (Moll, 1980). The age at sexual maturity is unknown, but 18 to 25 years may be required to attain these body sizes under wild conditions. In captivity, reproduction occurs at a much earlier age; a six-year old female produced a clutch of infertile eggs at the Bronx Zoo, and a 12-year old female reproduced successfully at a captive breeding facility in Malaysia.

Courtship among *B. baska* probably takes place in the lower reaches of estuarine rivers where turtles gather to feed. Courtship among wild turtles has rarely been observed, but Moll (1980) noted that males captured as early as September already displayed breeding coloration. Courtship undoubtedly occurs prior to the upstream migration of females to nesting beaches which begins as early as November (Moll, 1980). *Batagur baska* requires elevated banks of relatively fine sand for nesting (Moll, 1980). Nesting habitat is typically located along brackish or freshwater stretches of larger rivers (Moll, 1980; Platt et al., 2003), although nesting on offshore marine islands occurs or formerly occurred in Myanmar and India (Maxwell, 1911; Ghosh and Mandal, 1990; Bhupathy, 1997). Variables affecting nest site selection are not well understood; however, females seem to prefer open areas lacking ground vegetation, an observation not lost on egg collectors who encourage nesting by scraping beaches to bare sand. Egg collectors also construct sand hillocks on potential nesting beaches to attract females. Moll (1978) speculated that these may function to enhance the beach profile, and noted that nests are often clustered in the immediate vicinity of hillocks. The same beaches are used each year for nesting, and individual females appear to exhibit considerable site fidelity (Tikader and Sharma, 1985).

The nesting period varies geographically, but generally coincides with the beginning of the annual dry season after heavy rains associated with the Northeast monsoon have ceased (Moll, 1980). On the west coast of Peninsular Malaysia, the first clutches are deposited from 8 November to 16 January, while on the west coast nesting occurs in February and March (Moll, 1980). Nesting takes place in Cambodia from December through early March (Platt et al., 2003) and in Myanmar from mid-January to early March (Maxwell, 1911; Thorbjarnarson et al., 2000). The beginning of the nesting season in India has not been determined, although Bhupathy (1997) noted that nesting is completed by late March. Captive *B. baska* at the Cleveland Metroparks Zoo exhibits breeding coloration from September through December (Poynter, unpubl.).

Clutch deposition occurs at night and at least in former times, females emerged *en masse* to nest. According to Loch (1950), in the years prior to World War II "many hundreds" of females nested each night along the Perak river in

Malaysia. By the 1970s Moll (1980) recorded nesting cohorts of as many as 50 females and stated that egg collectors could recall only a single cohort as large as 100 females. Upon emerging from the water, females excavate a deep body pit (ca. 70 cm) with the nest cavity at the bottom (Moll, 1980). Eggs are deposited every 30 seconds and then the nest cavity (50 to 60 cm deep) is covered with sand. The female then compact the sand by repeated blows with the posterior end of the plastron, producing a loud thumping sound. The function of this drumming is unclear, although egg collectors in Malaysia believe the sound attracts other females to nesting beaches (Moll, 1980). Sand is pulled from the walls and used to fill the body pit before the female returns to the water (Moll, 1980).

Batagur baska lays elongated, hard-shelled eggs that measure approximately 70 × 40 mm (Maxwell, 1911; Smith, 1931; Moll, 1980). Egg mass in Malaysia averages 64 grams and is positively correlated with female mass, but not clutch size (Moll, 1980). Clutch size is variable and probably depends on the body size of the nesting female. In Malaysia clutch size ranges from 5 to 50 eggs with a mean of 26.4 eggs (Loch, 1950; Balasingam and Mohamed Khan, 1969; Moll, 1980). Clutch size averages between 50 and 60 eggs in Myanmar (Maxwell, 1911), and 11.3 ± 4.4 eggs (n = 6; range = 6 to 19 eggs) in Cambodia (Platt et al., 2003). There is some evidence to suggest that females occasionally partition a single clutch among multiple nests (Moll, 1980). Females deposit up to three clutches each nesting season and the interval between clutches is about 15 to 20 days (Maxwell, 1911; Smith, 1931; Moll, 1980; Tikader and Sharma, 1985). The reproductive lifespan of female *B. baska* probably exceeds 20 years.

Optimal incubation temperatures for *B. baska* eggs range from 29 to 31°C; temperatures greater than 33°C may prove lethal (Chan and Soh, unpubl.). Although

B. baska almost certainly exhibits temperature dependant sex determination, the critical temperature at which sex determining events occur has yet to be ascertained. However, in a preliminary study by Chan and Kuchling (2004), eggs incubated in Styrofoam boxes at temperatures averaging 29.8°C (range = 25.4 to 33.5°C) produced 100% male hatchlings, while eggs incubated in sand nests under natural conditions produced 100% female hatchlings in some years and a mixture of both sexes in others.

Incubation periods are inversely related to incubation temperature, i.e., the lower the incubation temperature, the longer the incubation period. Various incubation periods have been reported; 60 to 102 days in Malaysia (Moll, 1980; Chan, unpubl. data), 69 to 121 days in Cambodia (Sovannara and Holloway, unpubl.). Hatching occurs from March to June and coincides with the onset of the annual wet season and a concomitant rise in river levels. Hatchlings emerge from the nest at night and immediately make their way to water. The CL of hatchlings ranges from 58 to 71 mm. Moll (1980) noted that fishermen never encounter hatchlings in the vicinity of nesting areas except during the hatching period, and the presence of very small turtles in tidal estuaries strongly suggests that neonates begin traveling downriver immediately following emergence.

Range and Habitat

The mangrove terrapin (*Batagur baska* Gray, 1831) is a large aquatic turtle that inhabits or formerly inhabited mangrove swamps, coastal estuaries, and rivers in southeastern India, Bangladesh, Myanmar, Peninsular Malaysia, Sumatra (Indonesia), Thailand, Cambodia, and Vietnam (Moll, 1985; Ernst and Barbour, 1989; Iverson, 1992). Within this distribution, *B. baska* inhabits large rivers, estuaries, coastal mangroves, and inshore beds of marine vegetation. During the reproductive season adult turtles travel far upstream to reach nesting beaches that are often located well above tidal influence.

Diet

In the wild *B. baska* is omnivorous, although the bulk of the diet is composed of vegetation and to a lesser extent fruit (Moll, 1980). The serrated jaws of *B. baska* are thought to be an adaptation for cutting and shearing vegetation (Moll, 1980; Davenport et al., 1992). These serrations function in a ratchet-like fashion that allows large leaves to be progressively moved into the esophagus without the turtle losing contact with the food (Davenport et al., 1992). Among the plants reportedly consumed by terrapins are mangroves (*Sonneratia* sp.), sedges (*Scleria* sp.), screw palm (*Pandanus* sp.), *Colocasia* sp., figs (*Ficus* sp.), and water hyacinth (*Eichhornia crassipes*) (Moll, 1980; Das, 1986; Davenport et al., 1992). *Sonneratia* fruit appears to be particularly important in the diet (Moll, 1980); it is also used by fishermen as bait to capture adult turtles in Myanmar (Maxwell, 1911; Thorbjarnarson et al., 2000) and Cambodia (Platt et al., 2003). The presence of rice (*Oryza sativa*), watermelon, grape (*Vitis* sp.), durian (*Durio zibethinus*), rambutan (*Nephelium* sp.), and chili peppers (*Capsicum annum*) in fecal samples, suggest that terrapins scavenge human refuse from the vicinity of riverside villages (Moll, 1980). In addition to plant material, mollusk shells were also found in fecal samples (Moll, 1980) indicating *B. baska* is not strictly herbivorous as stated by previous authors (Smith, 1931; Hendrickson, 1961). There is nothing to indicate that a major ontogenetic dietary shift occurs in *B. baska* (Moll, 1980).

In captivity *B. baska* consume a variety of foodstuffs, including water bindweed (*Ipomoea aquatica*), dog grass (*Cynodon dactylion*), the red-flowers of *Hibiscus* sp., and fruits of banana (*Musa* sp.), figs (*ficus* sp.) and mango (*Mangifera indica*) as well as animal foods such as fish and dried prawns (Moll, 1980; Das, 1986; Moll, 1986; Bhupathy, 1995). Most captive propagation centers feed a staple diet of water bindweed. Enhanced growth of hatchlings and juveniles maintained on a diet of commercially-available pellet food was noted at KUSTEM (Chen and Chan, unpubl.). Likewise, Davenport et al. (1992) recommends that head-started animals be given fish to improve growth rates prior to release.

Little has been published on the foraging behavior of *B. baska*; it appears to be primarily an opportunistic herbivore, browsing on floating plants or vegetation overhanging the water (Moll, 1980; Davenport et al., 1992). In captivity, adults and juveniles seem to prefer floating food, often ignoring food placed underwater. However, the presence of aquatic mollusks in the scats of some wild turtles (Moll, 1980) suggests that at least occasional subsurface feeding occurs. Although frequently occurring in estuaries and marine habitats, *B. baska* will not feed in water salinities exceeding about 20 ppt owing to their limited physiological ability to cope with saline conditions (Davenport and Wong, 1986; Davenport et al., 1992). In marine habitats, terrapins tend to exploit bankside vegetation rather than floating plants to avoid ingesting saline water (Davenport et al., 1992).

Daily activity of *B. baska* coincides closely with the tidal cycle. During tidal ingress turtles move upstream with the current and enter smaller tributaries to forage until ebb tide when they once again follow the current back towards the sea (Moll, 1980). Moll (1980) noted that this cycle is repeated on the Perak River irrespective of photoperiod, while in the Dungun River on the east coast of Peninsular Malaysia movements associated with the tidal cycle were not discernible. In this region Chan (unpubl. data) observed a bimodal pattern of daily activity with turtles being most active during the late evening and early morning hours.

Seasonal movements are related to the breeding cycle; males generally remain in estuarine feeding areas, while females migrate long-distances upstream to find suitable nesting habitat (Moll, 1985). Upstream movements as much as 50 to 80 km to nesting beaches have been recorded for females in Cambodia (Holloway and Sovannara, unpubl. data) and Malaysia (Moll, 1985), respectively. Females remain in the vicinity of these beaches throughout the nesting season, only returning downriver after the last clutch has been deposited. Estuaries may also experience a local ingress of *B. baska* in response to the fruiting *Sonneratia* sp., a primary component of the diet.

Legal Status

Batagur baska is legally protected to some extent in each country where it occurs. Populations also benefit from laws designed to protect other species and regulate fishing activity. Moreover, *B. baska* is listed in Appendix I of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), an international treaty regulating trade in endangered wildlife and plants. All countries in which *B. baska* occurs are signatories to CITES. Commercial trade in Appendix I species is completely prohibited, although exceptions are made for scientific and research purposes.

Chapter 3

Distribution, the Current Population and Conservation Status of the Critically Endangered River terrapin, *Batagur baska* (Gray, 1831) in Perak River, Malaysia, Thailand and Myanmar

Abstract

The river terrapin, *Batagur baska* (Gray, 1831) formerly occurred in large rivers from western India and Bangladesh, through much of Southeast Asia, as far east as Vietnam, Peninsular Malaysia, and Sumatra. Populations throughout much of this region have declined or been extirpated as a result of chronic over-harvesting of eggs and adults, destruction of nesting beaches due to sand mining and sedimentation, and mangrove forest clearance. Consequently, *B. baska* is regarded as Critically Endangered throughout its geographic distribution. Herein, we provide an overview of the conservation status of *B. baska* in Malaysia, Thailand and Myanmar and the results of recent surveys in these countries. Peninsular Malaysia represents the last stronghold of *B. baska* and relatively large populations occur in several rivers on both the east and west coasts. Despite the release of thousands of head-started hatchlings since the inception of these projects, populations of *B. baska* in the Perak River continue to decline. Recent estimates indicate that less than 50 breeding females remain in the river. There is little information on the historic occurrence and distribution of *B. baska* in Thailand. As late as the 1970s remnant populations were known to occur at Pak Payoon in Phattalung Province, Amphur Ranote in Songkhra Province, and some rivers of Ranong Province. Our survey of the Langu Canal found small numbers of *B. baska*, and documented the occurrence of at least three nests; other potential nesting beaches are located along the river. Furthermore, the recent

capture of a large adult *B. baska* by a fisherman in TaKua Tung District, Western Thailand suggests that hitherto unidentified populations may persist in other regions of Thailand. Owing to the paucity of recent records, the IUCN regards *B. baska* as extinct in Myanmar. However, our surveys indicate that small populations persist in coastal regions of Mon and Rakhine States, and Ayeyarwady and Tanintharyi Divisions where a combination of local religious beliefs and areas of armed conflict confer some degree of protection.

Introduction

The river terrapin, *Batagur baska* (Gray, 1831) is a large aquatic turtle that ranges or formerly ranged from the Sunderbans region of the Ganges-Brahmaputra Delta in India and Bangladesh, eastward through Myanmar, southern Thailand, Cambodia, and Vietnam, and south to Peninsular Malaysia and Sumatra (Ernst and Barbour, 1989; Iverson, 1992). Within this distribution, *B. baska* inhabits large rivers, estuaries, coastal mangroves, and inshore beds of marine vegetation. During the reproductive season adult turtles travel far upstream to reach nesting beaches that are often located well above tidal influence.

Historically large numbers of females returned each year to deposit eggs on well-known nesting beaches, but populations have drastically declined throughout this range due to a combination of chronic removal of eggs from nesting beaches, destruction of nesting beaches, over-harvesting of adults, incidental drowning in active and discarded fishing nets, and widespread habitat degradation or loss from dam construction, water pollution, mangrove deforestation, and sand dredging and mining (Platt et al., 2006). Today, extant populations of *B. baska* no longer occur in Indonesia and Vietnam, scattered individuals persist in Thailand, Myanmar, and

Cambodia, and the viability of populations in Bangladesh and India is doubtful. (Platt, et al., 2006). Malaysia is the only remaining ranges country that appears to harbor viable wild populations of *B. baska*. Moreover, conservation efforts to date have proven largely unsuccessful and various reports strongly suggest that the remaining populations continue to decline (Bhupathy, 1997; Das, 1997; Rashid and Swingland, 1997; Thorbjarnarson et al., 2000; Platt et al., 2003; Platt et al., *in press*). Consequently, *B. baska* is now regarded as one of Southeast Asia's most threatened chelonians (Das, 1997), considered Critically Endangered by the IUCN (2004), Thailand Red Data (2005) and Turtle Conservation Fund (2002), and prioritized by the Turtle Conservation Fund (2002) as one of 25 chelonians in urgent need of conservation action if extinction of wild populations is to be prevented.

Materials and Methods

Field surveys were conducted from 2003 through 2005 to assess data on the current population status of *B. baska* in Malaysia, Thailand and Myanmar. In Malaysia, we conducted a field survey of the Perak River in Perak State from November 2004 to March 2005 to assess potential nesting and foraging habitat along the river, identify potential sources of water pollution that might impact turtles, and describe limnological parameters and riverine vegetation. During this survey we monitored potential nesting beaches, including a government-owned nesting beach and others belonging to licensed egg collectors. Potentially suitable nesting beaches were marked on a map, with the straight distance from river-mouth and GPS coordinates. We were unable to deploy fishing nets to capture turtles in the Perak River owing to the extremely swift current. To evaluate long-term population trends we obtained records of nesting activity at sandbars and beaches along the Perak River for the years 1996 through 2005 from PERHILITAN (Wildlife Department of Malaysia).

In Thailand, we conducted surveys for wild *B. baska* on Langu Canal, in Satun Province during January to April 2003, August to September 2004, and May to August 2005. These surveys encompassed a section of the canal 23 km long (6.4km upstream from the fishery station and 16.6 km downstream to the river mouth). Average temperature in this region is 27.5°C (range = 17°C in February to 38.9°C in April) and mean annual rainfall is 2,280.9 millimeters (range = 7.2 mm in January to 377.8 mm in September). Our survey team included staff from the Department of Fisheries and local fisherman. We searched for basking turtles and attempted to trap adults using nylon fishing nets (mesh size = 20.3 cm). Additionally we interviewed people living along waterways in coastal areas to seek information on recent sightings and possible nesting activities.

In Myanmar, we distributed 100 questionnaires to local fishery stations in coastal regions where *B. baska* were historically found and requested information on the recent occurrence of these large conspicuous turtles. Based on answers to the questionnaire, we conducted field surveys from January through July 2004 in coastal regions of Mon State, and Tanintharyi and Ayeyarwady Divisions to verify reports and search for viable wild populations. We also searched ponds at Buddhist pagodas for *B. baska*; however, because the provenance of these turtles is unknown, distributional records based on pagoda ponds must be interpreted with caution (Kuchling et al., 2004).

During field investigations in Myanmar and Thailand we obtained information on the local occurrence and exploitation of *B. baska* largely through interviews of fishermen, turtle egg collectors, and villagers. Such individuals are generally excellent sources of information on the local chelonian fauna, especially species of cultural or economic significance (Thirakhupt and van Dijk, 1994; Platt et al., 2004). Additionally, we accompanied informants to specific areas where *B. baska* were captured to obtain habitat information.

During field surveys in all countries we determined geographic coordinates with a Garmin® GPS 12; these units were also used to calculate distance traveled during surveys of sinuous coastal waterways. Human disturbance and river traffic was recorded at all survey locations. Likewise we noted the presence of beaches that might serve as suitable *B. baska* nesting habitat along coastal waterways, and described vegetation at these sites.

We measured the following on each turtle using calipers: straight-line carapace length (CL), maximum carapace width (CW), plastron length (PL), plastron width (PL), shell depth (SD) and Body Mass (BM). Turtles <3kg were weighed using an electronic balance and larger turtles were weighed with a spring scale. Sex was determined based on head, neck, and iris coloration, as well as tail characteristics. During the breeding season the skin on the head, neck, and legs of the male turns dark black, while females remain drably colored, and the iris color of male changes from yellowish to pure white, while the female iris is black; males also have longer, thicker tails than females (Moll, 1978; Moll, 1980; Ernst and Barbour, 1989).

Statistical analyses were conducted using Microsoft Excel for Windows 2006. Locality records for *B. baska* and the location of potential nesting habitat were incorporated into revised distribution maps for each range country using Global Information System (ArcView GIS 3.2a). The location of potential nesting beaches were marked on a map along with the estimated area, a description of vegetation, and notes on the level of human disturbance and river traffic.

Results and Discussions

Malaysia

The historical distribution of *B. baska* in Peninsular Malaysia is poorly documented (Moll, 1980). Boulenger (1912) stated *B. baska* was common in the larger rivers of Malaysia. Hendrickson (1961) used interview data from fishermen and egg collectors to identify nine *B. baska* nesting areas in Malaysia; however, owing to the similarity of *B. baska* and *Callagur borneoensis* eggs and because both species are known locally as *tuntong*, Moll (1980) suggested that some of the areas identified may actually be *C. borneoensis* rather than *B. baska* nesting sites. Moll (1980) verified the occurrence of *B. baska* in the Perak, Kedah, and Terengganu River systems, and considered reports from the Setiu-Chalok and Pahang River systems valid.

The Perak River on the west coast of Peninsular Malaysia harbors the best studied population of *B. baska*. Eggs have always been considered property of the Sultan and collecting was only carried out under royal license (Swettenham, 1993). In the years prior to World War II, up to 650,000 eggs were collected from beaches along the river (Moll, 1978). During the war the carefully regulated system collapsed and egg collecting as well as the harvest of adult turtles became widespread (Moll, 1978). Beside exploitation of eggs, habitat alteration and destruction have also played important role in the decline of terrapin population (Moll, 1989). Sand mining and dam activities along the river or upstream has change the river physically and effecting the nest and feeding areas.

Even so, Loch (1951) stated that “hundreds of turtles” remained in the Perak River in the early 1950s. This population declined steadily (Mohamed Khan, 1964), and Balasingam and Mohamed Khan (1969) estimated a breeding population of only

220 females. Using nesting records from the Department of Wildlife and National Parks (PERHILITAN), Moll (1980) revised this estimate and suggested that 401 to 1204 females remained, somewhat more than previously believed. Assuming that females comprise 33% of the Perak River population, then the total population numbered between 1200 and 3600 turtles (Moll, 1980). However, Chan (unpubl.) recently estimated that less than 50 breeding females and probably no more than 150 *B. baska* remain in the river.

Malaysia has a long history of active river terrapin conservation efforts and the country is the principal stronghold for *B. baska* in Southeast Asia today. Egg collection, although legal, remains under the control of local state governments. Conservation efforts have largely focused on *ex-situ* incubation of eggs and release of head-started juveniles. The Bota Kanan River Terrapin Conservation Center was established in 1975 along the Perak River in northeastern Perak State. The facility is administered by the State Wildlife and National Park Department. Egg collection data from PERHILITAN (Jabatan, unpubl. data) indicate significant declines the number of female *B. baska* nesting along the Perak River within the last decade; 1478 nests were recorded in 1996, while only 36 nests were collected in 2004-2005 nesting season, a decline over 95% (Figure 3.2). Of the 36 nests, four were collected by PERHILITAN and 32 by licensed egg collectors; none of the latter was made available to PERHILITAN for incubation.

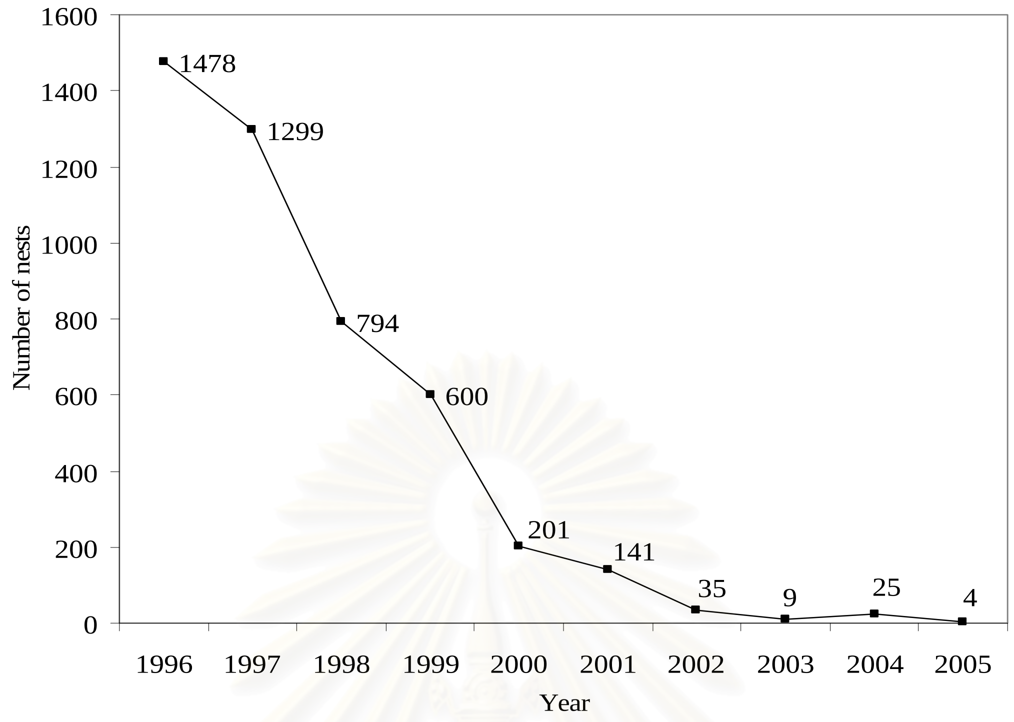

Figure: 3.1. Long-term trends in the number of *Batagur baska* nesting along the Perak River in Malaysia (1996-2005). These figures are based on nests collected by PERHILITAN staff and licensed egg collectors from both government beach and license eggs collector beach. Undoubtedly some nests collected by egg collectors are not reported so the actual number of turtles nesting in a particular year is probably somewhat greater than indicated.

This dramatic decline has occurred despite the release of 35,436 head-started juvenile *B. baska* into the river from 1969 to 2004. The reasons for this decline are unclear; however, but it is obvious that few if any of these turtles are surviving to augment the breeding population, calling into question the effectiveness of head-starting as a conservation strategy. Because head-starting programs have failed to achieve even basic population recovery goals, Platt et al. (2006) recommend a rigorous evaluation of their conservation merits before additional assets are expended.

Upstream dam construction and tin mining operations on the Perak River have intensified in recent years, likely resulting in significant changes to river morphology. Our survey and those of others (Moll, 1980) indicates *B. baska* inhabit tidal sections of the Perak river throughout the year except during the nesting season. The river mouth is wide with a mud bottom in most places, although sandy areas occur at several locations. The vegetation of the tidal reaches of the river is characterized by extensive stands of mangrove apple, *Sonneratia caseolaris*.

Owing to logistic constraints, we were unable to conduct a mark-recapture study to estimate the current wild population of *B. baska* in the Perak River; instead we follow previous workers and base our estimates on the number of nests recorded along the river. We identified 7 beaches where *B. baska* nesting occurred along the Perak River (Table 3.1, Figure 3.2). Many apparently suitable beaches along the river were not utilized by nesting females, probably because of a thick growth of vegetation. Vegetative growth is thought to be due to upstream dam construction that reduced scouring of the beaches by yearly floods that formerly occurred (Platt et al., 2006). Five known nesting beaches were manually cleared by egg collectors to encourage nesting; no effort was made by egg collectors to clear the other two known nesting beaches. According to the collectors, the latter beaches have not been used by nesting turtles for the past five years and consequently the cost of clearing vegetation can no longer be justified.

In addition to clearing vegetation, egg collectors construct small hillocks on nesting beaches and submerge bunches of bananas in shallow water at the beach to attract female *B. baska*. The efficacy of these practices is unclear, but these methods have a long tradition on the river (Moll, 1978, 1980). We also observed egg collectors pouring alcohol on small fires ignited on the beaches under the belief that the smell would provide further incentive to lure nesting turtles.

Licensed egg collectors found one nest on Pulau Pisang 1, another on Lope Salleh beach in Kampung Tanjun Aur and 30 nests on Pulau Padang beach north of Pulau Pisang village. In previous years, many of these eggs were sold to PERHLITAN to be incubated at the Bota Kanan station. However, egg collectors now sell their catch for local consumption and PERHLITAN has been unable to obtain eggs for head-starting during the 2004-05 nesting season. Notably, data were unavailable for Pentai Jambatan (Mustafa M. Shah) beach near the bridge linking Bota Kanan with Bota Kiri. In the past, this beach produced the majority of eggs collected from the river, but was abandoned and no longer cleared of vegetation following the death of the owner. The beach is now overgrown with dense vegetation and unlikely to be used by nesting females in the future.

During our survey of the Perak River we examined 36 clutches, including 32 deposited by wild females on license collector beaches and 4 nests deposited on Bota Kanan Wildlife Department Station beach. Based on nest counts, it thus appears likely that less than 50 breeding females remain in the river. Four nests from the PERHILITAN, Wildlife Department station beach (Pentai Jabatan; N 04° 20' 50.8", E 100° 52' 42.5") had a mean clutch size of 19.2 ± 1.5 eggs (range = 17 to 20 eggs). These eggs averaged 68.5 ± 3.65mm long × 43.2 ± 1.32 mm wide and weighed 75.92 ±6.84 g. Forty eggs from the first two clutches deposited were moved to the station beach and incubated under natural conditions in sand at an average temperature 30.3˚ C. Thirty-seven eggs from the remaining two nests were placed with sand in Styrofoam boxes and incubated at an average temperature of 29.5 ˚C. Hatching success of the four nests ranged from 0 to 94.1% (natural nests = 0 and 45%;

Styrofoam boxes = 60 and 94.1%). Incubation periods for the three nests that produced hatchlings ranged from 70 to 75 days. Based on this very limited sample, eggs incubated in Styrofoam boxes appear to require longer to complete development than eggs incubated in sand, most likely due to the cooler incubation temperatures of the Styrofoam boxes.

We made several observations of *B. baska* and their sign (tracks, slides, etc.) while conducting surveys along the Perak River. On 26 Dec 2004, we observed a *B. baska* feeding on *Alocasia* spp. near Kampong Palau Pisang (N 04˚ 22' 13.9", E 100˚ 53' 82.0"). Another adult *B. baska* was observed swimming near the nesting beach adjacent to the Bota Kanan station at approximately 1900 hours on the same day. On 27 Dec 2004 we found numerous fresh tracks on a small beach downstream from the station (N 04° 18' 36.3", E 100° 54' 01.7") where nesting has not been previously reported. Finally, according to fishermen, juvenile *B. baska* are occasionally taken in fishing nets set in irrigation channels and small creeks that feed into the main river channel near Bota Kiri.

Thailand

There is scant information on the historical occurrence of *B. baska* in Thailand. The first Thai record of this species resulted from a survey of northern Malaysia and Southern Thailand by Nelson Annadale and Herbert Robinson in 1901 and 1902 (Boulenger, 1903). A small *B. baska* was collected in the lower beaches of the Patani River. As late as the 1970s remnant populations were known to occur at Pak Payoon District in Phattalung Province, Ranote District in Songkhra Province, and some rivers of Ranong Province (Wirot, 1979; Moll, 1985). Moll (1985) considered these populations to be small remnants of once larger breeding populations that were decimated after many years of intense exploitation of eggs and adults. The few turtles remaining in the wild were threatened by continued collection by local fishermen (Moll, 1980). Thailand lists *B. baska* as a protected species in the first category according to Ministerial Regulation Chapter 14 (B.E. 2535) written in accord with the Reserves and Wildlife Management Act of B.E. 2503.

From 1996 to 2004, all 411 head started turtles from Satun Fisheries Station were released into a pond at monastery near Songkhra Lake, Haad Kai Tao and Thalae Luang in Pattalung District. Forty turtles were released into Langu River in 1999 as a river terrapin conservation project for reintroduction into the wild. Although efforts are currently underway to evaluate several potential reintroduction sites, a long-term conservation strategy for head-starting and reintroduction remains to be developed and is urgently needed. Alarmingly the breeding facility is situated on a low-lying bend along the river and subject to flooding during exceptionally wet years. Indeed, a number of *B. baska* escaped during a flood in 2003 and future unplanned liberation of *B. baska* is highly probable during wet years.

Our surveys were made at Langu River, Pakbara River in Satun Province and Haad Kai Tao, Thalae Luang in Pattalung Province. Although viable wild populations of *B. baska* are no longer thought to occur in Thailand, our survey indicated that scattered individuals persist in the Langu River and perhaps elsewhere in the southernmost region of the country. We found evidence of a small number of wild *B. baska* in the Langu River; three nests were harvested by villagers in January 2003 and a basking adult was photographed in October, 2004. We also identified eight potential nesting beaches along the river (Table 3.2, Figure 3.3). The beaches are composed of medium quartz sand, soil, and rocks. Local inhabitants engage primarily in small-scale gardening, plantation agriculture, and fishing. Both plantation agriculture and fishing activities cause considerable disturbance to the river; the former results in significant inputs of agro-chemicals and fishing nets inadvertently capture turtles. We placed fishing nets (mesh = 20.3 cm) across the canal at five locations near *Sonneratia* trees in an attempt to capture feeding *B. baska*. These nets were checked each hour, but no turtles were captured during our survey. Encouragingly however, a local villager fishing in a mangrove canal in TaKua Tung District in western Thailand captured a large adult *B. baska* (CL = 50 cm; mass = 28 kg) on 1 January 2006. Collectively, our observations and reports from villagers suggest that small numbers of *B. baska* continue to survive in southern Thailand, although the viability of these small populations is questionable.

Myanmar

Historic accounts indicate that *B. baska* was common in the Ayeyarwady Delta where large numbers nested each year on islands at the river mouth and sandbars as far upstream as Hinthada (formerly Henzada) District (Maxwell, 1911). At that time “herds” of 100 to 500 nesting females could be seen basking on beaches in the late afternoon and Maxwell (1911) estimated a nesting population of at least 1,175. The Colonial Administration leased the turtle nesting beaches to local businessmen, who hired laborers to collect eggs that were later sold in local markets or exported to Rangoon (Yangon). The annual harvest of 165,000 eggs during the early 1890s had declined to approximately 77,000 by 1897-98, and by the early 1980s only a few terrapins continued to nest on these islands (Salter, 1983). A survey in 1999 found no evidence of nesting activity and Thorbjarnarson et al. (2000) concluded *B. baska* was no longer extant in the lower Ayeyarwady River.

Elsewhere in Myanmar *B. baska* reportedly occurred in the Salween and Sittaung (formerly Sittang) rivers and museum specimens collected during the late 1800's and early 1900's are available from both rivers (Iverson, 1992). Gordon (1875) described large "river turtles" floating on the surface of the latter river that were most likely *B. baska*. Indeed, the extensive beaches along the Sittaung River described by Abreu (1858) would appear to be near-ideal nesting habitat. Even today there are few villages along either river and consequently fishing activity and riverside agriculture are minimal in comparison to other comparably large rivers in Myanmar, thereby increasing the likelihood that populations continue to survive. However, survey data are unavailable and the current conservation status of these populations remains unknown. Given the paucity of recent records, the IUCN (2004) regards *B. baska* as extinct in Myanmar. However, Salter (1983) and Platt et al. (in press) received apparently reliable descriptions of *B. baska* from villagers inhabiting the coast of Rakhine State, suggesting the IUCN conclusion is somewhat premature.

During this study, we verified the occurrence of *B. baska* at one location in Mon State and two localities in Tanintharyi Division where we obtained the carapace of a recently killed *B. baska*, examined a clutch of eggs, and were shown photographs of a large female recently captured by fishermen (Kalyar et al., submitted). The carapace (CL = 52.8 cm; CW = 42.4 cm) was obtained from fishermen residing at Khaw Za Town, a fishing village on the border between Mon State and Tanintharyi Division; the turtle was captured nearby on 11 January 2004 and consumed shortly thereafter by villagers. Security considerations prevented us from visiting Khaw Za Town, but according to fishermen, *B. baska* are regularly taken incidental to fishing activities; most are eaten by villagers. Villagers attribute the continued survival of *B.*

baska to armed conflict between government forces and Mon insurgent groups which discourages fishing in this area.

We accompanied an egg collector to a *B. baska* nesting area on Pyin Won Beach along the Tanintharyi River on 5 February 2004. This individual excavated a single *B. baska* nest containing 12 eggs that were collected and later eaten. This practice appears widespread as other villagers likewise report similar egg collections. Additional nesting beaches are thought to occur further upstream.

Additionally, the residents of Sinzeik Village provided us with photographs of a large (CL ca. 55.0-60.0 cm) female mangrove terrapin captured after it became entangled in a fishing net set in the Dawei River, approximately 38 km upstream from the river mouth. The turtle was captured on 26 January 2004 and released the following day. Fishermen regard *B. baska* as extremely rare in the Dawei River. *Batagur baska* also reportedly occur in the Par Chan River, which separates southern Tanintharyi Division from Thailand, and its tributary creeks. According to inhabitants of the riverside villages of Thaung Phyu and Kan Paw Gyi, juvenile *B. baska* are frequently taken in crab traps placed beneath mangrove trees and baited with salted fish. Small terrapins are generally released, while larger specimens are kept for local consumption.

We obtained only a single recent record of *B. baska* from Ayeyarwady Division; fishermen in Wet Bu Village reported the inadvertent capture of an adult in the Tha Baung River during January 2004. The turtle became entangled in a shad (*Tenualosa ilisha*) net and was released the following day. Although occasionally taken in fishing nets (1-2 turtles/year), fishermen regard *B. baska* as uncommon in the Tha Baung Estuary. Our surveys elsewhere in Ayeyarwady Division failed to find any evidence for the continued occurrence of *B. baska*.

Finally, we examined an adult female *B. baska* (CL = 55.8 cm; CW = 44.4 cm; PL = 53.7 cm; SD = 23.1 cm) inhabiting a pond on the grounds of Botahtaung Pagoda in Yangon. The provenance of this turtle is unknown, but we speculate that it originated from the now extinct (or nearly so) population that formerly inhabited the lower Ayeyarwady Delta (Maxwell, 1911; Thorbjarnarson et al., 2000).

To summarize, our survey and others (Platt et al., in press) indicate that populations of *B. baska* persist in coastal regions of Rakhine and Mon States, and Ayeyarwady and Tanintharyi Divisions of Myanmar (Table 3.3, Figure 3.4). As reported by Platt et al. (in press), a small number of *B. baska* probably occur near Ramree Island in Rakhine State, but are threatened by the continued harvest of eggs and adults. Although the large population that once nested at the mouth of the Ayeyarwady River was decimated by the late 1980's (van Dijk, 1997; Thorbjarnarson et al., 2000), our survey suggests that small numbers remain in the Tha Baung River and its tributaries. Given the intense levels of fishing activity in this river and the risk of drowning associated with the widespread use of fishing nets the long-term persistence of this population is unlikely.

The last stronghold of *B. baska* in Myanmar appears to be in Tanintharyi Division where a combination of local religious beliefs and areas of armed conflict confer some protection on remaining populations. Religious beliefs protecting *B. baska* are strong, but localized in Tanintharyi. Because *B. baska* often traverse great distances between foraging and nesting habitats (Moll, 1980; Platt et al., 2003), these localized beliefs prohibiting capture offer only limited protection.

TABLE 3.1: Coordinates of *Batagur baska* nesting beaches on Perak River, Malaysia. Numbers correspond to Figure 3.2. The name of the individual leasing the egg collection rights at each beach is in parentheses.

Location (Egg collector)	Latitude (N)	Longitude (E)
1. Pentai Jabatan (Station Beach)	04° 20' 50.8"	100° 52' 42.5"
2. Pentai Jambatan (Mustafa M. Shah)	04° 21' 11.9"	100° 52' 28.7"
3. Pulau Pisang beach 2 (M.Abd. Majid)	04° 21' 48.9"	100° 52' 53.7"
4. Pulau Pisang beach 1(Mohamad Kassim)	04° 22' 01.1"	100° 53' 31.1"
5. Pulau Padang (Haji Hasnat)	04° 22' 08.4"	100° 53' 42.0"
6. Kampung Tanjun Aur (Lope Salleh)	04° 22' 49.7"	100° 53' 00.2"
7. New Beach (Owner undetermined)	04° 18' 36.3"	100° 54' 01.7"

TABLE 3.2: Coordinates of potential *Batagur baska* nesting beaches located along the Langu Canal in southern Thailand. Numbers correspond to Figure 3.3.

Location	Latitude (N)	Longitude (E)
1. Station Beach	06° 55' 11.5"	99° 51' 33.2"
2. Beach 1	06° 56' 07.6"	99° 51' 46.4"
3. Beach 2	06° 55' 34.6"	99° 51' 38.7"
4. Beach 3	06° 55' 05.0"	99° 51' 27.4"
5. Beach 4	06° 54' 43.9"	99° 51' 23.2"
6. Beach 5	06° 54' 48.3"	99° 50' 48.0"
7. Beach 6	06° 54' 32.1"	99° 49' 56.9"
8. Beach 7	06° 54' 14.8"	99° 49' 33.7"

TABLE 3.3: Coordinates of localities mentioned in the text where evidence of *Batagur baska* was found in Myanmar. Numbers correspond to Figure 3.4. NA = coordinates not available. Khaw Za Town is located approximately 16 km south of Ye Town.

Location	Latitude (N)	Longitude (E)
1. Kan Paw Gyi	10°16' 38.6"	98° 59' 74.3"
2. Khaw Za Town	NA	NA
3. Par Chan River	10° 24' 41.3"	98° 60' 42.9"
4. Pyin Won Beach	12° 20' 84.8"	98° 91'05.5"
5. Sinzeik Village	14° 11' 02.8"	98° 19' 48.2"
6. Tanintharyi Town	12° 09' 13.3"	99° 01' 30.3"
7. Thaung Phyu	10° 06' 27.5"	98° 58' 54.0"
8. Wet Bu Village	16° 53' 66.6"	94° 61' 38.0"
9. Ye Town	15° 25' 17.3"	97° 86' 21.8"

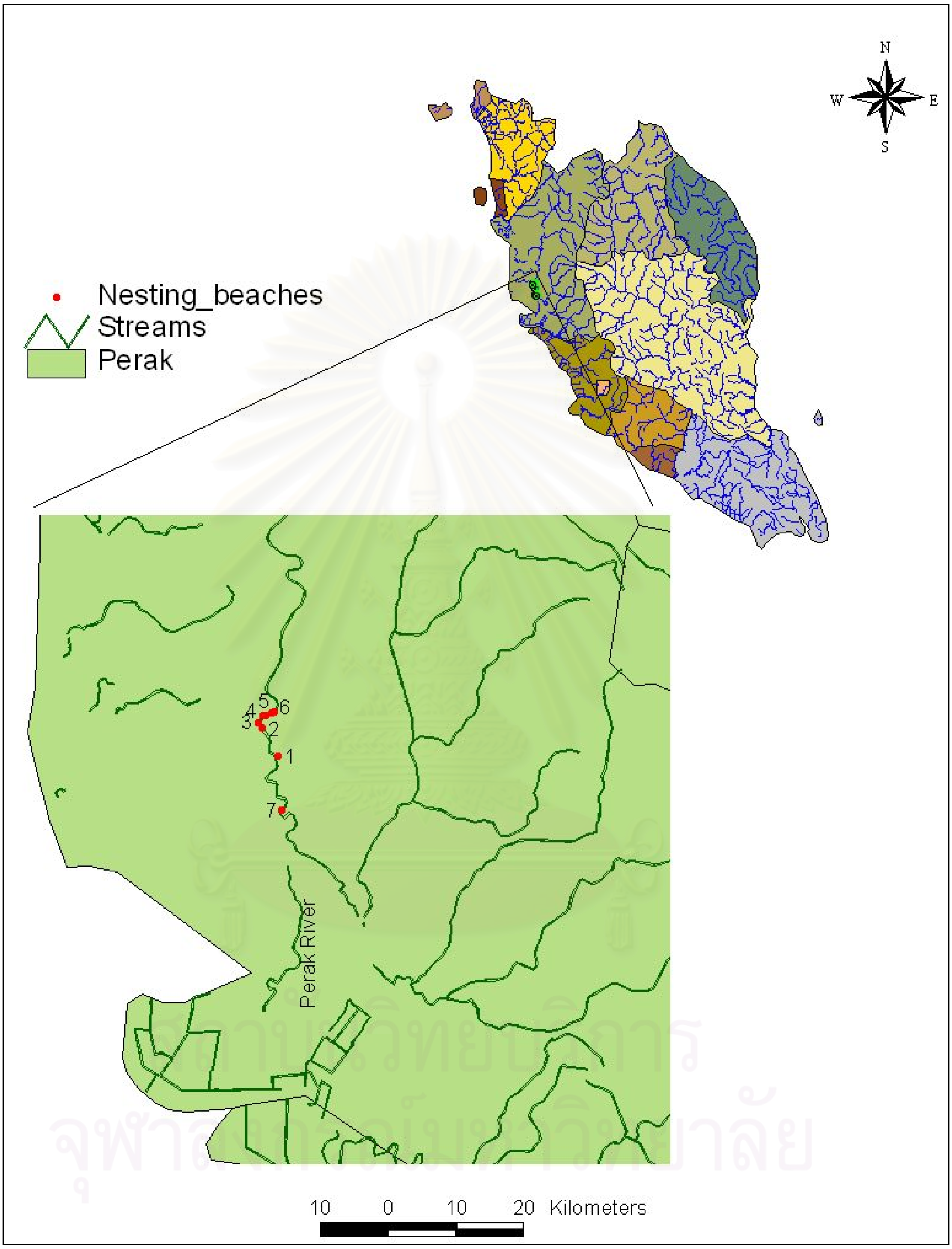

Figure: 3.2. Map of Perak River in Perak State, Malaysia. Numbers indicate *Batagur baska* nesting beaches identified in 2004-2005 and correspond to geographic coordinates in Table 3.1.

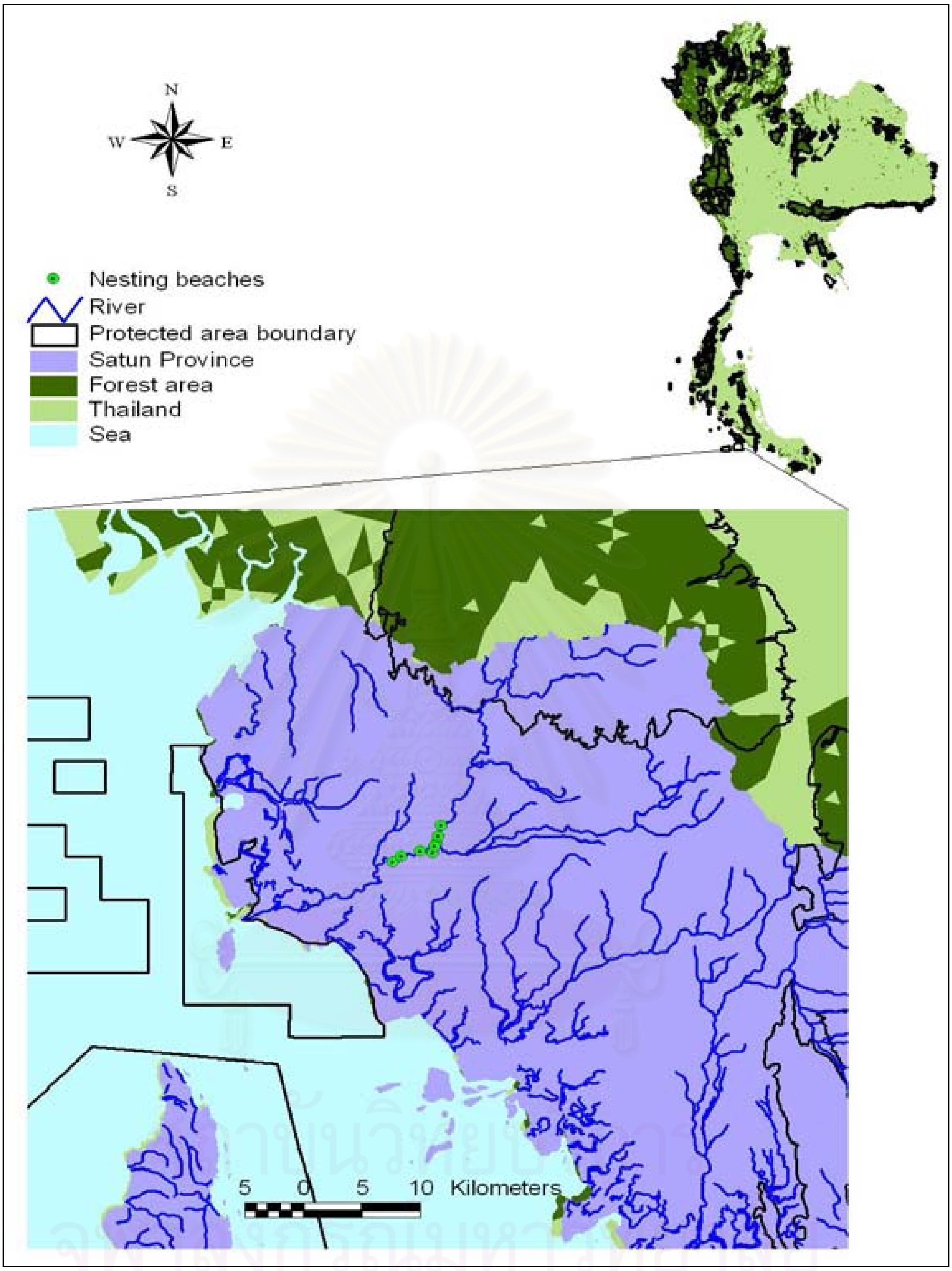

Figure: 3.3. Map of area in southern Thailand indicating locations (green dots) of potential *Batagur baska* nesting beaches along the Langu Canal.

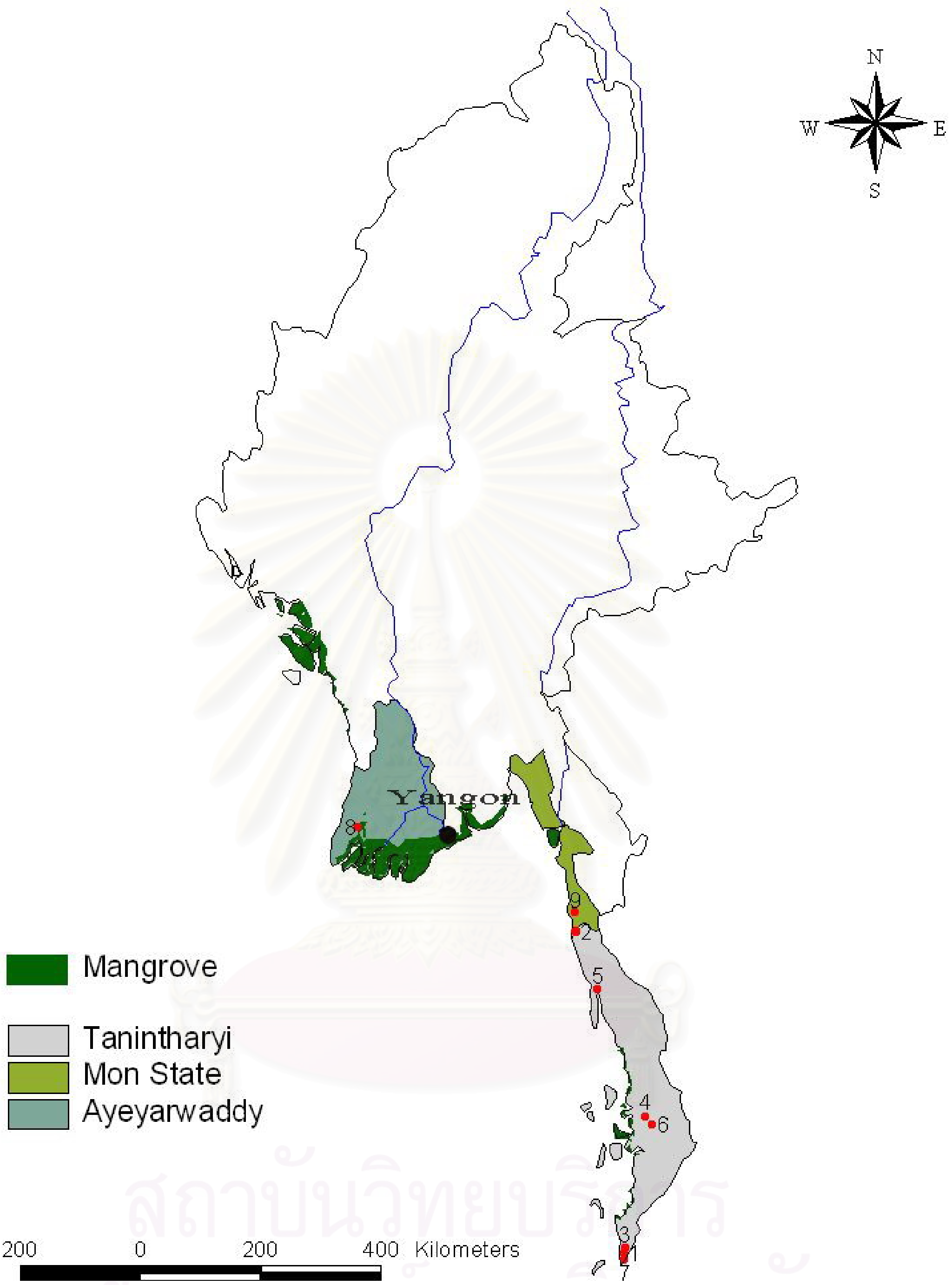

Figure: 3.4. Locations in southern Myanmar where *Batagur baska* were found during surveys in 2003. Numbers correspond to list of geographic coordinates in Table 3.3.

Chapter 4

Captive Breeding of the River Terrapin, *Batagur baska* (Gray 1831) at Satun Inland Fishery, Thailand and Bota Kanan Hatchery, Malaysia

Abstract

The reproductive biology of captive *Batagur baska* was studied at Satun Inland Fishery Station (SIF) in Langu, Thailand and Bota Kanan Hatchery (BKH) in Perak, Malaysia during 2002 to 2005. Peak nesting activity at both sites coincided with the lowest mean monthly air temperatures and hatchling emergence occurred when mean monthly air temperatures were highest. At SIF, 50 breeding adults (25 males: 25 females) are maintained in large ponds. Courtship and mating took place during October and November, followed by nesting in December and January. Secondary sexual characteristics were obvious in males with a carapace length (CL) as small as 250 cm. Mean clutch size among females (n = 14) was 21.7 ± 5.6 eggs (range = 18 to 25 eggs). Significant positive correlations were noted between female CL, and egg and clutch mass. Incubation periods ranged from 74 to 110 days depending on the method of incubation. Hatching success ranged from 40.8% to 58.1% depending on incubation method. During this study, 90.5% of hatchlings survived from 2002 to 2005. Repeated measurements of hatchlings indicate growth rates are high during the first year of life. Growth rate of hatchlings was considerably higher at SIF in comparison to BKH, most likely due to superior diet provided to hatchlings at the former facility. With the exception of a small number of turtles released into the Langu River in 1999, reintroduction of *B. baska* has not yet been attempted in Thailand. Based on the results of this study, I recommend that changes be made to incubation facilities to improve hatching success, turtles should be supplied with deeper water, stocking density should be reduced to provide individuals

with more space in each breeding pen, and calcium supplements be added to the diet to ensure proper eggshell formation. Most importantly, rivers in Thailand should be evaluated as potential reintroduction sites for establishing viable wild populations.

AT BKH in Malaysia, 75 adult turtles (20 males: 55 females) are maintained for breeding. Courtship and mating takes place from August through December, while nesting and clutch deposition occurs as early as October, with a peak in January, and continues until mid-March. Breeding coloration among males becomes evident at a CL of 302 cm and an age of 17 years. Clutch size produced by captive female averaged 15.2 ± 5.7 eggs (n = 10; range = 6-20). Clutch size at BKH was smaller than found in Thailand, probably due to the smaller body size of females at BKH. From 1993 to 2005, 1524 clutches were produced by adults maintained at BKH with hatching success ranging from 27.5 to 60.5%. Incubation periods ranged from 71 to 92 days. From 1969 through 2005, 35,263 head-started turtles were released into the Perak River. Despite the release of large numbers of hatchlings over the past 35 years, there has been little attempt to monitor the success of this program. Based on the number of nests collected along the Perak River, it appears that the number of wild females continues to decline, although the causative agents have yet to be identified. Therefore, a re-evaluation of the captive breeding and head-start program, monitoring of the wild population in the Perak River are urgently required. Additionally, I recommend that all eggs harvested by the commercial egg collectors be purchased by BKH and the sale of eggs in markets be legally banned. Finally, dietary improvements are urgently needed and frequent inspection by a veterinarian trained in reptile medicine are essential to ensure the health of captive turtles at the facility.

Introduction

Captive breeding programs can be an important conservation and management strategy which can be used to conserve riverine turtles under certain circumstances, particularly when suitable natural habitat remains for the release of head-started juveniles (Moll and Moll, 2000). Natural and artificial hatcheries are popular tool in global marine turtle conservation and research (Blanck and Sawyer, 1981; Whitmore and Dutton, 1985; Harry and Limpus, 1989; Molaoney et al., 1990) especially where it is necessary to protect nests from predators and natural catastrophes. There are numerous problems associated with *ex-situ* incubation of marine turtle eggs and release of hatchlings, including skewing of natural hatchling sex ratios for species with temperature dependant sex determination (TSD) (Limpus and Miller, 1980; Dutton et al., 1985; Mortimer, 1990a); predation of hatchlings (Mortimer, 1990a), and inconsistent hatch rates (Blanck and Sawyer, 1981).

In Malaysia and Thailand, four River Terrapin (*Batagur baska*) conservation centers have been established, namely Bota Kanan hatchery in Perak, Bukit Pinang hatchery in Kedah, Bukit Paloh hatchery in Terengganu, and Satun Inland Fishery Station in Langu, Thailand. I herein present an analysis of data provided by the Bota Kanan Hatchery (BKH) in Malaysia and Satun Inland Fishery Station (SIF) in Thailand. BKH was initially established in 1968 by Jabatan Mergastua Perak at Batu Gajah until 1975 when it was moved to its current location at Bota Kanan. This facility currently houses 75 breeding turtles; this total includes 20 males (mean CL= 40.8 ± 3.31 cm) and 55 females (mean CL = 46.6± 2.44 cm). Additionally, 279 sub-adults, 778 juveniles and 114 hatchlings were housed at BKH during 2004-2005.

In 1983, a captive breeding facility was established at SIF in southern Thailand. The facility was constructed on a known *B. baska* nesting beach along the

Langu River and stocked with locally obtained turtles from one of the only remaining wild populations in Thailand; females were captured as they came ashore to nest and males were netted in the river. Currently, the facility houses 25 males (mean CL = 44.9 ± 1.4 cm), and 25 females (mean CL = 51.1 ± 2.6 cm), in addition to 236 sub-adults, 594 juveniles and 141 hatchlings. Only a few eggs were successfully hatched during the early years of the program, but following improvements in husbandry methodology, approximately 200 hatchlings are now produced each year. According to the station records, 1649 hatchlings have survived during the 23 years of the program.

The objectives of this study were therefore to investigate the incubation of *B. baska* under different experimental treatments to determine the effect of gross incubation temperature on incubation period, hatching success, and hatchling emergence, the sex ratio of those captive bred *B. baska* reaching adulthood, and to evaluate the overall success of these conservation programs.

Materials and Methods

I collected morphometric data on captive *B. baska* at SIF and BKH during 2004 and 2005). The following data were collected from each turtle using calipers: straight-line carapace length (CL), maximum carapace width (CW), plastron length (PL), plastron width (PW), shell depth (SD), body mass (BM), total tail length (T1) and pre-anal tail length (T2). Turtles <3kg were weighed using an electronic balance; larger turtles were weighed with a spring scale. Sex was determined based on head, neck, and iris coloration, as well as tail characteristics. During the breeding season the skin on the head, neck, and legs of the male turns dark black, while females remain drably colored, and the iris color of male changes from yellowish to pure white, while the female iris is black; males also have longer, thicker tails than females (Moll, 1978; Moll, 1980; Ernst and Barbour, 1989).

At BKH, rangers remove vegetation from natural nesting beaches and nesting areas in hatchery enclosures two weeks prior to the beginning of the nesting season. Nesting generally occurred between 2300 hrs and 0300 hrs (En. Mohd Nazri, pers. comm). Nests were excavated by hand and eggs collected within 12 hours of being deposited, and transferred to the hatchery for incubation. The depth and width of the original nest hole on natural beaches were measured. Clutch size was determined and among captive turtles, clutch size and clutch frequency were recorded. I measured the length, width, and mass of each egg before reburying them in the standard artificial nests used at these facilities. Eggs were randomly mixed and allocated in groups of 20 before reburying them in artificial nest chambers at a depth of 30 cm. One third of total clutches were incubated in Styrofoam boxes filled with beach sand and placed in a shaded area. These were sprinkled with water 2 times a week. Nest temperatures were determined by placing a Maxim/Dallas IButton® thermal data logger in each nest, although not in physical contact with the eggs. Each nest was surrounded by a wire mesh screen to contain emerging hatchlings. Air temperature was also recorded twice daily by Maximum/Minimum thermometer. After incubating for 60 days, nests were monitored every 3 days for emergent hatchlings by noting depressions in the sand over the egg chamber. To prevent predation by ants, a repellent powder was placed around the hatchery two weeks before incubation. Ants have previously been known to cause serious mortality to newly emerged hatchlings in captive facilities.

Terrestrial activity and breeding behavior of *B. baska* in the breeding ponds at SIF were monitored through the year. Mating behavior and the duration of copulation were also observed and recorded. *Batagur baska* nests at SIF and BKH were monitored from 2002 through 2005. In addition, I also incorporated long-term nesting records (1993 to 2004) collected by Wildlife and National Park personnel in my analyses. A similar protocol was followed at SIF. Each clutch was separated into 3 groups and eggs randomly assigned to one of three different incubation regimes that are commonly used at SIF: 1) outdoor hole nests simulating natural conditions; 2) a sand-filled concrete pond; 3) sand-filled foam containers. These artificial nests were marked with the date of oviposition and the clutch size. A circular wire mesh was placed around each clutch to retain emerging hatchlings. Temperature was recorded and nests protected from predators in the same manner as described for BKH.

Upon emergence hatchlings were counted, separated by clutch, and placed in a plastic basket filled with water to a depth of 30 cm (BKH) or kept in a fiber glass aquarium filled with water to a depth of 10 cm (SIF). If the number of hatchlings did not match the number of the eggs initially placed in the nest, I then waited for another 3 days and excavated the nest. At that time I recorded live hatchlings, dead hatchlings, and unhatched eggs. In each method, the number of hatchlings emerging was recorded and the respective hatching success rates calculated. Incubation period was also calculated for each clutch. CL, CW, PL, PW, SD and BM were determined for each hatchling.

River terrapins were fed 30 to 40 kg of fish on Monday, Wednesday and Friday and 20 kg of commercial fish pellets was provided on Tuesday, Thursday and Saturday. Terrapins were also fed with 40 kg of morning glory *Ipeomea* spp. daily, except during the dry season when feeding these plants became cost prohibitive. The center has also provided *Ficus* spp. fruits *ad libitum* during the fruiting season. Water was changed daily and according to standard protocol at each center, the hatchlings were fed chopped fish and *Ipomea* spp. in a 1:1 ratio. Hatchlings were permanently marked by notching a unique series of marginal scutes and measured upon emergence, and then again after one, two, and three years of age. Morphometric comparisons of each variable were examined by a t-test. Statistical analyses were conducted using Microsoft Excel for Windows 2006 and with SPSS 10.00 for Windows. Mean values are presented as ± 1 SD and the results were considered significant at $P \leq 0.05$.

Results

Stocking rates and general husbandry

At SIF, 25 females and 25 males were maintained in an outdoor concrete pond measuring 10m × 20m ×1m. Water depth varied from 60-80 cm and a $30m^2$ artificial sand bank extending approximately 80-90 cm above the water level was provided for nesting in its enclosure. A roof covered each sandbank to provide protection from direct sunlight and prevent excessive heating of the water. Each pond was enclosed in a fence to deter predators. Currently, SIF facility houses 1021 *B. baska* in 10 different ponds. The number of terrapins in each pond is summarized in Table 4.1.

Pond No.	Aproximate Age	Male	Female	Juveniles	Hatchlings	Total
1	40+	25	25			50
2	18	67	16			83
3	17	40	33			73
4	16	58	24			82
5	7 year			98		98
6	4 year			121		121
7	3 year			130		130
8	2 year			166		166
9	1 year			77		77
10	3 months				141	141
Total		190	98	594	141	**1021**

Table 4.1: Total number of *Batagur baska* housed at Satun Inland Fishery Station, Thailand (2004-2005).

In 2004 the Bota Kanan Hatchery housed 20 male and 55 female breeding *B. baska* in a sheltered pool (ca. 10 m^2) filled to a depth of 2 m (Pond A). Pond A has 2 nesting beaches; one measuring approximately 20 × 10m and the other only $10m^2$. The total number of river terrapins of different ages that are housed in various ponds is given in Table 4.2. A few adult terrapins were housed in Pond C and D, and these have contributed a small, but undetermined number of clutches in recent years; no nests were found in these ponds during my study. The oldest adults in Pond A were captured as juveniles in 1968-1969. Nesting among this group was first reported in 1980. The sex ratio of the captive population is female biased (1:3). All age classes of river terrapins at BKH are fed primarily *kankong (Ipomea sp),* supplemented with occasional bananas and fish. The cost of feeding is reportedly RM1, 200 per month (=$US 300).

Pond	Approximate Age	Male	Female	Juveniles	Hatchlings	Total
A	35+	20	55			75
B	19	51	69			120
C	18	29	77			106
D	17	16	37			53
E	1			123		123
F	2			376		376
G	3			280		280
H	Hatchlings				107	107
Total		116	238	779	107	**1240**

Table: 4.2. Summary of *B. baska* held at the Bota Kanan Hatchery in Perak, Malaysia.

Air Temperature

The results show that mean monthly temperature was highest in March and April at SIF. The peak nesting period coincided with the lowest mean monthly air temperature (26.2 ± 0.3 ˚C) and peak hatching period coincided with the highest mean monthly air temperature (30.2 ± 0.2 ˚C) (Figure: 4.1). A positive correlation was found between monthly nesting effort and mean monthly air temperature. At BKH, the onset of nesting occurred during January and December, the months with the lowest mean air temperature. Hatching occurred late in the dry season (April and May) when mean air temperatures were greatest (Figure: 4.2).

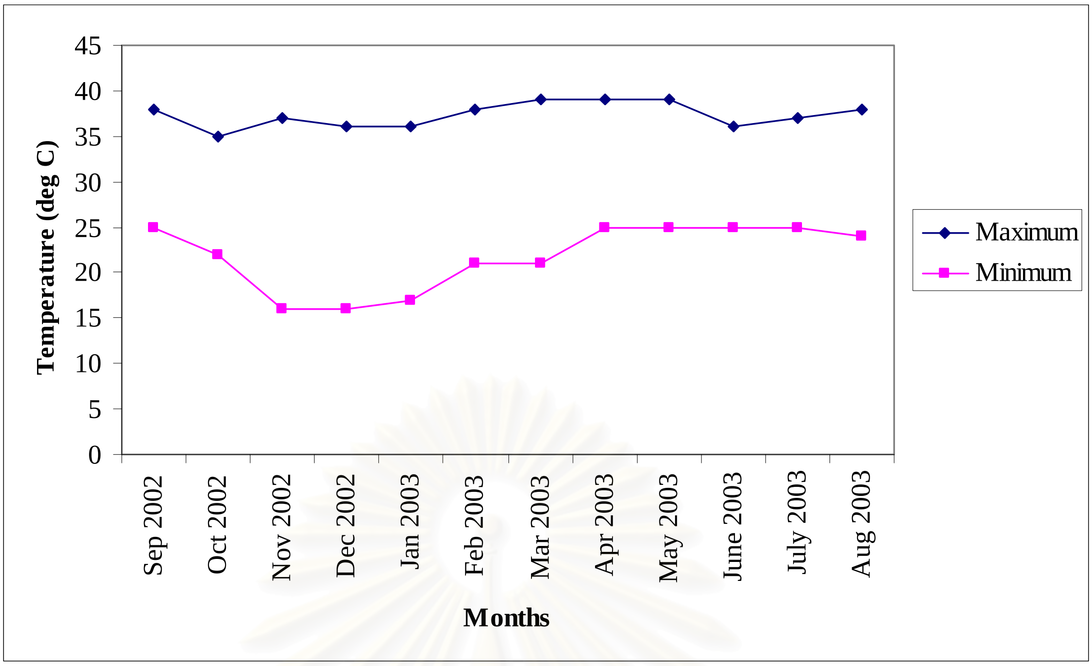

Figure 4.1: Mean monthly air temperature from September 2002 to August 2003 at SIF. Lines indicate the average maximum and minimum of air temperature in each month.

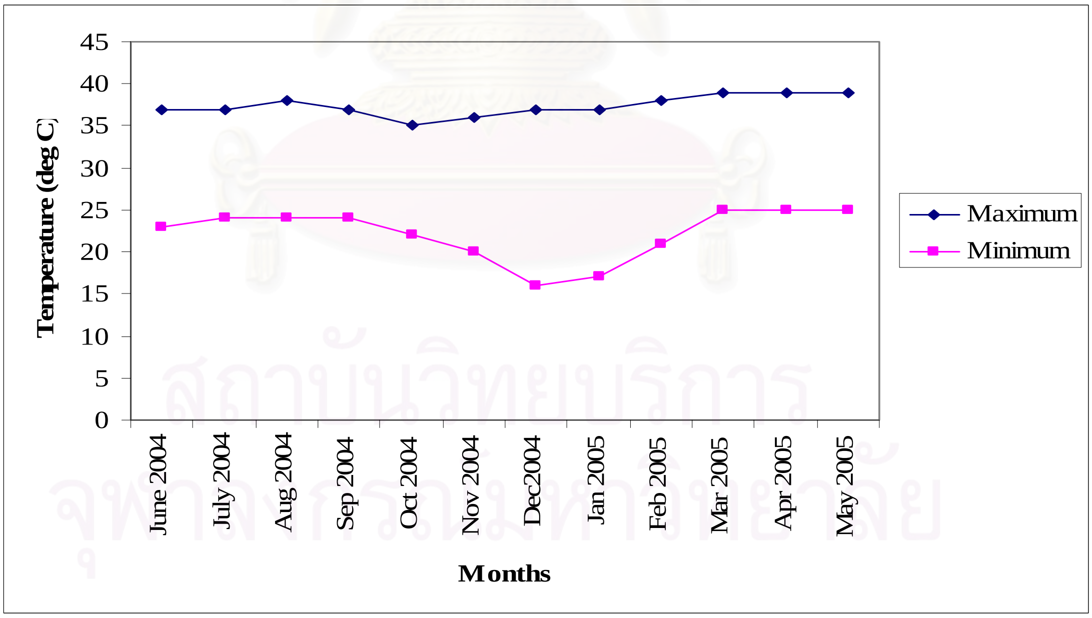

Figure: 4.2. Mean monthly air temperature from June 2004 to May 2005 at Bota Kanan Hatchery. Lines indicate the average maximum and minimum of air temperature in each month.

Mating

Among wild populations of *B. baska*, males exhibit secondary sexual characteristics after attaining a CL of 280 mm, while the CL of nesting females is usually ≥ 400mm CL (Moll, 1981). However, among captive populations in Thailand, 7-year old males with carapace lengths as small as 250 mm often exhibit secondary sexual characteristics. Reproductive characteristics have been observed in these captives from May through December. During the breeding season, males and females coupled, performed courtship and then mated in the water at a depth of 50 cm. Courtship and mating among *B. baska* at SIF began in October and ceased in November. Males attain breeding coloration (skin of the head, neck and legs turning black, iris turning from yellow-cream to white) and courtship and mating occurs from August through December at BKH. Captive males in Malaysia exhibited secondary sexual characteristics upon attaining a CL of 302 cm at 17 years of age. Courtship activity among captive turtles proved difficult to observe owing to the sensitivity of the turtles to disturbance and the murky water of the ponds.

Nesting

Egg deposition among *B. baska* at SIF occurred from December through January. Nesting generally took place from 7:00 pm to 3:00 am and about 2 hours elapsed from the time the female exited the water until she returned to the pond. Nests averaged 90 cm wide and 67 cm deep. While laying, the females moved their rear flipper to prevent sand falling into the nest. The female also produced mucus while depositing a number of eggs. Females laid continuously until the complete clutch was deposited and then covered the nest hole with sand, after which she used her flippers to compact it. Females repeatedly slammed their plastrons onto the top of the nest, creating a noise that was audible to humans standing 10-20 m away. After laying and compacting the sand, the female camouflaged the nest by dragging her flipper over the sand making it hard to determine the precise location of the clutch. Once nesting is completed, the females remain at the site for approximately 30 minutes and then gradually move back towards the water. Morphometric measurements of female *B. baska* at SIF taken immediately after clutch deposition are presented in Table 4.3 (n=25). Most nesting at BKH occurred among the oldest (35+ years) adults housed in Pond A, which usually nested between 2300 and 0300 hours local time. After depositing eggs, females compacted the nest surface by repeatedly raising her body and dropping it on the sand; the resulting drumming sound is the source of the Malay name *Tuntong*. Mean morphometric measurements for female *B. baska* at BKH are presented in Table 4.4 (n=55). The average size of females from SIF is larger than those from BKH.

Variable	**Mean**	**Standard Deviation**	**Range**
CL(mm)	500	21.4	487-512
CW(mm)	399	19.9	387-410
PL(mm)	459	20.3	447-470
PW(mm)	245	15.7	235-254
SD(mm)	207	14.7	199-216
T1(mm)	150	17.2	140-160
T2(mm)	80	13.3	72-88
BM(kg)	22.04	2.08	20-23

Table 4.3: Morphometrics of female *B. baska* (n=14) at Satun Inland Fishery station, Thailand (2002-2003). (CL=Carapace Length, CW=Carapace Width, PL=Plastron Length, PW=Plastron Width, SD=Shell Depth, T1=Total Tail Length, T2=Pre-anal Tail Length, BM=Body Mass).

Variable	Mean	Standard Deviation	Range
CL(mm)	466.2	24.44	459-472
CW(mm)	371.0	17.53	366-375
PL(mm)	416.8	26.33	409-423
PW(mm)	252.9	17.99	248-257
SD(mm)	190.9	15.69	186-195
T1(mm)	112.4	15.24	108-116
T2(mm)	71.8	9.87	69-74
BM(kg)	18.3	2.04	17.7-18.8

Table: 4.4. Morphometric measurements of nesting female *B. baska* at BKH, Malaysia (2004-2005). (CL=Carapace Length, CW=Carapace Width, PL=Plastron Length, PW=Plastron Width, SD=Shell Depth, T1=Total Tail Length, T2=Pre-anal Tail Length, BM=Body Mass) (N=55).

Batagur baska lays white, elongated, hard-shelled eggs. Our results indicated that no female deposited more than one clutch during the study period. There was a significant positive correlation between female CL and egg mass, and clutch mass (Figure 4.3). Clutch size of *B. baska* at BKH averaged 15.2 ± 5.79 eggs (n = 10; range = 6 to 20 eggs) during the 2004-2005 nesting season. Ten clutches were deposited by nesting females, but because I did not observe nesting events, it was not possible to determine which female was associated with individual nests. Long term data on clutch size is unavailable from either center for comparison. However, mean clutch size among *B. baska* at BKH was significantly less than found at SIF during the 2004-2005 nesting season (see Table: 4.5 and 4.6). Likewise eggs produced at SIF (75.9±6.8 g) were slightly heavier than those at BKH (72.16±3.68 g), although this difference was not significant. This is likely due to female body size of these respective captive populations; CL of females at BKH (46.6±2.44 cm) was significantly less than CL of females at SIF (51.1±2.6 cm).

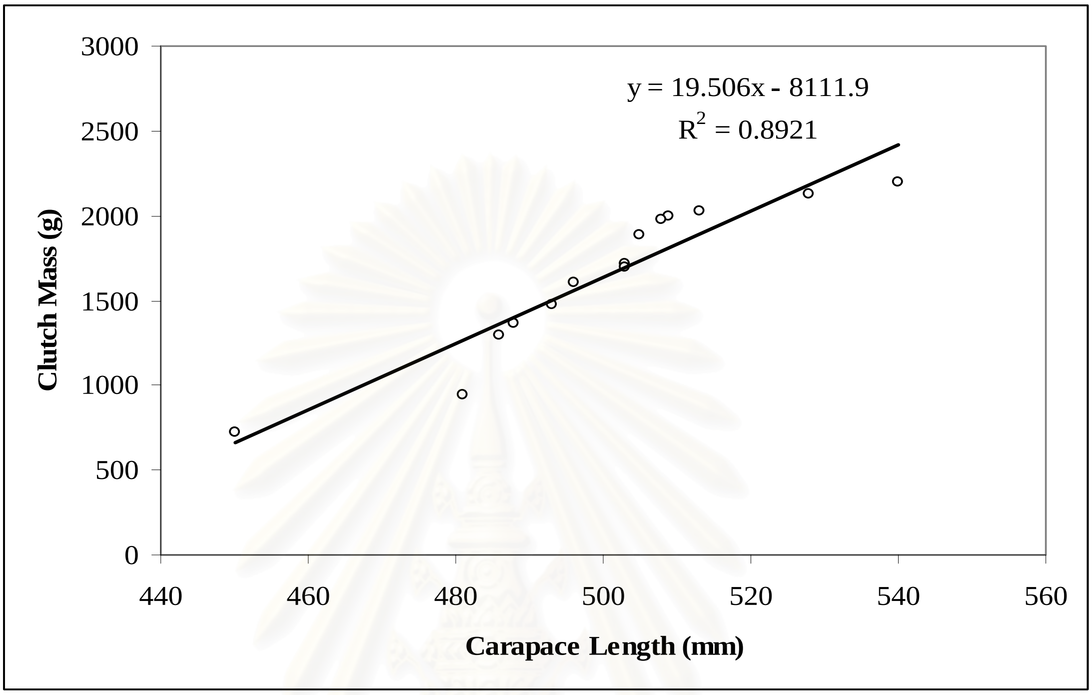

Figure 4.3: Relationship between carapace length of adult female *B. baska* and clutch mass at Satun Inland Fisheries Station, Thailand (n=14).

At SIF, mean clutch size was 21.78±5.68 and ranged from 18 to 25 eggs. The mean egg width, length, and mass of 305 eggs from 14 nests were 68.57 ± 3.05mm, 43.42 ± 2.2mm, and 75.92 ± 6.85g, respectively (Table: 4.5).

Variables	**Mean value**	**Standard Deviation**	**Range**
Clutch Size	21.78	5.68	18-25
Egg Length	68.57	3.05	66-71
Egg Width	43.42	2.2	42-45
Egg Mass	75.92	6.85	71-80

Table 4.5: Mean clutch size (n=14) and dimensions of *B. baska* eggs (n=305) at Satun Inland Fisheries Station, Thailand (2002-2003).

At BKH, mean clutch size was 15.2±5.79 and ranged from 6 to 20 eggs. The mean egg width, length, and mass of 229 eggs from 14 nests were 69.93 ± 1.25mm, 41.68 ± 1.1mm, and 72.16 ± 3.68g, respectively (Table: 4.6).

Variables	Mean value	Standard Deviation	Range
Clutch Size	15.2	5.79	6.0-20.0
Egg Length	69.93	1.25	69.0-70.8
Egg Width	41.68	1.10	40.8-42.4
Egg Mass	72.16	3.68	62.8-68.1

Table: 4.6. The mean value of *B. baska* eggs dimensions and clutch size in 2004-2005 at BKH.

Longer eggs are narrower in width and mean egg length was the best predictor of mean egg mass (Figure: 4.4 and 4.5).

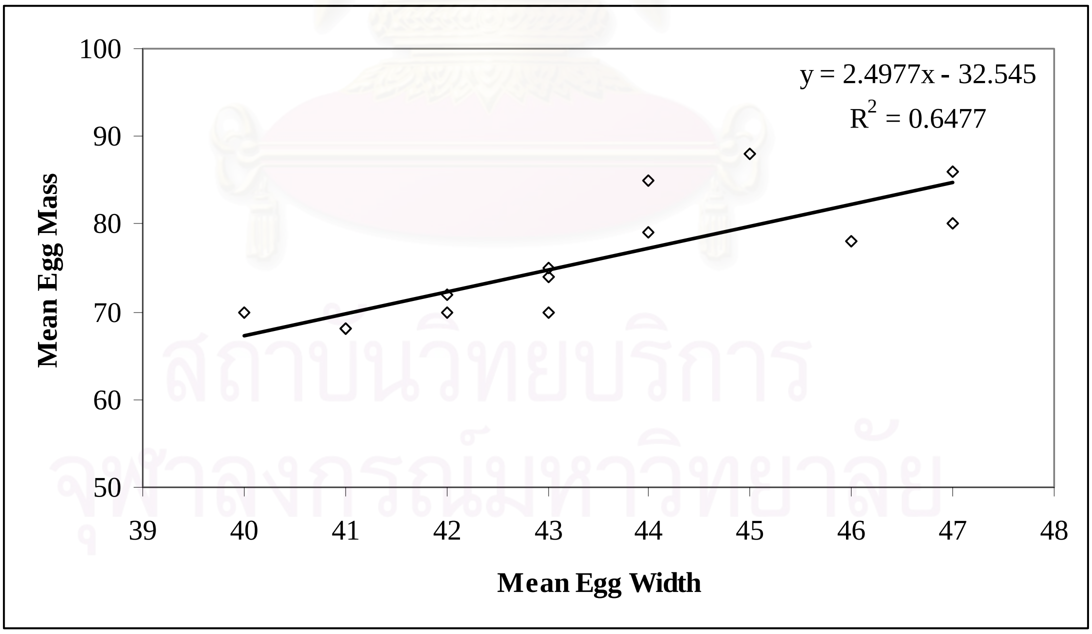

Figure: 4.4. Relationship between mean egg width and mean egg mass for 14 *B. baska* clutches at Satun Inland Fisheries Station, Thailand (2002-2003).

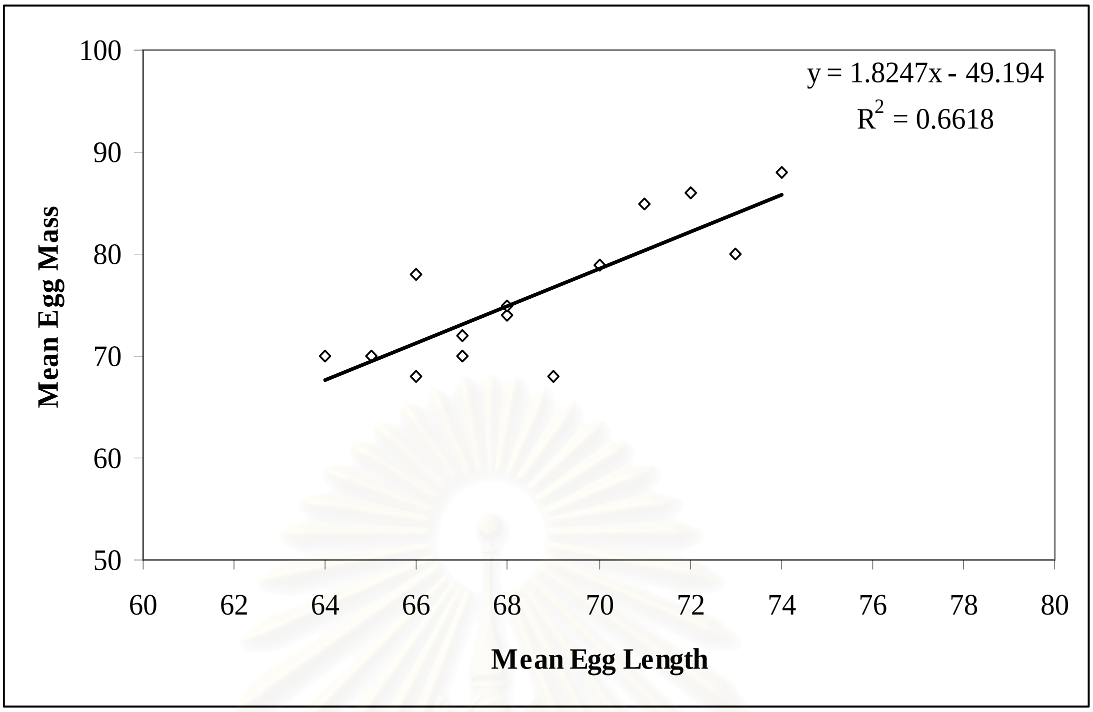

Figure: 4.5. Relationship between mean egg length and mean egg mass of 14 *B. baska* clutches at Satun Inland Fisheries Station, Thailand (2002-2003).

From 1995-96 to 2005-05, female *B. baska* at BKH produced an average of 31.2 ± 13.87 clutches per season (range=10 to 52) from (Figure: 4.6).

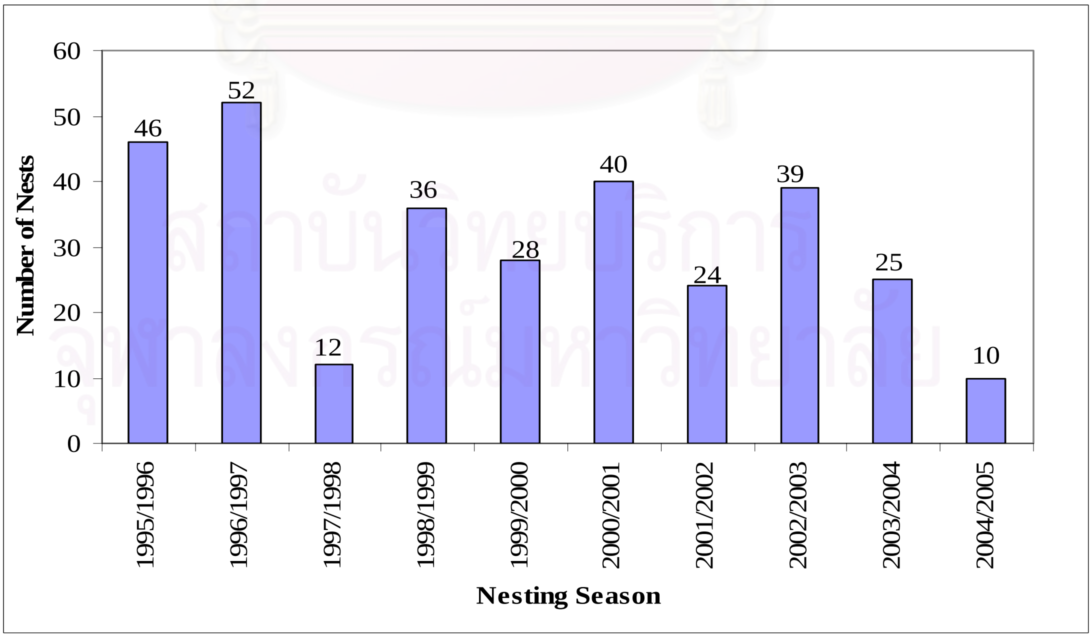

Figure: 4.6. The nesting density of *B. baska* for 10 years at Bota Kanan Hatchery, Perak, Malaysia. Data from records of PERHILITAN.

Based on data obtained from PERHILITAN and my own observations, nesting among *B. baska* at BKH began as early as October, peaked in January, and continued until mid-March. The length of the annual nesting period averaged 110.9 ± 36.7 days (range = 43-150 days) (Figure: 4.7).

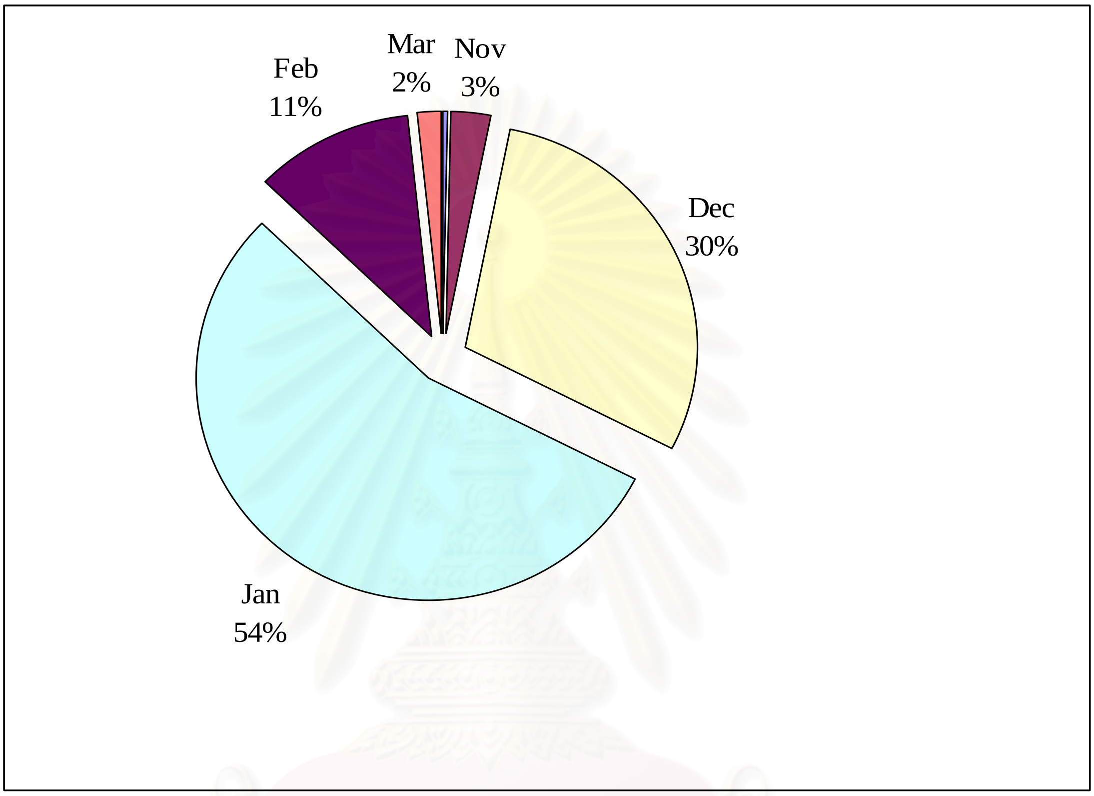

Figure: 4.7. Percent of the total number of *Batagur baska* nests deposited each month. Based on 10 years of data obtained from records at BKH.

Incubation and Hatching success at Satun Inland Fisheries Station

The facility initiated captive breeding with a foundering stock of 25 males and 25 females, only a few eggs hatched during the early years of the program, but following improvements in husbandry 28.57 to 85.56% of the total eggs incubated produced hatchlings each year. According to station records, 1,649 hatchlings have hatched during the 23 years of the program. By 2004 the surviving offspring of these turtles numbered 236 sub-adults, 594 juveniles, and 141 hatchlings. Of the subadult cohort, 73 were females and 163 were males (1 female: 2.23 males).

As in table 4.7, experiments conducted to determine effects of incubation temperature on hatching success determined that eggs incubated inartificial nests constructed in natural beach sand with an average incubation temperature of 28.8°C hatched in 100-110 days; 40 of 98 eggs hatched (40.8%). Eggs incubated in a sand-filled concrete pond, with an average incubation temperature of 30.5°C hatched in 74-84 days; 57 of 98 eggs hatched (58.16%). Eggs incubated in sand-filled Styrofoam containers with an average temperature of 29.7°C hatched after an incubation period of 90-100 days; 54 of 98 eggs hatched (55.1%).

Hatchlings generally emerged at night. Hatchlings that emerged without assistance from artificial nests (n=109) exited the nest both singly and in groups. These hatchlings had a hard, unfolded carapace with the yolk sac fully retracted into the coelom, and a completely sealed plastron with no umbilicus visible. More than 80% of these hatchlings emerged during periods when the sand temperature was relatively cooler. Forty-two (27.8%) of hatchlings were too weak to exit the nest unassisted; these generally exhibited a folded carapace, partially retracted yolk sac, and plastrons that were incompletely sealed along the midline.

Method	**No. of Eggs incubated**	**Average Sand Temperature**	**No.of Hatchlings emerged**	**Incubation period**	**Hatch rate (%)**
Breeding Pond	98	28.8 ˚C	40	100-110 days	40.82%
Styrofoam Box	98	29.7 ˚C	54	90-100 days	55.10%
Concrete Pond	98	30.5 ˚C	57	74-84 days	58.16%

Table: 4.7. Incubation and hatching success parameters of the three incubation treatments at Satun Inland Fisheries Station, Thailand.

Incubation and Hatching success in Bota Kanan Hatchery

There was no significant difference in the incubation period of eggs incubated in Styrofoam boxes and those incubated in natural beaches (Table 4.8). Hatching success was higher among eggs incubated in Styrofoam boxes according to limited experiments.

Method	No. of Eggs incubated	Average Sand Temperature	No. of Hatchlings emerged	Incubation period	Hatch rate (%)
Natural Beach	146	31 ˚C	49	71-92 days	33.56%
Styrofoam Box	83	30.5 ˚C	55	72-76 days	66.26%

Table: 4.8: Mean incubation temperatures, incubation periods, and hatching success for *B. baska* eggs incubated on natural beaches and in Styrofoam boxes at BKH, Perak, Malaysia.

During the period of 1993-2005, the largest number of clutches were produced in 1996 when 1524 clutches were recorded. In addition to breeding *B. baska* at BKH, eggs were also obtained by PERHILITAN from nesting beaches along Perak River. These eggs were collected from seven beaches and sandbars by licensed egg collectors who provide 10% of their harvest to BKH for incubation. Hatching success among these all clutches was relatively low, ranging from 27.5 to 60.5% (Table. 4.9).

Season	No of Eggs incubated	Total Hatching	Percentage of Hatching
1993/1994	1919	990	52.6
1994/1995	2353	1259	53.5
1995/1996	3070	1719	60
1996/1997	3894	2356	60.5
1997/1998	1683	464	27.5
1998/1999	3025	1219	40.2
1999/2000	1035	412	39.8
2000/2001	1007	482	47.8
2001/2002	357	114	32
2002/2003	588	196	33
2003/2004	491	168	34
2004/2005	229	114	49.7

Table: 4.9. The number of *B. baska* eggs incubated and hatching success at Bota Kanan Hatchery, Perak, Malaysia (1993 to 2005). Incubation methods were evaluated in the 2004-05 nesting season.

Hatchling size at Satun Inland Fisheries Station and Bota Kanan Hatchery

It was not possible to determine with any degree of certainly which hatchlings were associated with particular eggs. However, significant correlations were not found to exist between mean hatchling dimensions and mean egg length, mean egg width, or mean egg mass of individual clutches. In SIF, mean hatchling CL, CW, and BM were 61.3 ± 2.63 mm (range = 61.0-61.7 mm), 60.8 ± 4.45 mm (range = 60.2-61.4 mm) and 47.7 ± 8.4 g (range = 46.6-48.9 g), respectively. Correlations between morphometric variables of hatchling (n=151) were made in 2003. Hatchling CL was the best predictor of hatchling body mass (Table 4.10). In addition, CL was strongly correlated with CW (r=0.835, p<0.001), but less so with PL (r =0.642, p<0.001) or PW(r=0.666, p<0.001),or SD (r=0.296, p<0.001).

Variable	Pearsons correlation (r)	p
Carapace Length	0.651	<0.001
Carapace Width	0.581	<0.001
Plastron Length	0.553	<0.001
Plastron Width	0.542	<0.001
Shell Depth	0.345	<0.001

Table: 4.10. Correlations between hatchling (n=151) body mass and other attributes at Satun Inland Fisheries Station, Thailand.

At BKH, mean hatchling CL, CW, SD and BM were 61.4±2.46 mm (range=60.9-61.9 mm), 60.7± 4.25 mm (range=59.9-61.5 mm), 28.0±1.74 mm (range=27.6-28.3 mm) and 48.2± 8.4 g (range= 46.6-49.8 g) respectively. Correlations between morphometric variables of hatchling (n=114) were made in 2005. Hatchling CL was the best predictor of hatchling body mass (Table 4.11). In addition, CL was strongly correlated with CW (r=0.790, p<0.001), but less so with PL (r =0.684, p<0.001) or PW (r=0.648, p<0.001), or SD (r=0.269, p<0.001).

Variable	Pearsons correlation (r)	p
Carapace Length	0.600	<0.001
Carapace Width	0.547	<0.001
Plastron Length	0.547	<0.001
Plastron Width	0.562	<0.001
Shell Depth	0.336	<0.001

Table: 4.11. Correlations between hatchling (n=114) body mass and other attributes at Bota Kanan Hatchery, Perak, Malaysia.

Growth of hatchlings and juveniles at Satun Inland Fisheries Station

The growth of *B. baska* (n=151) from 2002 to 2005 are described in Table. 4.12. The survival rate of the hatchlings from 2002 to 2005 was 90.53%. Results indicate that CL, CW, PL, PW, SD, BM, T1 and T2 are strongly correlated with one another and with age. A significant relationship was noted between the amount of food provided per day and hatchling growth over the three years of observation period.

Morphologica Variables	Hatchling	One Year Old	Two Years Old	Three Years Old
Carapace Length	61.3±2.63	143.5±13.41	194.0±17.4	226.3±15.2
CL (mm)	(61.0-61.7)	(140.4-146.5)	(191.3-196.7)	(223.7-228.9)
Carapce Width	60.8±4.45	127.7±12.07	171.6±14.3	196.1±11.62
CW(mm)	(60.2-61.4)	(125.0-130.5)	(169.4-173.8)	(194.1-198.1)
Plastron Length	54.5±2.98	119.59±10.93	166.1±15.03	196.0±16.3
PL(mm)	(54.1-54.9)	(117.1-122.0)	(163.8-168.4)	(193.2-198.8)
Plastron Width	41.5±3.63	81.85±7.72	112.3±12.58	128.6±8.31
PW(mm)	(40.9-41.9)	(80.1-83.6)	(110.4-114.3)	(127.1-130.0)
Shell Depth(mm)	27.9±1.72	49.32±5.77	64.8±7.38	77.1±7.53
SD(mm)	(27.6-28.1)	(48.0-50.6)	(63.6-65.9)	(75.8-78.4)
Total Tail Length(mm)	19.7±1.6	33.72±5.97	49.0±7.08	54.1±8.17
T1 (mm)	(19.5-19.9)	(32.3-35.0)	(47.9-50.1)	(52.7-55.5)
Pre-anal Tail Length(mm)	8.79±0.88	14.9±3.5	23.9±4.06	25.4±5.12
T2 (mm)	(8.6-8.9)	(14.1-15.7)	(23.3-24.5)	(24.5-26.3)
Body Mass	47.7±8.4	424.2±113.49	1143.9±305.99	1756±361.7
BM (gram)	(46.6-48.9)	(398.5-450.0)	(1097-1190.8)	(1693-1818)

Table: 4.12. Morphometric comparison between hatchling, one year old, two year old, and three year old *B. baska* at Satun Inland Fisheries Station, Thailand. Values are given as mean ±1 SD. Range in parentheses.

Growth of hatchlings and juveniles at Bota Kanan Hatchery

The analysis (what analysis??) was based on the measurements of *B. baska* (n=114) for hatchlings in 2005 and based on the measurements of head-started *B. baska* being kept in the station prior to their release.

Morphological Variables	Hatchling	One Year Old	Two Years Old	Three Years Old
Carapace Length	61.4±2.45	99.6±11.3	152.1±15.62	157.6±11.25
CL (mm)	(60.9-61.9)	(97.5-101.6)	(150.5-153.7)	(156.2158.9)
Carapce Width	60.7±4.25	92.6±9.61	133.7±12.62	136.0±8.69
CW(mm)	(59.9-61.5)	(90.9-94.3)	(132.4-135.0)	(135.0-137.0)
Plastron Length	54.7±2.68	84.9±9.05	130.1±13.2	135.5±9.65
PL(mm)	(54.3-55.1)	(83.3-86.5)	(128.7-131.4)	(134.4-136.7)
Plastron Width	41.4±3.10	58.7±6.17	84.7±8.28	85.3±6.50
PW(mm)	(41-41.8)	(57.6-59.80	(83.9-85.5)	(84.5-86.0)
Shell Depth(mm)	28.0±1.7	39.1±4.26	59.1±6.54	61.6±4.43
SD(mm)	(27.7-28.2)	(38.3-39.8)	(58.5-59.8)	(61.1-62.1)
Total Tail Length(mm)	19.6±1.58	26.7±3.74	34.3±5.83	41.9+5.12
T1 (mm)	(19.3-19.8)	(26.1-27.4)	(33.7-34.9)	(41.2-42.5)
Pre-anal Tail Length(mm)	8.75±0.89	12.8±2.07	15.1±3.26	20.3±3.10
T2 (mm)	((8.5-8.9)	(12.4-13.2)	(14.8-15.4)	(20.0-20.7)
Body Mass	48.2±8.42	160.8±46.85	493.5±141.7	542.2±111.12
BM (gram)	(46.6-49.8)	(152.4-169.1)	(479.1-507.9)	(529.1-555.2)

Table: 4.13. Morphological attributes of juvenile *B. baska* at Bota Kanan Hatchery, Malaysia. Values presented as mean ± 1SD. Range in parentheses.

Turtles released from Satun Inland Fisheries Station

A number of head-started turtles from SIF were released into a monastery pond near Songkhra Lake and another pond in Pattalung Reserve Area, and approximately 40 *B. baska* were released into the Langu River in 1999 as part of a conservation project (Table: 4.14). However, with the exception of the latter, reintroduction into the wild has yet to be attempted in Thailand. Alarmingly the breeding facility at SIF is situated on a low-lying bend along the Langu River that is subject to flooding during exceptionally wet years. Indeed, 50 *B. baska* escaped during a flood in 2003 and future unplanned liberation of *B. baska* is highly probable.

Year	**No. of turtles**	**Approximate Age**	**Location of release**	**Remark**
1996	100	9,11,12,13	Not recorded	
1998	172	13	Kai Tao Beach, Pattalung	
1999	40	8	Langu River	Langu Protected Project
2000	50	18,20	Langu River	Flooded
2001	29	8	Pattalung Farm	King's Project
2004	20	3	Pattalung Reserve Area	

Table: 4.14. A summary of planned releases and escapes of *B. baska* at the Satun Inland Fisheries Station from 1996 to 2004.

Turtles released from Bota Kanan Hatchery

From 1969 through 2003, 35,236 *B. baska* produced at BKH and ranging in age from hatchlings to 12-year old turtles, have been released into the wild in an attempt to augment existing populations in Malaysia. This total includes 34,951 hatchling and juvenile *B. baska* released into the Perak River, and an additional 285 two-year old juveniles returned to the Terengganu River in 1999. Hatchlings and juveniles were released into the Perak River every year during this period except 1979, 1981, and 2002; the largest releases occurred in 1983 and 1997 (Table 4.15).

Year	No. of Turtle released	Year	No. of Turtle released
1969	560	**1987**	230
1970	1,161	**1988**	820
1971	332	**1989**	280
1972	620	**1990**	1204
1973	200	**1991**	1000
1974	1461	**1992**	726
1975	1011	**1993**	730
1976	1665	**1994**	2090
1977	2507	**1995**	2214
1978	300	**1996**	1902
1979	0	**1997**	3519
1980	1816	**1998**	43
1981	0	**1999**	293(285*)
1982	1200	**2000**	200
1983	3720	**2001**	381
1984	940	**2002**	0
1985	1381	**2003**	530
1986	200		
Grand Total = 35,236			

Table: 4.15. Total number of *B. baska* produced at Bota Kanan Hatchery and released into the wild (1969 to 2003). * Released into Terengganu River.

Discussion

Mating and Nesting

The annual period of courtship and mating activity as determined by the presence of breeding coloration among captive male *B.baska* was similar in Thailand (May to December) and Malaysia (August to December), although it began somewhat earlier in Thailand. In both countries this period coincides with the annual wet season. Likewise, captive male *B. baska* at the Cleveland Metroparks Zoo, USA exhibit breeding coloration from September through December (Brad Poynter, unpubl. data). Moll (1980) noted that wild males in Malaysia displayed breeding coloration as early as September. During the mating season, the head, neck and legs of the male turn black and iris color changes from yellowish cream to pure white (Moll, 1978). Among captive males in Thailand, iris color changed to bright yellowish while in Malaysia males display more whitish color in the iris.

Reproduction among wild populations of *B. baska* has been well-studied in Malaysia (Moll, 1978; 1980), Myanmar (Maxwell, 1911), and to a lesser extent in India (Bhupathy, 1995, 1997; Ghosh and Mandal, 1990) and Cambodia (Platt et al., 2003). Reproductive data from wild populations elsewhere are unavailable. In captivity, reproduction apparently occurs at a much earlier age; a six-year old female produced a clutch of infertile eggs at the Bronx Zoo, and a 12-year old female reproduced successfully at a captive breeding facility in Malaysia (Platt, et al., 2006). Size and age at sexual maturity appear to vary according to sex; males exhibit secondary sexual characteristics and females begin nesting upon attaining a CL of 400 and 450 mm, respectively (Moll, 1980). My observations in Malaysia and Thailand indicate that secondary sexual characteristics are obvious among captive males at much smaller body size than reported by Moll (1980).

Courtship among wild *B. baska* undoubtedly occurs prior to the upstream migration of females to nesting beaches which begins as early as November (Moll, 1980). *Batagur baska* require elevated banks of relatively fine sand for nesting (Moll, 1980). Nesting habitat is typically located along brackish or freshwater stretches of larger rivers (Moll, 1980; Platt et al., 2003), although nesting on offshore marine islands occurs or formerly occurred in Myanmar and India (Maxwell, 1911; Ghosh and Mandal, 1990; Bhupathy, 1997).

Variables affecting nest site selection are not well understood, although captive female *B. baska* in both Malaysia and Thailand seem to prefer open areas of bare sand. Likewise, wild females in Malaysia are reported to preferentially select open areas lacking ground vegetation, an observation not lost on egg collectors who encourage nesting by scraping beaches to bare sand (Moll, 1978). Egg collectors also construct sand hillocks on potential nesting beaches to attract females. Moll (1978) speculated that these may function to enhance the beach profile, and noted that nests are often clustered in the immediate vicinity of hillocks. The same beaches are used each year for nesting, and individual females appear to exhibit considerable site fidelity (Tikader and Sharma, 1985).

Among captive populations of *B. baska* in Thailand, nesting occurs from November to February, a period coinciding with the lowest mean monthly air temperatures. My data and that of others (Moll, 1980) indicates that nesting occurs somewhat earlier in Malaysia and extends over a longer period (October to April). Similar to Thailand, the nesting period in Malaysia coincides with the lowest mean monthly air temperatures. In the wild, the nesting period varies geographically, but generally coincides with the beginning of the annual dry season after heavy rains associated with the Northeast monsoon have ceased (Moll, 1980). On the west coast of Peninsular Malaysia, the first clutches are deposited from 8 November to 16 January, while on the west coast nesting occurs in February and March (Moll, 1980). Nesting takes place in Cambodia from December through early March (Platt et al., 2003) and in Myanmar from mid-January to early March (Maxwell, 1911; Thorbjarnarson et al., 2000). The beginning of the nesting season in India has not been reported, although Bhupathy (1997) noted that nesting is completed by late March.

Clutch size

The differences in clutch size that I noted among captive populations of *B. baska* in Thailand and Malaysia are probably due to differences in mean female body size among these respective populations. Moll (1980) demonstrated that clutch size of *B. baska* is variable and depends on the body size of the nesting female. Additionally, the clutch size that I found among captive populations of *B. baska* in both Thailand and Malaysia is within the range of clutch sizes reported elsewhere. In Malaysia clutch size among wild populations ranges from 5 to 50 eggs with a mean of 26.4 eggs (Loch, 1950; Balasingam and Mohamed Khan, 1969; Moll, 1980). Clutch size averages between 50 and 60 eggs in Myanmar (Maxwell, 1911), and 11.3 ± 4.4 eggs (n = 6; range = 6 to 19 eggs) in Cambodia (Platt et al., 2003). There is some evidence to suggest that females occasionally partition a single clutch among multiple nests (Moll, 1980). Females deposit up to three clutches each nesting season and the interval between clutches is reportedly 15 to 20 days (Maxwell, 1911; Smith, 1931; Moll, 1980; Tikader and Sharma, 1985). The reproductive lifespan of female *B. baska* probably exceeds 20 years.

Egg size

Batagur baska eggs from BKH were longer, but less wide relative to those from SIF, and egg mass was significantly greater among eggs from SIF compared to those from BKH. Egg size in turtles is a function of female nutrition (energy acquisition) and probably age and body size of the female (Frazer and Richardson, 1985; Etchberger and Ehrhart, 1987; Iverson, 1992). Observed differences in linear egg dimensions and egg mass among the two populations could therefore be the result of several factors. First, *B. baska* at SIF and BKH were provided with different foods and second, females at SIF were significantly larger and older than those at BKH. The linear egg dimensions and egg mass found at SIF and BKH is within the range of values reported among other *B. baska* populations. Smith (1931) reported that eggs measure approximately 70 × 40 mm, and egg mass in Malaysia averages 64 grams and is positively correlated with female mass, but not clutch size (Moll, 1980).

The average egg size (68.57±3.05, range 66-71 mm X 43.42± 2.2, range 42-45 mm) is smaller in length and larger in width from SIF than those from BKH (69.93±1.25, range 69-70.8 mm X 41.68±1.1, range 40.8-42.4 mm). Average egg mass is larger in SIF and the longer eggs are narrower in width and the mean egg length is a better predictor of mean egg mass compared to egg width.

Incubation Period

Various incubation periods have been reported for *B. baska*; eggs in Malaysia required 60 to 102 days to complete incubation (Moll, 1980; Chan, unpubl. data), and 69 to 121 days in Cambodia (Sovannara and Holloway, unpubl.). The incubation periods at both SIF and BKH were within this previously reported range. Gross incubation temperatures under hatchery conditions significantly affected the incubation period, which appear to be inversely related to incubation temperature, i.e., the lower the incubation temperature, the longer the incubation period. Measurements of incubation temperature at hatcheries can therefore be used by hatchery managers to predict incubation period and date of hatchling emergence. Optimal incubation temperatures for *B. baska* eggs range from 29 to 31°C; temperatures greater than 33°C may prove lethal (Chan and Soh, unpubl.). Although *B. baska* almost certainly exhibits temperature dependant sex determination, the critical temperature at which sex determining events occur has yet to be ascertained. However, in a preliminary study by Chan and Kuchling (2004), eggs incubated in Styrofoam boxes at temperatures averaging 29.4 29.8°C (range = 25.4 to 33.5°C) produced 100% male hatchlings, while eggs incubated in sand nests under natural conditions produced 100% female hatchlings in some years and a mixture of both sexes in others.

Hatching success

At SIF, mean hatch success of eggs incubated in concrete pond (58.16%) was significantly higher compared to eggs incubated at captive ground beach (40.82%) and not much different to Styrofoam box incubators (55.10%). At BKH, mean hatch success at artificial sandy beach (33.56%) is significantly lower compared to eggs incubated in Styrofoam boxes (66.26%). However, the sex ratios of hatchlings in captive breeding centers may have skewed by incubation methods. The low hatching success is believed due to the lengthy period required for excavating and then relocating the eggs to BKH.

Hatchling size and growth

Hatching body size was similar at both SIF and BKH, and hatchling CL was the best predictor of hatchling body weight among both populations. My repeated measurements of neonate *B. baska* at SIF indicate that growth is very rapid during the first year of life. A comparison of the body size of juvenile *B. baska* up to 3 years of age at SIF and BKH suggests that growth rates differ between the two facilities, most likely as a result of differing husbandry methods, particularly diet. The mixture of green vegetables and fresh fish provided at SIF appears to produce the most growth among young *B. baska*. Notably, the average body size of juvenile turtles at SIF is only slightly less than average body size of 2 year old juveniles at BKH.

Hatchling Emergence

Batagur baska hatchlings were able to emerge unassisted from artificial nests at the both SIF and BKH. Most hatchlings emerged within a single day, although a few required as long as three days to exit the nest. Hatchlings that emerged without assistance from the nest were different from hatchlings that were manually excavated from the nests; the latter differed had an abnormally curved carapace, the residual yolk was not fully absorbed, and the plastron was only partially sealed along the midline. These differences are attributed to the longer period hatchlings that naturally emerge from the nest spend below-ground before coming to the surface; during this subterranean post-hatching period the yolk sac is absorbed. The morphological characteristics observed among neonate *B. baska* are common to most turtles (with the exception of Kinosternids) (Ewert, 1979). Moreover, the unfolding of the carapace in neonates is facilitated by yolk absorption in several emydids, which generally occurs after hatching but before the hatchling emerges from the nest (Hirth, 1971; Ewert, 1985).

Like many marine and freshwater turtles, *B. baska* hatchlings emerge from the nest during late afternoon or at night (Witzel and Banner, 1980; Neville et al., 1988). Nocturnal emergence of hatchlings is thought to facilitate predator avoidance and reduce mortality from thermal stress reduces mortality through thermal stress. Mid-afternoon surface temperatures are probably sufficient to cause hyperthermic mortality among loggerhead (*Carretta carretta*) hatchlings, and the nocturnal emergence of hatchlings avoids this potential source of mortality (Witherington et al., 1990). Furthermore, hatchling activity is reduced at high temperatures, leaving them vulnerable to predation prior to nightfall when temperatures decrease (Mrosovsky, 1968). It is also probable that hatchlings emerging before nightfall are more visible to predators and likely to be taken (Stancyk, 1982). Finally, thermal cues are important in triggering the emergence of marine turtle hatchlings and the high surface temperatures (>40˚ C) attained by sandy beaches late in the day appear to discourage diurnal emergence (Mrosovsky, 1968, Witherington et al., 1990). Although the role of thermal cues in the emergence of *B. baska* hatchlings has not been studied, these turtles undoubtedly face a suite of similar selective pressures as marine turtles.

Chapter 5

Morphometric comparisons of River Terrapin, *Batagur baska* in Malaysia , Thailand, Myanmar and Cambodia

Abstract

The measurements of male, female and hatchling *Batagur baska* from Myanmar, Thailand, Malaysia and Cambodia were compared by using Student T-Test. Based on 79 females and 50 males, the analysis indicates that there is no significant morphological difference between *B. baska* among these populations. Sexually dimorphism was evident with males having significantly narrower carapace width, shallower shells, shorter planstrons, and smaller body mass than those in females at all locations.

Introduction

The river terrapin, *B. baska*, inhabits coastal estuaries and mangrove swamps from eastern India and Bangladesh, west to Myanmar, southern Thailand, Cambodia, southern Vietnam, and south to peninsular Malaysia and Sumatra, Indonesia (Bourret, 1941; Ernst and Barbour, 1989; Iverson, 1992). Populations throughout this range have drastically declined or been extirpated from their historical range by a combination of habitat destruction and chronic over harvesting of eggs and adult turtles (Wirot, 1979; Moll,1980; Groombridge, 1982; Tikadar and Sharma,1985; Thirakupt and Vandijk,1994; Bupathy,1997; Das,1997; Platt et al.,2000). Very little is known about the morphological and genetic variability of the species, and this could play an important role in its conservation management. *Batagur baska* is listed as Critically Endangered by the World Conservation Union (IUCN) and is listed on Appendix I of the Convention on International Trade in Endangered Species of Wild

Fauna and Flora (CITES). To further clarify the level of differentiation between Myanmar, Thai, Malaysia, Cambodia *B. baska*, morphological characteristics were examined and analyzed.

Materials and Methods

Data Analysis on morphological comparison

Body measurements were recorded for *B. baska* from Thailand (25 male, 25 female), Malaysia (20:55), Cambodia (0:3) and Myanmar (0:1). The following measurements were taken using calipers: straight-line carapace length (CL), maximum carapace width (CW), plastron length (PL), plastron width (PL), shell depth (SD), Weight (Wt), total tail length (T1) and pre-anal tail length (T2). Turtles <3kg were weighed using an electronic balance; larger turtles were weighed with a spring scale. Wild caught *B. baska* those being kept in hatchery station or pagoda ponds and confiscated turtles, were used as study animals for this analysis. The mean relative parameters were then compared between the same species among isolated populations by using Student T-Test.

Sexual Dimorphism

In each location, the data of morphological characters between sexes were compared. Equation for the prediction of sex was created by using Discriminant Function Analysis. In each comparison, probability ($p \leq 0.05$) was considered to be significantly different. General calculations were performed a computer using Microsoft Excel for Window 2006.

Results

Morphological differences among isolated populations

Among Malaysian *Batagur*, males had significantly narrower carapace width, shallower shells, shorter planstrons, and smaller body mass than females (Figure: 5.1, 5.2, 5.3, and 5.4).

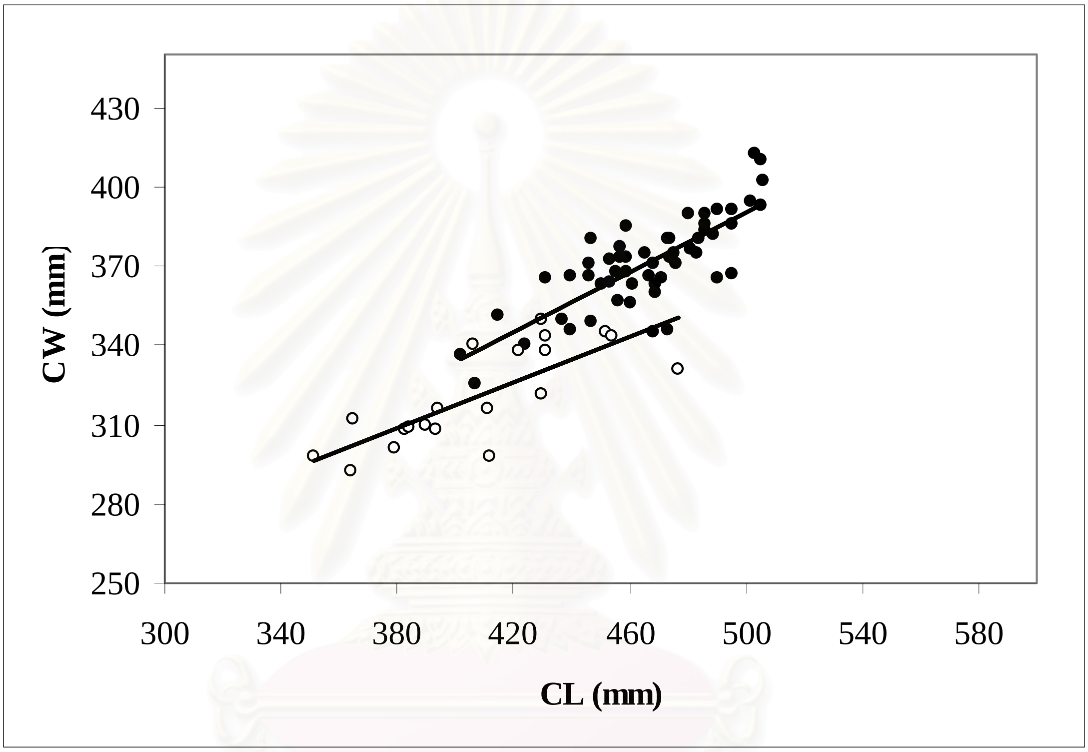

Figure: 5.1. Relationship of carapace width to carapace length in 75 adult *B. baska* (20 males, 55 females) from Bota Kanan, Malaysia. Open circles represent males and dots represent females. Regression lines were calculated from the formula CW= 105.5+0.56CL for females and CW=144.7+0.43CL for males.

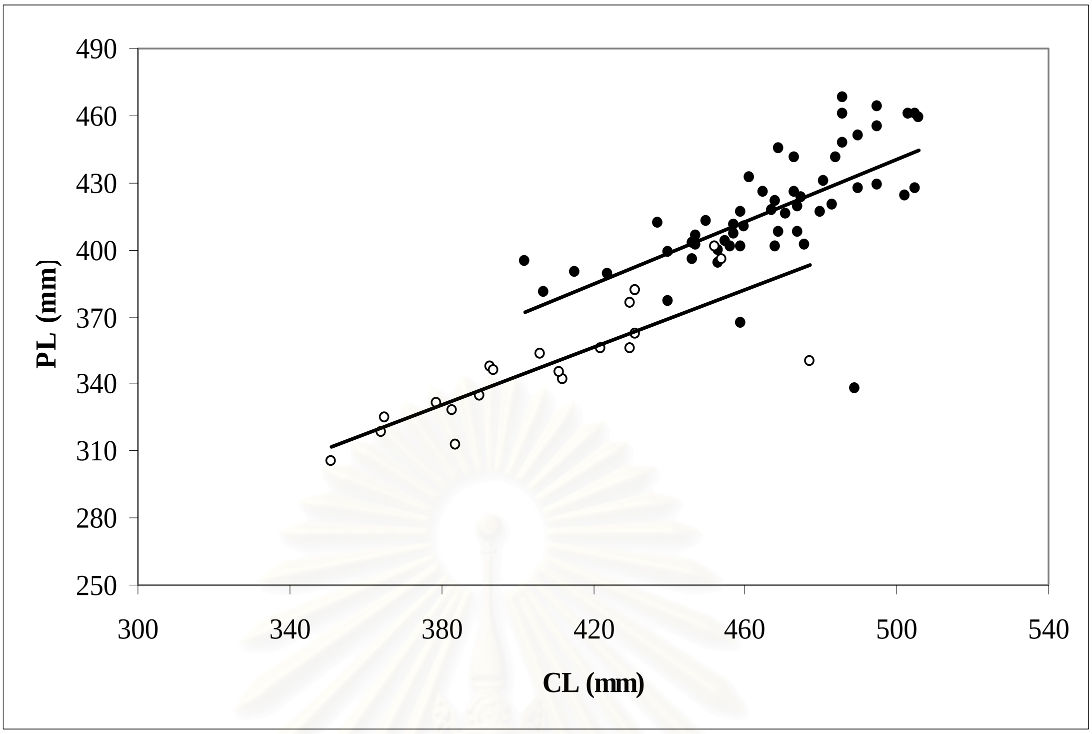

Figure: 5.2. Relationship of Plastron Length to carapace length in 75 adult *B. baska* (20 males, 55 females) from Bota Kanan, Malaysia. Open circles represent males and dots represent females. Regression lines were calculated from the formula PL= 89.5+0.7CL for females and PL=84.7+0.64CL for males.

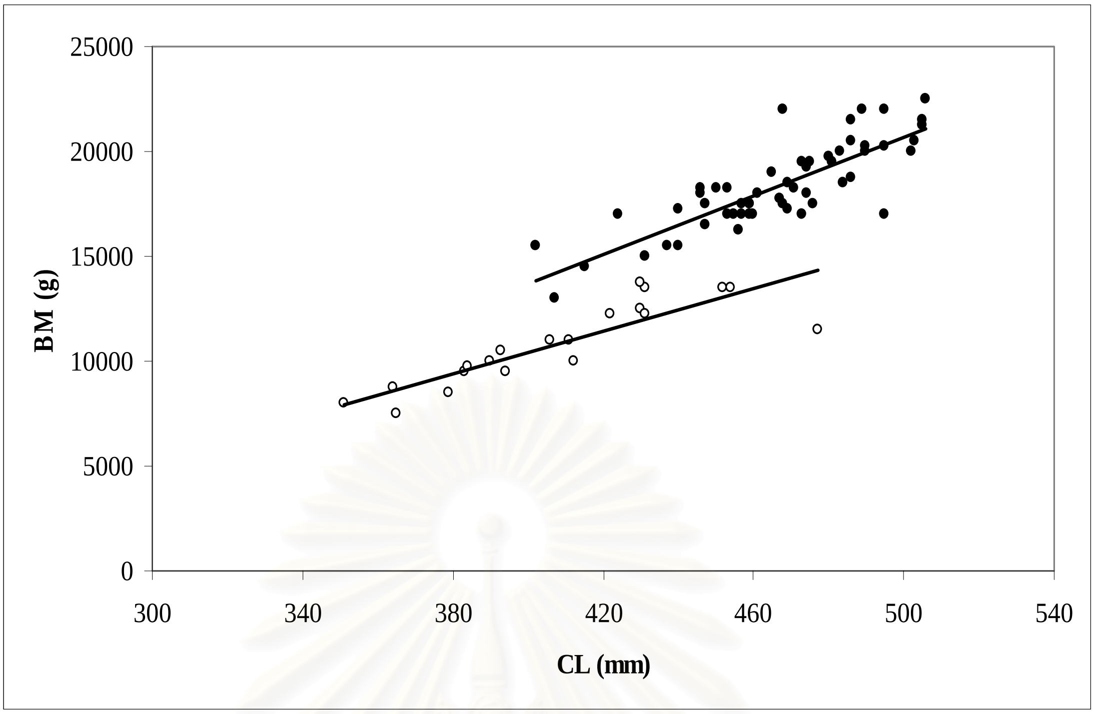

Figure: 5.3. Relationship of Body Mass to carapace length in 75 adult *B. baska* (20 males, 55 females) from Bota Kanan, Malaysia. Open circles represent males and dots represent females. Regression lines were calculated from the formula BM= -14041+69.4CL for females and BM=-9859+50.7CL for males.

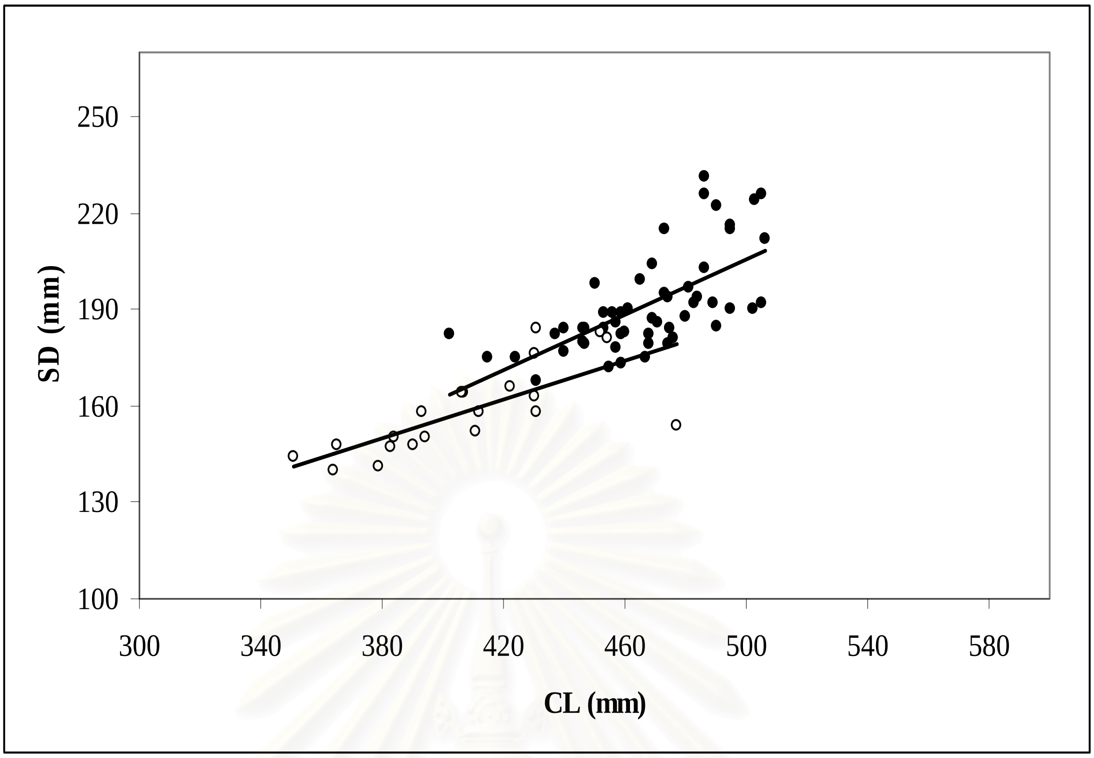

Figure: 5.4. Relationship of Shell Depth to carapace length in 75 adult *B. baska* (20 males, 55 females) from Bota Kanan, Malaysia. The measurements are in mm. Open circles represent males and dots represent females. Regression lines were calculated from the formula SD= -9.0+0.4CL for females and SD=34.4+0.3CL for males.

Male *B.baska* from Thailand also shows that significantly narrower carapace, shallower shells, shorter planstrons, and smaller body mass than females (Figure: 5.5, 5.6, 5.7, and 5.8). However, comparing between adults *Batagur*, both males and females Thai terrapins are significantly larger than Malaysian terrapins in size.

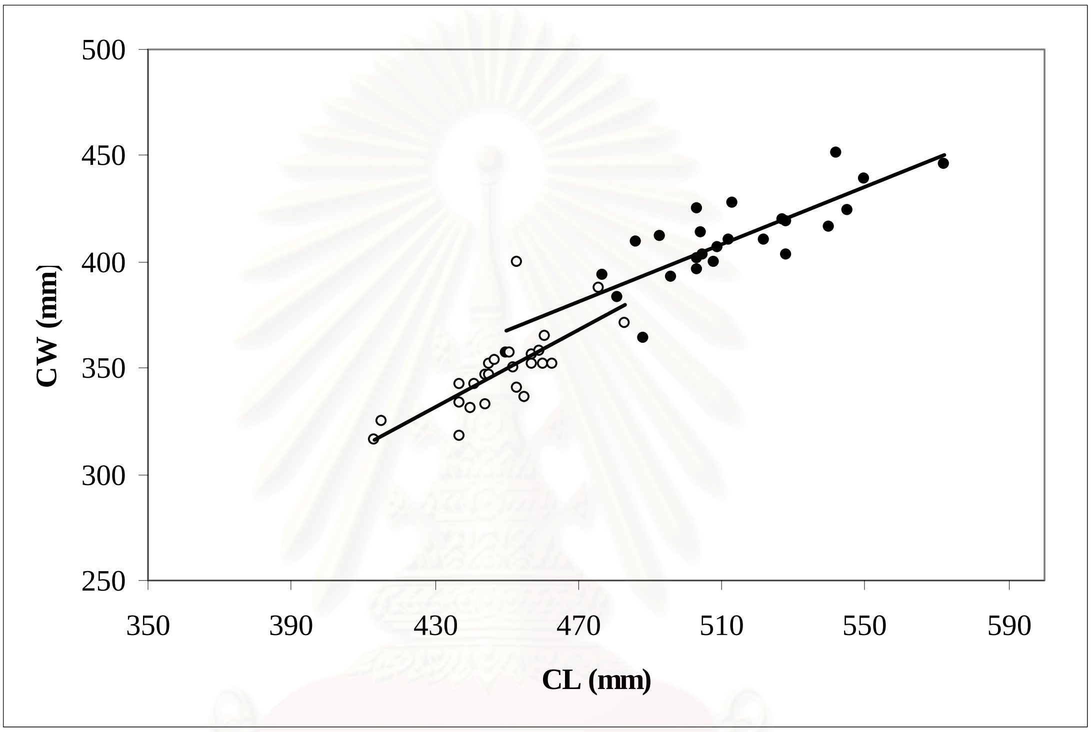

Figure: 5.5. Relationship of Carapace Width to carapace length in 50 adult *B. baska* (25 males, 25 females) from Langu River, Thailand. The measurements are in mm. Open circles represent males and dots represent females. Regression lines were calculated from the formula CW= 62.0+0.67CL for females and CW=-62.4+0.9CL for males.

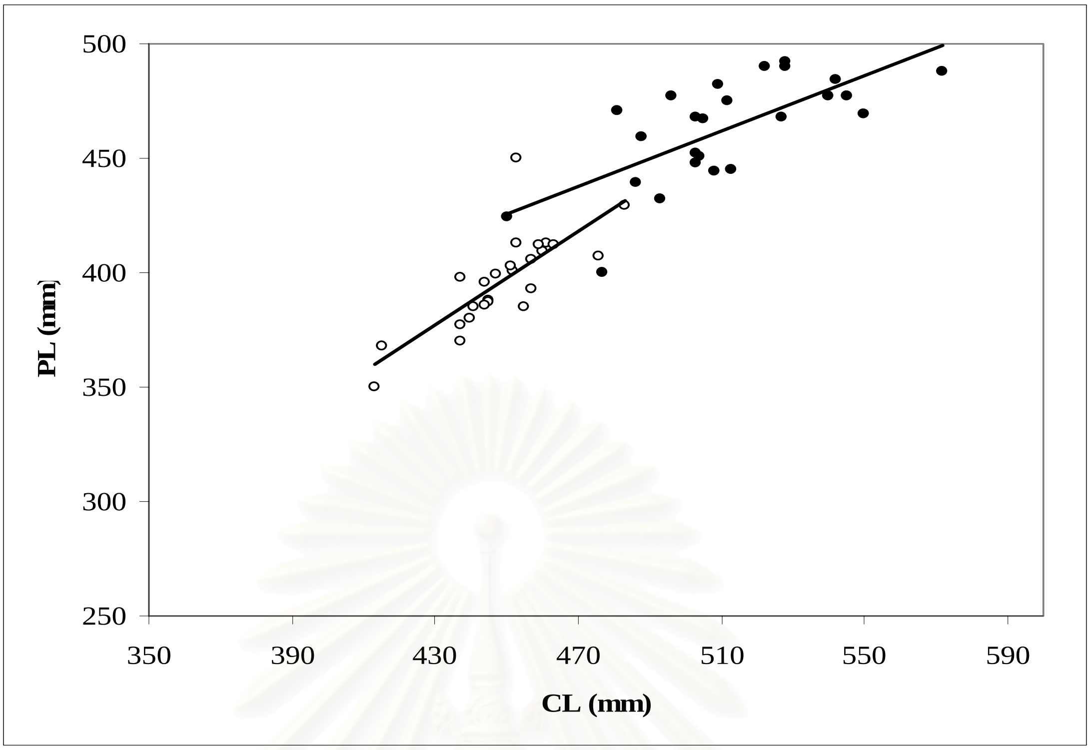

Figure: 5.6. Relationship of Plastron Length to Carapace Length in 50 adult *B. baska* (25 males, 25 females) from Langu River, Thailand. The measurements are in mm. Open circles represent males and dots represent females. Regression lines were calculated from the formula PL= 155.5+0.6CL for females and PL=-64.0+1.02CL for males.

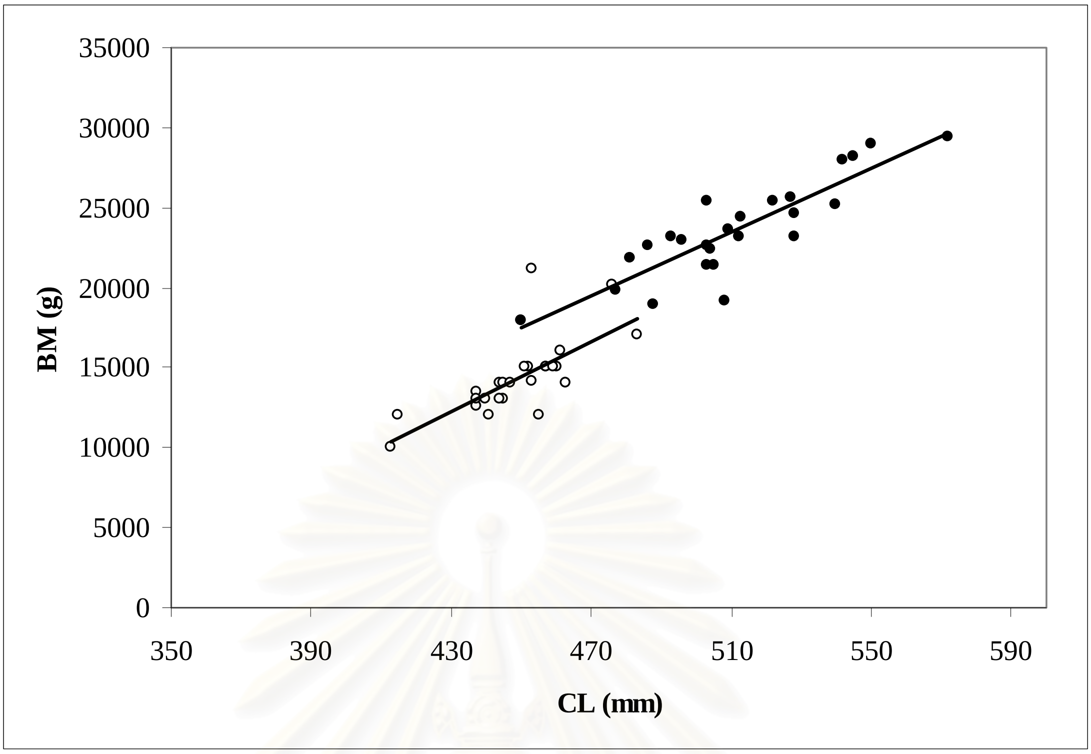

Figure: 5.7. Relationship of Body Mass to Carapace Length in 50 adult *B. baska* (25 males, 25 females) from Langu River, Thailand. Open circles represent males and dots represent females. Regression lines were calculated from the formula BM= -27319+99.5CL for females and BM=-34972+109.8CL for males.

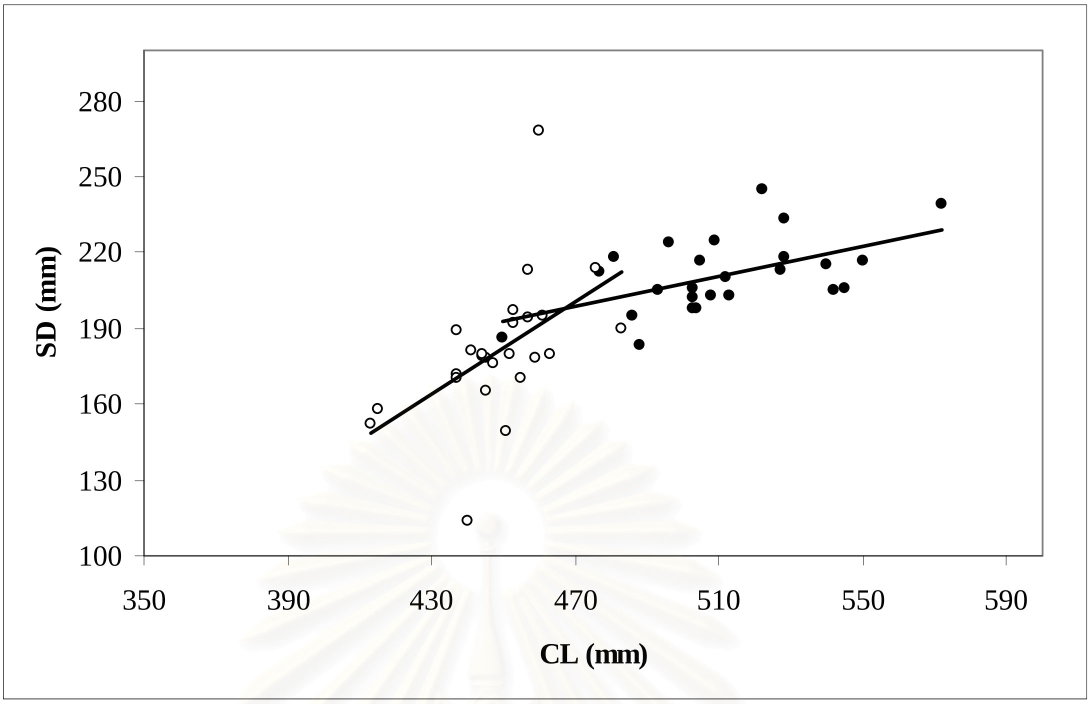

Figure: 5.8. Relationship of Shell Depth to Carapace Length in 50 adult *B. baska* (25 males, 25 females) from Langu River, Thailand. The measurements are in mm. Open circles represent males and dots represent females. Regression lines were calculated from the formula SD= 57.2+0.3CL for females and SD=-230.0+0.9CL for males.

In particular, all morphological characters were again transformed by using CL as divisor to compare the proportional differences among isolated populations (Table: 5.1). The analyses on each parameter were shown no significantly differences between same species among isolated populations. It can only be concluded that males compared to females had significantly narrower, shallower shells with shorter plastron. Tail proportions (pre-anal tail length/ total tail length) were significantly dimorphic. Hatchlings tail ratio (N=265) is 0.45, females (N=79) is 0.55 and males (N=50) is 0.64.

	CW/CL				**PL/CL**				**SD/CL**				**T2/T1**			
	TH	MY	MM	CM	TH	MY	MM	CM	TH	MY	MM	CM	TH	MY	MM	CM
Hatchlings	0.99±.05	0.99±.05			0.89±.03	0.89±.03			0.46±.03	0.46±.3			0.45±.04	0.45±.04		
range	(0.7-1.1)	(0.7-1.1)			(0.7-1.0)	(0.7-1.0)			(0.3-0.6)	(0.3-0.6)			(0.3-0.6)	(0.3-0.6)		
Males	0.78±.03	0.79±.04		0.8±.03	0.88±.03	0.86±.04		0.76±.43	0.4±.05	0.39±.02		0.4±.01	0.64±.07	0.53±.07		
range	(.73-.88)				(.85-.99)	(.84-.98)			(.38-.47)	(.32-.43)			(.44-.75)	(.50-.76)		
Females	0.8±0.03	0.8±0.03	0.8±.01	0.67±.38	0.89±.04	0.89±.04	0.96	0.76±.43	0.41±.03	0.41±.02	0.43	0.39±.22	0.55±.05	0.68±.11	0.69	0.39±.22
range	(.75-.84)	(.73-.85)			(.84-.98)	(.69-.98)			(.38-.47)	(.37-.48)			(.45-.65)	(.54-.83)		

Table: 5.1. Morphometrics proportions in 79 females, 50 males and 265 hatchlings *Batagur baska* from Thailand (TH), Malaysia (MY), Myanmar(MM) and Cambodia(CM). Mean value are described with SD and range are in the parentheses. Measurements were taken in millimeters.

Discussions

Batagur baska is a member of subfamily Batagurinae of the family Emydidae. Based on the most recent reviews of this subfamily (Loveridge and Williams, 1957 and McDowell, 1964), the river terrapin's closet relatives are *Kachuga* and *Callagur*. Loveridge and Williams included the aforementioned genera in a complex with *Morenia* and *Hardella*. McDowell considered Morenia and Hardella more closely related to *Geoclemys* and separated *Batagur, Callagur* and *Kachuga* into a separate complex with *Hieremys, Malayemys, Chinemys* and *Ocadia.* Suffice it to say, ecologically as well as phylogenetically *Batagur* is closely allied with *Kachuga* and *Callagur* (Moll, 1980).

The carapace of hatchlings and small juveniles is armed with spines that disappear with age and are thought to deter predators. The well-developed, uniformly yellowish or cream colored plastron is extensively sutured to the carapace, with a small anal notch. The plastral scute formula is abdominal > pectoral >< femoral > humeral > anal > gular. The head is small to moderately size for such a large turtle, with a characteristic upturned snout and a notched, serrated jaw. The head is olive gray dorsally, but lighter gray laterally and ventrally with light-colored jaws. Juveniles are drably colored. The stout forelimbs are somewhat paddle-shaped with four claws. The skin is olive gray and occasionally darker. The sexes are strongly dichromatic during the breeding season; the skin on the head, neck, and legs of the male turns dark black and iris color changes from yellowish to pure white, while females remain drably colored. The iris of the female is black. Even when not breeding, males tend to be somewhat darker than females. The sexes can also be distinguished on the basis of tail characteristics; males have longer, thicker tails than females (Moll, 1978; Moll, 1980; Ernst and Barbour, 1989).

Geographic variation in the coloration of *B. baska* is not well described. Anderson (1879) noted that the head and forelimbs of males from Burma or India turned bright red during the reproductive season, a condition not observed elsewhere (Moll, 1980); however, this may have been the result of confusion with sympatric species of *Kachuga* (Platt, et.al). Although less pronounced, Moll (1980) likewise observed differences in coloration between populations of *B. baska* on the east and west coast of Peninsular Malaysia. The red coloration was never been observed in this survey in Myanmar, Thailand, Cambodia and west coast of Malaysia. Thai male *Batagurs* show very bright yellowish iris during breeding season while cream to whitish in elsewhere in the range. The hatchlings are colored similarly in the whole range.

Among Malaysian *Batagurs*, male compared to females had significantly narrower (CW/CL= 0.79 in male, 0.80 in female), shallower (SD/CL= 0.39 in male, 0.41 in female) with shorter plastron (PL/CL= 0.88 in male, 0.89 in female). Tail proportions to (pre-anal length/total tail length) were also significantly dimorphic. Juveniles (N=114) had a ratio of 0.45, females (N=55) had 0.55, males (N=20) had 0.64.

Among Thai *Batagurs*, male compared to females had significantly narrower carapaces (CW/CL= 0.78 in male, 0.80 in female), shallower carapaces (SD/CL=0.40 in male, 0.41 in female) and shorter plastrons (PL/CL=0.88 in male, 0.89 in female). Tail proportions to (pre-anal length/total tail length) were also significantly dimorphic. Juveniles (N=151) had a ratio of 0.45, females (N=25) had 0.55, males (N=25) had 0.68.

Chapter 6

Threats to River Terrapin, *Batagur baska* throughout its range and Conservation needs

The river terrapin, *Batagur baska* is a large aquatic turtle that once inhabited mangrove swamps, coastal estuaries, and large rivers in southeastern India, Bangladesh, Myanmar, Peninsular Malaysia, Sumatra (Indonesia), Thailand, Cambodia, and Vietnam. Historically large numbers of females deposit eggs on well-known nesting beaches, but populations have sharply declined as a result of chronic egg-collecting, over-harvesting of adults, destruction of nesting habitat, and clearance of mangrove swamp forest. Available survey data suggest that the downward spiral of *B. baska* populations continues.

Today, extant populations of *B. baska* are no longer thought to occur in Indonesia and Vietnam, scattered individuals persist in Thailand, Myanmar, and Cambodia, and the viability of populations in Bangladesh and India is doubtful. Malaysia is the only remaining range country that appears to harbor viable wild populations of *B. baska*. Consequently, *B. baska* is now considered Critically Endangered by the IUCN and the Turtle Conservation Fund, and regarded as one of Southeast Asia's most threatened chelonians. Furthermore, the Turtle Conservation Fund recently prioritized *B. baska* as one of 25 chelonians worldwide most need of conservation action.

Despite the recognition of its critically endangered status, little has been done to ameliorate the threats faced by wild populations of *B. baska*. These threats include the loss of eggs, hatchlings, juveniles, and adult terrapins to native and introduced predators, drowning in fishing gear, anthropogenic destruction of nesting and feeding habitat, direct human exploitation of eggs and adult terrapins, water pollution, and altered stream flows due to dam construction. Although *B. baska* is afforded some degree of legal protection in each country where it occurs, enforcement of protective legislation is negligible or non-existent in many countries. To date, conservation efforts have largely centered on developing captive breeding and head-start programs designed to bolster juvenile recruitment into populations that would otherwise decline as a result of the wholesale harvest of eggs from nesting beaches. However, *B. baska* numbers continue to plummet suggesting that head-starting alone is insufficient to stabilize wild populations. It is thus obvious that in addition to *ex situ* captive breeding and head-starting programs, there is an immediate need to initiate steps for conserving the remaining wild populations of *B. baska*. These recommendations are listed below:

Threats to *Batagur baska*

Batagur baska populations face a variety of threats including predation, incidental capture as a result of fishing activity, habitat loss, subsistence and commercial harvest of eggs and turtles, exposure to environmental pollutants, and global climate change. Each of these threats is examined below.

1. Fishing

Even when turtles are not purposefully targeted for harvest, many fishing practices pose a serious threat to the continued viability of *B. baska* populations. The widespread use of fishing nets in rivers where terrapins feed and nest pose the greatest threat; turtles often become inadvertently entangled and drown in unattended nets. Monofilament nets are especially likely to capture turtles. *Batagur baska* may also become entangled in discarded fishing nets that drift with the tides or lodge in mangrove feeding areas. Other destructive fishing practices that result in the accidental death of terrapins include the use of dynamite, cyanide and other fish poisons, and electro-fishing. While illegal in most countries, enforcement of fisheries regulations is often lax and these practices are widespread along many remote rivers in Southeast Asia. Finally, judging from observations of extensive carapacial damage and scarring, accidental kills resulting from collisions with boat propellers are another source of mortality, especially on rivers with heavy boat traffic.

2. Habitat destruction

Next to the harvest of eggs and living turtles, the destruction of both nesting and foraging habitat is the most serious threat faced by wild populations of *B. baska* in every range country. The loss of nesting beaches as a result of sand mining is a particularly acute problem (Moll, 1997). Sand is in great demand for construction and sandbanks offer a readily available source of this building material. In former times excavation was done by hand and there was little danger of beach destruction as floods replenished sandbanks from upstream sources. Today mechanization is the rule and existing sandbanks are rapidly being depleted. According to Moll (1997), every river inhabited by *B. baska* has been impacted by sand mining. Dams exacerbate the situation by blocking the downstream movement of sand and sediments necessary for beach creation and nourishment (Moll, 1997). Altered river flows caused by dams also negatively impact the quality of riverine habitat. Dams reduce peak flows during wet periods, precluding the natural scouring by floodwaters required to prevent vegetation from choking nesting beaches. Increased flow during low water periods often erodes beaches or results in unseasonable flooding of nesting areas (Moll, 1997). Dams can also interfere with the annual movement of females from estuarine feeding areas to upstream nesting beaches (Moll, 1997). The construction of smaller scale embankments and tidal barrages can block direct access to beaches by nesting females. In some range countries (e.g., Myanmar) villagers cultivate gardens on riverside beaches that are exposed by falling water levels during the dry season, thereby further depriving turtles of already limited nesting habitat.

Forest clearance is generally not considered to be a direct threat to *B. baska* populations, but increased runoff and soil erosion can smoother nesting beaches under a deep layer of silt (Moll, 1997; Thorbjarnarson et al., 2000). Furthermore, silt enrichment of riverside sandbanks provides an organic base that encourages the growth of annual grasses such as *Imperata cylindrica*, which degrade the site as nesting habitat (Moll, 1997). Clearance of mangrove forests threatens *B. baska* populations by reducing the availability of mangrove fruits, an important food resource and dietary mainstay in estuarine habitats.

3. Direct exploitation of eggs and turtles

Egg collecting is a ubiquitous threat faced by *B. baska* wherever the turtles nest. *Batagur baska* eggs are regarded as a delicacy and in some areas (e.g., Malaysia; Moll, 1985) considered to have aphrodisiacal properties. Consequently, *B. baska* eggs are intensively collected for human consumption throughout its range. Eggs are both consumed locally and exported to distant markets. Historically in Malaysia (Swettenham, 1993) and Cambodia (Pavie, 1881; Tirant, 1884), *B. baska* eggs were considered royal property and could only be collected under patronage of the ruling family. This system persists in Perak State of Malaysia, albeit in a somewhat modified form; collecting rights are leased to area businessmen who must provide the local Sultan with a certain portion of their harvest. During the colonial period in Myanmar, egg harvests were managed by the Fisheries Department. Harvest rights were leased to professional egg collectors who combed the beaches early in the season and then allowed area villagers to harvest eggs for personal use (Thorbjarnarson et al., 2000). Although collectors were required by law to leave 10% of the eggs *in situ*, this stipulation was largely ignored (Maxwell, 1911). Despite attempts to manage this resource in a sustainable manner, *B. baska* rookeries have been decimated in most areas. Because eggs and juvenile turtles typically experience very low survival rates, these age classes are generally assumed to be demographically expendable; i.e., management strategies that protect even large numbers of nests will have only a minimal impact on the size of adult populations (Gibbs and Amato, 2000). Nonetheless, chronic egg harvesting, which leaves few if any clutches to hatch, has eliminated recruitment in many populations leading to their decline and eventual extinction. The apparent persistence of some remaining *B. baska* populations may simply be due to the longevity of surviving adults rather than continued recruitment of juveniles into reproductive cohorts.

Larger juveniles and adult *B. baska* are hunted for food in many areas, although this harvest has proven difficult to quantify. Additionally, there is indication that some *B. baska* are harvested for export to food and medicinal markets in southern China and Taiwan; indeed, specimens have been found in these markets but the extent of the trade is difficult to determine. Although nominally protected in most range countries, laws are difficult to enforce and prohibitions against capture appear to be widely ignored. As with most turtles, the demographic consequences of harvesting larger size classes can be especially devastating to *B. baska* populations. In long-lived organisms such as turtles, populations are particularly sensitive to increases in levels of adult mortality (Gibbs and Amato, 2000), and the removal of even a few mature individuals can result in dramatic population declines (Congdon et al., 1993). Thus it is questionable whether any level of harvest that removes reproductive adults from a population can be regarded as truly sustainable (Thorbjarnarson et al., 2000).

4. Water pollution

Water pollution from industrial and agricultural sources is an obvious threat to aquatic organisms in general and river turtles in particular (Moll and Moll, 2004). Pollutants may act directly by killing turtles, or indirectly by affecting organisms on which turtles depend for food or some other critical aspect of its habitat (Moll and Moll, 2004). Unfortunately, little is known about specific threats that water pollutants pose to *B. baska* populations. Given the polluted state of many inland waters in Southeast Asia and the widespread use of agricultural chemicals in the region (Cunningham et al., 2003), environmental contaminants may pose a greater threat than has been previously recognized.

5. Predators

Batagur baska is vulnerable to a variety of native and introduced predators, including estuarine crocodiles, wading birds, monitor lizards, otters, monkeys, and perhaps sharks and tigers. In addition to natural predators, domestic animals associated with riverside villages can pose a significant threat; water buffalo and cattle often trample nests, and domestic dogs and pigs occasionally unearth and consume eggs. Eggs and hatchlings are undoubtedly the demographic cohorts most at risk from predation, but adults are not immune and occasionally fall victim to large predators such as estuarine crocodiles and tigers. In former times when hundreds of female terrapins deposited thousands of eggs on a limited number of beaches, predation probably had little effect on populations. Indeed, the large numbers of nests may have functioned to satiate local predators with an overly abundant food resource, thus insuring that at least some eggs hatched successfully. In contrast, the small numbers that are typical of extant populations are at much greater risk from predation and the loss of even a few nests or adults can have potentially disastrous demographic consequences.

6. Global warming

The effect of global warming on *B. baska* populations remains largely speculative at this point. Sex in *B. baska* is likely determined by incubation temperature (Moll and Moll, 2004), although empirical data on pivotal temperatures and the thermosensitive period are currently lacking. Thus it is conceivable that rising global temperatures could alter hatchling sex ratios in the future. Additionally, global sea level rise that might accompany a meltdown of the polar ice caps could inundate coastal beaches currently used as nesting sites. On a promising note, the projected increases in global temperature will probably be dampened in the tropics in comparison to higher latitudes (Cunningham et al., 2003).

Conservation Needs

Establish assurance colonies of *B. baska* in all range countries. Because so little is known regarding intraspecific genetic variability in *B. baska*, it is important that founding stock for these colonies originate within each range country if possible. In addition to captive breeding, developing improved husbandry techniques and communicating this information to others involved in captive propagation is an important objective of these assurance colonies. Importantly, the stated objective of all *ex situ* programs (both within and outside of range countries) should be the maintenance and recovery of viable wild populations of *B. baska*. Most importantly, *ex situ* programs should not become an end unto themselves, but a means to promulgate effective *in situ* conservation. Moreover, all *ex situ* programs should include a strong conservation education component. Reintroduction of *B. baska* into viable protected areas of Thailand and Malaysia. Reintroductions should closely adhere to IUCN Guidelines. In particular, sites selected should be within the known historic range of *B. baska*. Factors responsible for the original extirpation should be determined and addressed. Moreover, habitat evaluations must be undertaken prior to release to determine if the area is capable of supporting a viable *B. baska* population. Continue research by university-based academics and graduate students to undertake conservation-related projects. Increase media coverage through press releases, interviews, etc. of *B. baska* conservation efforts and develop local and national education programs on turtle conservation with special emphasis on *B. baska*. Reach out to policy and law makers to ensure adequate legal instruments are in place to protect *B. baska* and its habitat from various threats. It is important to stress that policies favorable to terrapins often benefit rural communities as well.

Further Research needs

1. **Population Genetics**: There is an urgent need to characterize the genetic variability of *B. baska* throughout its global distribution. Genetic differences are an essential consideration when developing plans for captive breeding, translocation, and reintroduction projects.
2. **Home-Range Size and Movement Patterns**: Much remains to be learned about the habitat requirements and movement patterns of all life history stages of *B. baska*. This information is essential for designating critical habitat, designing effective protected areas, and developing species-specific conservation legislation.
3. **Reproductive Biology**: Information on the reproductive biology of wild populations of *B. baska* is required to develop effective conservation strategies and assess the potential impact of human activities on wild populations. Field studies are necessary to determine various reproductive parameters.
4. **Nutritional Needs**: There is an urgent need for long-term dietary studies of wild populations of *B. baska*. This information may improve captive husbandry, but it is also essential for understanding movement patterns in wild populations and assessing the risk of human impacts to tropical river ecosystems.
5. **Monitoring of Head-started Terrapins**: Head-starting programs have returned thousands of juvenile *B. baska* into the wild since their inception in the late 1970s and yet there has been little or no systematic attempt to monitor the released turtles to determine survivorship, growth rates, or recruitment into reproductive cohorts. It is therefore critical to determine the fate of the head-started turtles.

Chapter 7

Conclusions and Recommendations

Batagur baska small populations persist in coastal regions of Mon and Rakhine States and Ayeyarwady and Tanintharyi Division in Myanmar where a combination of local religious beliefs and areas of armed conflict confer some degree of protection. Peninsular Malaysia represents the last stronghold of *B. baska* and recent estimates indicate that less than 50 breeding females remain in Perak River, Malaysia. Despite the effort on release of thousands of head-started hatchlings in the Perak River, the populations continue to decline. A small numbers of *B. baska* still inhabited in Langu Canal in Satun Province, Thailand and also documented the occurrence of three wild nests and other potential nesting beaches along the river. A large adult *B. baska* was captured by a fisherman in TaKua Tung District, Southern Thailand.

Peak nesting activity at both hatchery stations coincided with the highest mean monthly air temperatures and hatchling emergence occurred when mean monthly air temperatures were lowest. Courtship and mating took place during October and November, followed by nesting in December and January. Mean clutch size among females (n = 14) was 21.7 ± 5.6 eggs (range = 18 to 25 eggs). Incubation periods ranged from 74 to 110 days depending on the method of incubation. Hatching success ranged from 40.8% to 58.1% depending on incubation method. Growth rate of hatchlings was considerably higher at SIF in comparison to BKH, most likely due to superior diet provided to hatchlings at the former facility. In BKH, Courtship and mating takes place from August through December, while nesting and clutch deposition occurs as early as October, with a peak in January, and continues until mid-March. Clutch size produced by captive female averaged 15.2 ± 5.7 eggs (n = 10; range = 6-20). Clutch size at BKH was smaller than found in Thailand, probably due to the smaller body size of females at BKH. From 1993 to 2005, 1524 clutches were produced by adults maintained at BKH with hatching success ranging from 27.5 to 60.5%. Incubation periods ranged from 71 to 92 days.

The measurements were compared between males, females and hatchlings of *B. baska* from Myanmar, Thailand, Malaysia and Cambodia by using Student T-Test. Based on 79 females and 50 males, the analysis indicates that there is no significant morphological difference between *B. baska* among isolated populations and it could only be concluded that *B. baska* males had significantly narrower carapace width, shallower shells, shorter planstrons, and lighter body weight than those in females at all locations.

Batagur baska populations face a variety of threats including predation, incidental capture as a result of fishing activity, habitat loss, subsistence and commercial harvest of eggs and turtles, exposure to environmental pollutants, and global climate change. Predators include native and introduced animals, in addition, domestic animals are significant threats. Fishing practices are still serious threats when *B. baska* are not even purposely targeted for harvest. The turtles are entangled and drown in unattended fishing nets. Boat propellers are another source of mortality on rivers with heavy boat traffic. The destruction of both nesting and foraging habitat is the most serious threat faced by wild populations of *B. baska.* Sand mining, dams construction, cultivation on the nesting beach, forest clearance is also threats to *B. baska*. Hunting adult turtles and collections of eggs are serious threats to *B. baska* throughout its range. Water pollution from industrial and agricultural sources is an obvious threat to river turtles. Global warming could alter sex ratios in the future as sex in *B. baska* is likely determined by incubation temperature.

Based on the results of this study, I recommend that changes be made to incubation facilities in SIF, to improve hatching success, turtles should be supplied with deeper water, stocking density should be reduced to provide individuals with more space in each breeding pen, and calcium supplements be added to the diet to ensure proper eggshell formation. Most importantly, rivers in Thailand should be evaluated as potential reintroduction sites for establishing viable wild populations. From 1969 through 2005, 35,263 head-started turtles from BKH were released into the Perak River. Despite the release of large numbers of hatchlings over the past 35 years, there has been little attempt to monitor the success of this program. Based on the number of nests collected along the Perak River, it appears that the number of wild females continues to decline, although the causative agents have yet to be identified. Therefore, a re-evaluation of the captive breeding and head-start program, monitoring of the wild population in the Perak River are urgently required. Additionally, I recommend that all eggs harvested by the commercial egg collectors be purchased by BKH and the sale of eggs in markets be legally banned. Finally, dietary improvements are urgently needed and frequent inspection by a veterinarian trained in reptile medicine are essential to ensure the health of captive turtles at the facility.

Batagur baska is considered as critically endangered and keystone species in its habitat. It should receive the highest priority for conservation because at present it is facing to extinct in the wild. All known population is declining in its range countries. Public awareness and education are urgently needed. This study has attempted to study the current population, conservation status captive reproduction and threats to this critically endangered species. The proper conservation and management of *B. baska* will, however, have to rely on further in-depth research.

Recommendations

Malaysia

I. Legislation

Existing legislation in Malaysia for the protection of wildlife is, in general wholly inadequate. For example, the Wildlife Protection Act of 1972 lists several levels of protection for endangered species of wild animals (mammals, birds, reptiles, and insects), but completely omitted all species of terrapins and tortoises. It is therefore necessary for the Ministry of Natural Resources to revamp existing legislation and extend protection to all species of endangered animals and plants in the country. Malaysia urgently needs an Endangered Species Act at the federal level in order that all endangered species can be afforded protection that is badly needed, both at the federal and state levels. The following should be taken into consideration during the review of conservation legislation:

1. Ban collection of *B. baska* eggs and their sale in markets. The Ministry should consider writing a letter of appeal to the Sultan of Perak requesting that the annual mandatory "gift" of terrapin eggs to the palace be suspended. It is essential that this practice be viewed in light of the imminent risk of extinction faced by *B. baska*.
2. Ban destructive fishing methods and provide means of enforcement.
3. Control speedboat traffic in terrapin habitat.
4. Designate all nesting sites, home-ranges, and foraging areas as protected habitat. Sand mining should be banned in these areas.

5. Establish buffer zones for agricultural and aquaculture use in mangrove areas and along river channels.
6. Mandate Environmental Impact Assessments (EIA) for all projects in sensitive areas.

II. Research needs

1. Conduct surveys and interviews to verify location and status of existing wild populations, threats to these populations, and perceptions of local populace to conservation of *B. baska*.
2. Conduct research to develop effective, standardized methods of head-starting juvenile *B. baska*.
3. Monitor post-release growth and survival of head-started juvenile *B. baska*.
4. Assess fishing mortality of *B. baska* and develop terrapin-friendly fishing gear and methods.
5. Assess pollution status of terrapin habitat and effects of environmental pollutants on wild populations.
6. Initiate studies of reproductive biology in wild populations of *B. baska.*
7. Identify habitats utilized by *B. baska*.
8. Explore possibilities for caging boat propellers to reduce propeller hits on terrapins.
9. Determine nutrient levels of eggs (proteins, fats, cholesterols, etc.).

III. Education

1. Conduct campaigns to educate all stakeholders, including decision makers, fishers, egg collectors, local school children, etc.
2. Integrate conservation education into village-level school curriculum and develop teaching materials suitable for this task.

IV. Review of existing *B. baska* Conservation Centers managed by Perhilitan Capacity building for workers in these centers.

1. Ensure proper maintenance of brood stock and rearing ponds.
2. Ensure proper feeding practices so that terrapins grow optimally and avoid malnourishment.
3. Monitor breeding, nesting, growth, and health of captive terrapins.
4. Introduce student internships to assist with monitoring of captive terrapins.
5. Provide adequate levels of funding to accomplish these tasks.
6. Station a biologist or veterinarian at facility.
7. Conduct regular assessment of the performance of facility by an external panel to determine if objectives have been met.
8. Continue intensive procurement of terrapin eggs from natural nesting beaches.

Thailand

1. Survey Songkhra Lake and Ranong for the presence of remnant populations of *B. baska*.
2. Factors causing the original extirpation should be determined and addressed.
3. Designate the Langu River as protected area owing to the presence of a remnant *B. baska* population. Evaluate the river with a view towards possible augmentation of existing population using captive reared terrapins from Satun Inland Fisheries Station.
4. The potential seven nesting beaches along Langu River should be protected during the nesting season.
5. Evaluate the river with a view towards possible augmentation of existing population using captive reared terrapins from Satun Inland Fisheries Station.

6. Reintroduction to Taleban National Park (TNP) pending outcome of habitat evaluation. Reintroduction of *B. baska* should be closely adhere to IUCN Guidelines and followed by monitoring. Moreover, habitat evaluations must be undertaken prior to release to determine if the area remains suitable.
7. Capacity building and technical input for captive breeding and head-starting programs at Satun Inland Fisheries Station.
8. Turtle-specific training for Thai conservation and zoo personnel.
9. Increase law enforcement presence at potential reintroduction sites.

Myanmar

1. Conduct public awareness and education programs in fishing communities of coastal Ayeyarwady Division and Rakhine State.
2. Conduct additional surveys in coastal regions of Ayeyarwady and Tanintharyi Divisions, and Mon and Rakhine States.
3. Law enforcement training for government fisheries staff and local authorities in coastal regions of Ayeyarwady Division and Rakhine State.
4. Establish captive breeding program if a coterie of suitable *B. baska* can be located.

A number of minor changes in the husbandry at both facilities in Thailand and Malaysia could be made to improve incubation success, hatchling survival, and overall welfare of captive turtles. Recommended changes are outlined separately for each facility below.

Satun Inland Fishery Station, Thailand

There is an urgent need at SIF to provide turtles with deeper water and more space in individual pens. The nesting beach in each breeding pond should be improved by clearing vegetation and providing deep, clean, beds of sand for nesting. Owing to shading that results in very low water temperatures in Ponds 1 to 4, it will be necessary to prune trees growing on the eastern perimeter of these ponds provide adequate exposure to solar radiation. Conversely, the newly constructed pond across the Langu River has little shade and consequently the water temperatures reach excessively high temperatures that may endanger the turtles; thus, some form of over-head cover should be provided at this pond. The diet provided to breeding females requires re-evaluation and the possible inclusion of calcium supplements may be required to ensure proper eggshell development. In the wild approximately one fifth of the adult diet is comprised of mollusks (Moll, 1980). Thus, small claims and snails might prove adequate sources of calcium for captives. To avoid possible bacterial infection and prevent ants from invading the nesting areas, the sand used for incubating eggs should be replaced after every nesting season. Finally, provisions should be made to move forward with plans to release head-started juveniles at secure sites in Thailand. These sites should not include monastery ponds and artificial reservoirs, which are unsuitable sites for establishing viable wild populations. Potential rivers should be evaluated with a view towards augmenting any remaining remnant wild populations of *B. baska*. The most promising potential reintroduction site yet identified is Taleban National Park (TNP). A habitat evaluation is urgently required and any release of head-started turtles should be followed by a long-term monitoring program. Finally, capacity building and technical input for captive breeding and head-starting programs at Satun Inland Fisheries Station are urgently needed. Also, frequent visits by a veterinarian trained in reptile medicine are essential to ensure continuing good health of captive turtles.

Bota Kanan Hatchery, Malaysia

A number of changes are necessary for the continued long-term success of the captive propagation program at Bota Kanan Hatchery. First, there is an urgent need to improve the diet provided to all size classes of *B. baska* at the station. A proper diet is necessary to achieve optimal growth, avoid malnourishment, and improve reproductive success of adult females. In particular, fish, mollusks, and fruit should be incorporated into the existing diet that consists almost solely of *Ipomea*. The Sultan of Perak currently retains the privilege of purchasing *B. baska* eggs for consumption at the palace. I suggest that a meeting be arranged with the Sultan and an agreement made with the remaining egg collectors for BKH to purchase all eggs that are harvested each year. Additionally, the sale of *B. baska* eggs in markets should be legally banned. The efficacy of the current head-starting and release program is questionable and requires re-evaluation. If the program is to be continued, all released turtles should be permanently marked prior to release. Moreover, monitoring of post-release growth and survival of head-started juveniles is an essential prerequisite for formulating future conservation and management strategies. Finally, public access to nursery ponds should be prohibited or visitors should only be allowed on the premises if accompanied by hatchery staff, and like SIF, care by a veterinarian trained in reptile medicine is essential.

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Appendix

Figure1: Breeding coloration of *Batagur baska* at Satun Inland Fishery Station. Note prominent yellow iris.

Figure 2: Large female *Batagur baska* (carapace length = 52.8 cm) inhabiting in Botahtaung Pagoda pond inYangon, Myanmar. This turtle likely originated from a population that once occurred in the lower Ayeyarwady Delta.

Figure 3: A comparison of the breeding coloration typical of female (right) and male (left) *Batagur baska*. Photographed in 13 December 2003 at Bota Kanan Hatchery, Malaysia.

Figure 4: Mangrove apple (*Sonneratia caseolaris*), a dietary staple of *Batagur baska* in coastal regions of Southeast Asia.

Figure 5: Bananas placed in shallow water at nesting beaches by egg collectors to attract female *Batagur baska*. Photographed along the Perak River in Malaysia (December, 2004).

Figure 6: Small hillocks constructed by egg collectors on a nesting beach along the Perak River in Malaysia. Egg collectors believe these hillocks will attract nesting female *Batagur baska*. Photographed along the Perak River in Malaysia (December, 2004).

Figure 7: Measuring *Batagur baska* egg with a dial caliper at Bota Kanan Hatchery in Perak Malaysia.

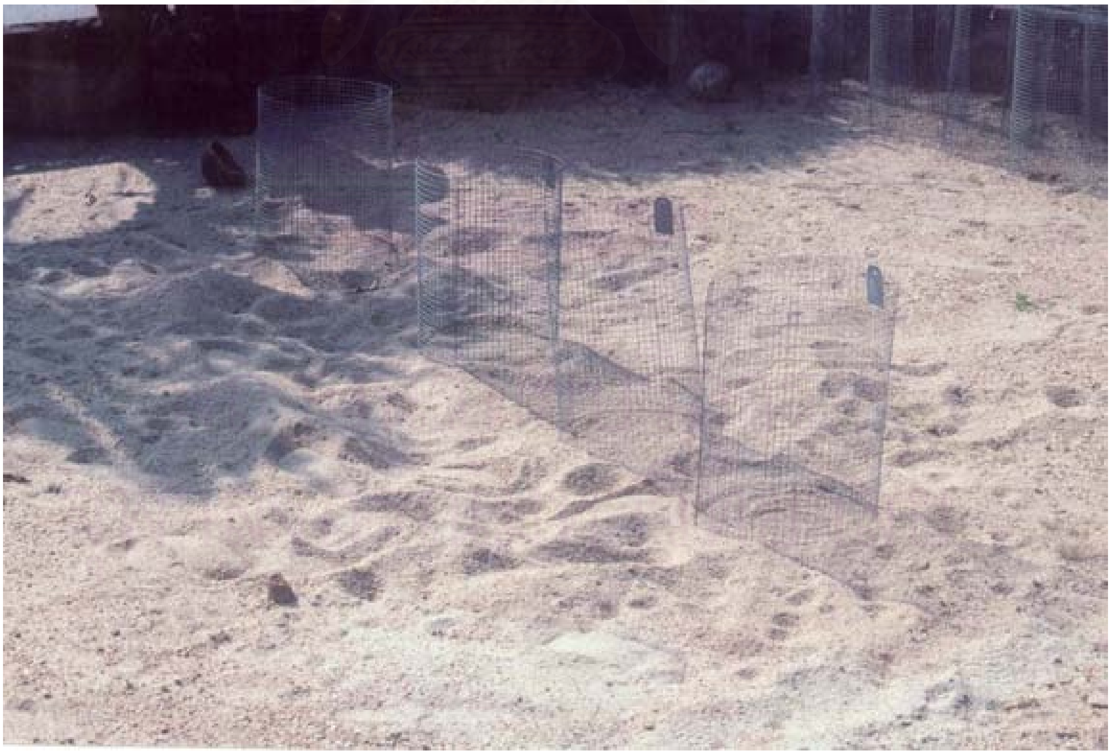

Figure 8: Artificial *Batagur baska* nests at Bota Kanan Hatchery in Perak Malaysia. Fences are constructed around each nest to deter predators.

Figure 9: Concrete incubation pond for *Batagur baska* eggs at Satun Insland Fishery Station, Langu, Thailand.

Figure 10: An I-Button "thermal data logger" placed in *Batagur baska* nests both in Thailand and Malaysia to record incubation temperatures. A string glued to the data logger facilitated recovery following hatching.

Figure 11: *Batagur baska* nesting beach along Langu River, Thailand. Three female turtles nested on this beach in January 2003.

Figure 12: An adult *Batagur baska* basking along the Langu Canal at 14:23 hours on 28 October 2004 (photo courtesy of Ms. Saowakhon Rungruang).

Figure 13: *Batagur baska* breeding pond at Satun Inland Fishery Station in Langu, Thailand. This pond contains 50 adult turtles.

Figure 14: *Batagur baska* breeding pond at Bota Kanan Hatchery in Perak Malaysia. This pond contains 75 adult turtles.

Figure 15: Nursery ponds for *Batagur baska* ranging in age from hatchlings to 3 years old at Bota Kanan Hatchery in Perak, Malaysia.

Figure 16: Nursery ponds for *Batagur baska* ranging in age from hatchlings to 3 years old at Satun Inland Fishery Station in Langu, Thailand.

Figure 17: Sand dredging along Perak River, Malaysia. Photographs were taken in December 2004.

Biography

Kalyar, the daughter of U Nyunt Thein and Daw San San, was born on 2nd October 1972 in Yangon, Myanmar. She attended Basic Education High School No.2 Latha, Yangon. In 1991, she entered Yangon Arts & Science University (Hlaing Campus) and graduated in 1995 with a Bacheor of Science, Honor degree in Zoology. Kalyar graduated her Master of Science degree in Zoology from the same university in 2000. She began her graduate study with Chulalongkorn University in Department of Biology, Faculty of Science Since June 2002. The project received financial support from number of sources. Financial support for surveys in Myanmar was provided by Wildlife Conservation Society, and those in Thailand and Malaysia were supported by Office of the Commission for higher education-CU Graduate Thesis grant, and the small grants program of the Cleveland Metroparks Zoo.