ECOLOGY AND USE OF THE ASIAN SOFT-SHELL TURTLE (*AMYDA CARTILAGINEA*), WITH NOTES ON OTHER SPECIES

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DEDICATION

This thesis is dedicated to the memory of my mother, Francis Marita Huffaker Jensen. She instilled my passion for the outdoors and animals by making me ride my first horse at four years old, teaching me to swim before I could walk, sending me to my grandparents' farm every summer, and especially for those long hikes to the top of "Thunder Mountain" with the wild horses.

DECLARATION

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification to this or any other university or institution of higher learning.

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Karen A. Jensen

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ABSTRACT

Turtles and tortoises play important, albeit incompletely understood and largely unappreciated, roles in both the ecology of their ecosystems, and in the economy and sociology of the human cultures that interact with these enigmatic creatures. South-east Asia is home to a high diversity of freshwater turtle species. However, none of the species known from Borneo have been studied at length and consequently, little is known of their ecology. The present work is the first ecological study of *Amyda cartilaginea* not only in Borneo, but Malaysia. Notes were opportunistically collected on other freshwater turtle species, termed hard-shell turtles and included individuals of *Cyclemys dentata, Cuora amboinensis, Heosemys spinosa, Notochelys platynota*, and another native soft-shell turtle, *Dogania subplana*. Field work was concentrated at the primary study area, Loagan Bunut National Park (LBNP), but two visits were made to Balai Ringin, a fishing village located within a peat swamp to augment data collected at LBNP. Information collected pertaining to cultural use and trafficking of turtles was done opportunistically throughout Sarawak and on one visit in Sabah. Study site choice was based on available funding and opportunities for field visits. Capture rates for *Amyda cartilaginea* were extremely low. Out of 2,046 trap-nights at LBNP, 14 *Amyda cartilaginea* were captured, representing a success rate of 0.54%. Out of 720 trap nights at Balai Ringin, five *Amyda cartilaginea* were captured, representing a success rate of 0.69%. Relatively few hard-shell turtles were found during the course of this study. At LBNP, three *Cuora amboinensis* and seven *Cyclemys dentata* were captured. At Balai Ringin, one *Cyclemys dentata* and one *Heosemys spinosa* were captured. Several environmental factors seem to affect turtle behaviour or at least capture rates. Hard-shell turtles had the greatest capture rate during the full moon phase, indicating that lunar illumination is necessary for foraging and other activities. Both *Amyda cartilaginea* and the hard-shell turtles favoured overcast weather versus clear skies or rain, for moving and foraging. Seasons did not have a dramatic affect on the capture rate of turtles. Results of size class examination for three species, *Amyda cartilaginea, Cuora amboinensis*, and *Cyclemys dentata* possibly indicate that animals may not be living long enough to attain large size.

However, it is possible more animals from Borneo should be measured to determine a true range of sizes and determine if there is indeed a lack of recruitment into the largest known size classes. Sexual size dimorphism was not statistically significant, perhaps an effect of skewed size of captured animals. This may be a factor of equipment or techniques used biased towards medium-sized animals and the largest individuals are relatively trap-shy, or perhaps a result of past exploitation. All allometric analyses indicate strong proportional changes with growth of all species. *Cyclemys dentata* stands out in that this species shows great variation among individuals. Some animals are flattened in shape while others are high domed. *Amyda cartilaginea* from Borneo have a distinct series of black splotches and a black saddle band over a brown base colour on the carapace, unique from other patterns found on this species on the Asian continent. Dietary analysis of *Amyda cartilaginea* indicates that they are opportunistic omnivores, playing an important role in the peat swamps of Borneo by cycling energy from both animal and plant material. The other species analysed for diet also contribute to the ecosystem by breaking down cellulose material into energy and also in seed dispersal. Scavenging behaviour is one of the more important aspects of nutrient cycling for both the wetlands and for human populations. Wet market surveys and interviews with turtle hunters and fishermen show that *Amyda cartilaginea* is a prized food item in Sarawak culture. These surveys suggest that cultural use of turtles remain high although they are protected by State legislation, but the level of commercial use for food is unclear. Pet trade in local and exotic turtles is active in Sarawak. The harvest rate of turtles in Sarawak along with any international trafficking needs to be investigated.

ABSTRAK

Labi-labi dan kura-kura memainkan peranan penting dalam ekologi, ekonomi dan sosiologi manusia yang berinteraksi dengan haiwan tersebut walaupun peranan ini kurang difahami dan tidak dihargai. Asia Tenggara adalah habitat bagi berbagai jenis labi-labi dan kura-kura. Namun demikian, tiada spesies dari kepulauan Borneo yang telah dikaji dengan teliti, oleh itu tidak banyak diketahui mengenai ekologinya. Kajian ini merupakan kajian pertama mengenai ekologi *Amyda cartilaginea* bukan sahaja di Borneo tetapi juga di Malaysia. Juga dikumpulkan secara oportunis ialah maklumat tentang spesies labi-labi dan kura-kura lain termasuk jenis yang bercenkerang keras ("hard-shell") iaitu *Cyclemys dentata, Cuora ambionensis, Heosemys spinosa, Notochelys platynota* dan jenis yang bercenkerang lembut ("soft-shell") *Dogania subplana*. Kebanyakan kerjalapangan dilakukan di Taman Negara Loagan Bunut (LBNP). Dua lawatan juga dibuat ke Balai Ringin, sebuah kampung nelayan yang terletak di hutan paya gambut, untuk menyokong maklumat yang diperolehi dari LBNP. Maklumat mengenai penggunaan dan penjualan penyu dibuat secara oportunis di seluruh Sarawak dan melalui satu lawatan ke Sabah. Pemilihan tempat kajian adalah berdasarkan adanya pembiayaan dan peluang untuk membuat kerjalapangan. Kadar tangkapan untuk *Amyda cartilaginea* amat rendah. Daripada 2,046 malam-perangkap di LBNP, 14 ekor *Amyda cartilaginea* telah ditangkap, bersamaan kadar tangkapan sebanyak 0.54%. Daripada 720 malam perangkap di Balai Ringin, lima ekor *Amyda cartilaginea* telah ditangkap, bersamaan kadar tangkapan sebanyak 0.69%. Tidak banyak kura-kura bercenkerang keras dijumpai dalam kajian ini. Di LBNP, tiga *Cuora ambionensis* dan tujuh *Cyclemys dentata* ditangkap. Di Balai Ringin, se ekor *Cyclemys dentata* dan se ekor *Heosemys spinosa* telah ditangkap. Ada berberapa factor abiotik yang mempengaruhi kelakuan labi-labi and kura-kura atau kadar tangkapan. Labi-labi dan kura-kura berkulit keras banyak ditangkap semasa fasa bulan purnama, ini menunjukkan bahawa labi-labi dan kura-kura memerlukan keadaan terang untuk mencari makan dan aktiviti lain. Kedua *Amyda cartilaginea* dan kura-kura bercenkerang keras suka cuaca mendung banding cuaca cerah atau hujan untuk bergerak dan mencari makan. Musim tidak mempunyai kesan terhadap kadar tangkapan penyu. Hasil kajian keatas kelas

saiz bagi tiga sepsis, *Amyda cartilaginea, Cuora ambionensis* dan *Cyclemys dentata* menunjuk kemungkinan haiwan-haiwan tersebut tidak cukup tua untuk mencapai tahap saiz yang besar. Mungkin juga perlu lebih banyak lagi haiwan dari Borneo yang perlu diukur untuk menentukan saiz julat badan yang sebenar dan mengenalpasti jika benar labi-labi membesar hanya ke kelas saiz yang tertentu. Dimofisme seksual tidak signifikan, mungkin kesan saiz tangikapan ya tidak normal. Ini mungkin kerana faktor peralatan or teknik yang lebih cenderung ke arah haiwan yang sederhana saiznya dan haiwan yang besar agak susah ditangkap atau mungkin kesan eksploitasi sebelum ini. Kesemua analisis alometri menunjukkan perubahan perbahagian dengan pertumbuhan bagi setiap spesies. *Cyclemys dentata* menonjol di dalam variasi antara individu. Ada individu yang lebih pipih dan ada yang lebih melenkung belakangnya. *Amyda cartilaginea* dari Borneo mempunyai tanda-tanda kehitaman dan jalur hitam pada bahagian belakang, bahagian karapace lain berwarna coklat; corak ini adalah unik bagi sepsis ini dan berlainan dari sepsis yang terdapat di daratan Asia. Analisis keatas pemakanan *Amyda cartilaginea* menunjukkan bahawa mereka adalah omnivore oportunis, memainkan peranan penting dalam paya gambut di Borneo dengan memutarkan tenaga dari kedua tumbuhan dan haiwan. Spesies lain yang dianalisis dietnya juga menyumbang kepada ekosistem dengan menghuraikan bahan selulos kepada tenaga dan menyebarkan benih. Tingkahlaku makan bangkai merupakan salah satu daripada aspek pemutaran zat bagi kedua kawasan berair dan populasi manusia. Survei dipasar basah serta temuramah dengan pemburu penyu dan nelayan menunjukkan bahawa *Amyda cartilaginea* adalah item makanan yang amat digenari di Sarawak. Survei tersebut menunjukkan bahawa kegunaan penyu dalam kebudayaan adalah tinggi walaupun ia dilindungi oleh perundangan Negeri tetapi tahap penggunaan sebagai makanan komersial tidak jelas. Perdagangan penyu tempatan dan eksotik sebagai haiwan mainan di Sarawak adalah aktif. Kadar tangkapan penyu di Sarawak dan perdagangan haram antarabangsa penyu tersebut perlu diselidik.

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LIST OF ABBREVIATIONS

Asin	Arcsine
ATTWG	Asian Turtle and Tortoise Working Group
°C	degrees Centigrade
cc	cubic centimeter
CDC	Center for Disease Control
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
cm	centimetre
GPS	global positioning system
ha	hectare
HSUS	Humane Society of the United States
IUCN	World Conservation Union
kg	kilogram
KV	kilovolts
km	kilometre
L	litre
LBNP	Loagan Bunut National Park
m	metre
μA	milliAmperes
mg	milligram
ml	millilitres
mm	millimetre
pH	power of hydrogen
RM	Malaysian Ringgit
SCL	straight carapace length
SCW	straight carapace width
SH	shell height or carapace depth

LIST OF ABBREVIATIONS continued

SD	standard deviation
ULAM	Unit for Laboratory Animal Medicine
UNDP-GEF	United Nations Development Programme - Global Environment Fund
UNIMAS	Universiti Malaysia Sarawak
X	mean

CHAPTER 1

INTRODUCTION

Turtles and tortoises play important, albeit incompletely understood and largely unappreciated, roles in both the ecology of their ecosystems, and in the economy and sociology of the human cultures that interact with these enigmatic creatures. Non-marine turtles can be found in three broad categories by habitat use; freshwater turtles which share a dependency on slow moving or stagnant freshwater habitats; river turtles which inhabit lotic environments, and the tortoises and some turtles whose relatives inhabit either of the two aforementioned habitats. Each is a valuable component of their ecosystem providing functions such as energy flow and nutrient cycling, dispersal of vegetation, maintaining water quality and creating microhabitats for other species. The following sections highlight the varied roles turtles play in their ecosystems and in human culture.

1.1 The Roles of Turtles in the Ecosystem

1.1.1 Herbivory

Many turtles are herbivorous, or predominately so as adults. Herbivores, in general, perform an important function of nutrient cycling by breaking down the energy of plant material and converting it into protein. River turtles consume a wide variety of aquatic vascular and non-vascular plants in a variety of habitats, and both freshwater turtles and tortoises eat terrestrial plants, flowers, and fruits: *Carettochelys insculpta* (Georges and Rose, 1993); *Elseya dentata* (Kennet and Tory, 1996); *Homopus signatus signatus* (Loehr, 2002); *Dermatemys mawei* (D. Moll, 1989); *Batagur baska* (E.O. Moll, 1980); and *Pseudemys* and *Graptemys* (Webb, 1961).

Some herbivorous turtles, *Dermatemys mawei*, *Pseudemys concinna*, and *Pseudemys nelsoni*, have been shown to have a symbiotic relationship with gut micro-organisms, which assist in the breakdown of plant structure for digestion (Bjorndal and Bolten, 1990, 1992; Vogt and Flores-Villela, 1992; Thomas *et al.*, 1994). A few species of turtles, *Batagur baska*, *Podocnemis unifilis*, and *Pangshura tentoria*, are known to regularily eat water hyacinths (*Eichhornia* sp.) (Davenport *et al.* 1992; Varghese and Tonapia, 1986; Fachin-Terán *et al.*, 1995). In recent years, water hyacinths, an introduced species, have become an invasive problem in tropical and sub-tropical wetlands, clogging waterways and altering river flow. These stagnant waters, then, attract disease spreading mosquitoes, that are responsible for the resurgence of malaria and filariasis. The dietary preference of these turtles for water hyacinth therefore is beneficial to humans.

1.1.2 Seed Dispersers

Several species of turtles are known to eat fruits and seeds and are likely seed dispersers for many plant species: *Batagur baska* (*fide* E.O. Moll, 1980); *Staurotypus triporcatus* (*fide* Vogt and Guzman Guzman, 1988); *Chelonoidis chilensis* (*fide* Varela and Bucher, 2002); *Terrapene carolina bauri* (*fide* Liu *et al.*, 2004). Passage of seeds through the digestive system may be important for effective germination of some plant seeds (Macdonald and Mushinsky, 1988), and seed dispersal by animals plays an important role in the gene flow, demography, distribution, and evolution of plants (Howe and Smallwood, 1982; van der Pijl, 1982).

1.1.3 Predators

Many turtles are opportunistic omnivores, yet a few species are primarily carnivores, however, little research has been done with enough detail to be certain. Some turtles have been known to prey on everything from benthic invertebrates to fish. In India, turtles have been known to hunt in groups to take large prey (Das, 1995a). A group of *Aspideretes gangeticus* was observed by Singh (2000) to attack and kill a Nilgai antelope (*Boselaphus tragocamelus*) in India.

1.1.4 Scavengers

An extremely important role played by many turtles is scavenging. Even many predominantly herbivorous species will eat carrion when it is available. Furbank (1996) observed *Chelodina longicollis* eating road-killed animals. Spencer *et al.* (1998) identified that *Emydura* *macquarii* feed on the carrion of fish, primarily the European carp (*Cyprinus carpio*). In Australia, Armstrong and Booth (2005) observed *Elseya* sp. feeding on dead cane toads (*Bufo marinus*). Esque and Peters (1994) reported that *Gopherus agassizii* may consume bones found in the Utah deserts. Soft-shell turtles are noted for their importance in river ecosystems by scavenging. Taskavak (1995) and Taskavak and Atatür (1998) observed *Rafetus euphraticus* feeding on carrion, including a horse carcass (*Equus caballus*) in Turkey. *Trionix triunguis* was observed by Akani *et al.* (2001), to feed on a bush pig (*Phacochoerus africanus*) and goat (*Capra hircus*) carcasses. Das (1995a) noted *Aspideretes gangeticus* and *Aspideretes hurum* were raised and recruited to help clear half-burnt corpses from the Ganges River.

1.1.5 Disease Control

Some snails are agricultural pests or are the intermediate hosts of human parasites. *Filopadulina sumatrensis* and *Brotia costula* are introduced to Thailand and Malaysia (Srinarumol, 1995). They are known as intermediate hosts of trematode parasites in the Family Echinostomatidae and *Brotia costula* is an intermediate host to the lung fluke (*Paragonimus westermani*) (Srinarumol, 1995). After malaria, schistosomiasis is the second most prevalent tropical disease in the world (CDC, 2004). Contamination occurs when humans come in contact with fresh water sources containing the snail carriers (CDC, 2004). Currently, native fishes are being used in Malawi (Chiotha *et al.*, 1991) and Zimbabwe (Chimbari *et al.*, 1996) to control the snails carrying this disease. *Malayemys* (including *subtrijuga* and *macrocephala*) and *Geoclemys hamiltonii* are snail predators, and may naturally control this disease.

1.1.6 Prey

Rounding out the food web is the fact that turtles often become prey themselves. They are most vulnerable to predation in the earlier stages of development, eggs and hatchlings and become less so as they grow older. Ernst *et al.* (1994) presented a review of North American turtles and their natural history, included accounts of predation on various turtle species. There are a several accounts and publications noting predation on turtles indicating their importance as a food item. Some specific and personally interesting, examples are as follows. Souza and Abe (2000), noted that *Phrynops geoffroanus* were preyed upon by piranhas (Serrasalminae) in Brazil. Martuscelli (1995) observed that jaguars (*Panthera onca*) fed on *Hydromedusa tectifera* in Brazil. Even smaller turtle species, and juveniles of larger species may be taken by larger turtles such as *Macroclemys temminckii* and *Staurotypus triporcatus* (*fide* D. Moll, 1990). Golden eagles (*Aquila chrysaetos*) have been observed taking adult *Gopherus agassizi* from the desert floor (K. Jensen, pers. obs. 2001). Large adult soft-shells like *Pelochelys bibroni*, have been preyed upon by large crocodiles (*Crocodylus porosus)* (Rhodin *et al.*, 1993).

1.1.7 Habitat Alteration

Turtles also alter their surrounding habitat in ways that have a beneficial effect to other plants and wildlife, most notably in the land tortoises. The gopher tortoise (*Gopherus polyphemus*) found in the south-eastern United States, digs an array of large burrows throughout its home range. These burrows create a suitable shelter from the sun, rain, cold temperatures and predators for many other species. Ernst *et al.* (1994) reviewed the literature documenting this occurrence and found opossums (*Didelphis*), mice and rats (*Neotoma*, *Polomys*, *Peromyscus*, and *Sigmodon*), rabbits (*Sylvilagus*), weasels (*Mustela*), skunks (*Mephitis*, *Spilogale*), otters (*Lutra*), red foxes (*Vulpes*), coyotes (*Canis*), burrowing owls (*Speotyto*), quail (*Colinus*), snakes (*Agkistrodon*, *Cemophora*, *Coluber*, *Crotalus*, *Drymarchon*, *Elaphe*, *Heterodon*, *Masticophis*, *Micrurus*, *Pituophis*, *Sistrurus*, and *Thamnophis*), amphisbaenians (*Rhineura*), lizards (*Anolis*, *Cnemidophorus*, *Eumeces*, *Ophisaurus*, *Sceloporus*, and *Scincella*), and anurans (*Acris*, *Bufo*, *Eleutherodactylus*, *Gastrophryne*, *Rana*, and *Scaphiopus*) have been observed using the burrows of this species. Similarly, desert tortoises (*Gopherus agassizi*) dig several burrows within their home range. In Utah, Woodbury and Hardy (1948) noted woodrats (*Neotoma* sp.) and western rattlesnakes (*Crotalus viridis*) using desert tortoise burrow. I have observed use of desert tortoise burrows by a badger (*Taxidea taxus*), a sidewinder (*Crotalus cerastes*), Mohave green rattlesnake (*Crotulus scutulatus*), and a family of gray foxes (*Urocyon cinereoargeteus*).

1.1.8 Bio-indicators

Turtles amplify environmental signals through bio-magnification, thus making them extremely sensitive bio-monitors (Gibbons, 1988; Gibbons and Greene, 2004). Turtles are effective, long-term bio-accumulators that can function as sentinels of the chemical makeup of a region. Heavy metals accumulate through the ingestion of contaminated food and Albers *et al.* (1986) suggested that turtles would be good pollution bio-indicators. Rie *et al.* (2000) are also using turtles, *Chrysemys picta*, as bio-indicators in their toxicological research of Cape Cod in North America.

1.2 Cultural Roles of Turtles

1.2.1 Turtles as Food

Rural people throughout the world have depended on turtles and their products for subsistence, medicine, jewellery, and more. Foremost among human use is their use as food. Turtles have been used for food for at least the last 20,000 years (Nicholls, 1977). Harrisson (1962a, 1962b, 1967) reported the discovery of bones belonging to the green sea turtle (*Chelonia mydas*) during his 1957 excavation in the Niah Caves of Sarawak, Malaysian Borneo. The most intense use of turtles for food occurs in the tropics; however turtles have been a part of the human diet in more temperate areas as well. In Central and South America, and the Caribbean Islands, turtles continue to be widely hunted and are highly valued as a food source (E.O. Moll and Legler, 1971; Alvarez del Toro *et al.*, 1979). In Africa, Pritchard (1979) reported that *Trionyx triunguis* and both species of *Cyclanorbis* were eaten by local peoples. Akani *et al.* (2001) found *Trionyx triunguis* for sale in bush-meat markets of Nigeria. In Australia some native turtles are consumed by the Aborigines, but it is not considered to be a significant problem. However, in Papua New Guinea, both *Carretochelys insculpta*

(Georges and Rose, 1993) and *Pelochelys bibroni* (Rhodin *et al.* 1993) are actively hunted and consumed. In North America, turtle consumption has occurred for hundreds of years and there are several published accounts documenting this activity. Carr (1952) listed 13 aquatic turtle species commonly used for food. Today the most widely exploited species for consumptions is *Chelydra serpentina* and *Apalone spinifera*. In Asia, turtle consumption ranges from India to China. In peninsular Malaysia, E.O. Moll (1976) and Sharma (1999) reported that indigenous hunter-gatherers, the Orang Asli, consumed soft-shell turtles and also some of the forest dwelling species such as *Heosemys spinosa*. In India, Choudhury and Bhupathy (1993) reported that 22 of 26 species of turtles were used commercially or for subsistence.

1.2.2 Turtle Farming and Ranching

Turtle farming and ranching has been used for years to obtain animals for food or pets. Ranching involves rearing turtles to marketable size then slaughtering them (Klemens, 2000). The eggs, hatchlings, or breeding stock are taken from the wild. Farming is similar to ranching but no eggs or turtles are taken from the wild (Klemens, 2000). It is a self contained operation of captive raised animals. In Asia, the species most commonly farmed is *Pelodiscus sinensis*. This soft-shell turtle is a sought after food item and several farms exist throughout south-east Asia and eastern China. In Costa Rica, Pritchard (1993) reported that a ranching program for *Trachemys scripta* was operating to provide hatchlings for the pet trade. In the United States, at least 150 turtle ranches reared *Trachemys scripta* for the pet trade until the sale of hatchlings less than 10 cm in length was banned. They also sold adults for food in the United States, but on a smaller scale (Warwick, 1986).

1.2.3 Turtles as Pets

People have been keeping turtles as pets for hundreds of years, but the interest and demand exploded after World War II in the United States, Europe, and Japan (HSUS, 1994). At least in the United States, surveys by the pet industry and veterinary associations estimated between 1.5 and 3.2% of the general public owns a pet turtle and that 35% of these people obtained their pets from the wild (HSUS, 1994). Exotic turtles are growing in popularity and thousands of turtles native to Africa, Asia, Europe, and Central and South America are imported, exported, and traded annually. In peninsular Malaysia, Jenkins, (1995) commonly saw *Cuora amboinensis* and *Amyda cartilaginea* in pet stores. However, it was not clear how many were sold for pets or for food because the pet stores sell turtles for both purposes. In Sarawak, I have seen the native *Cuora amboinensis* for sale, as well as the exotic *Pelodiscus sinensis*, *Carretochelys insculpta*, *Trachemys scripta*, and *Geochelone elegans*. Other species noted in Sarawak pet shops have been *Chelydra serpentina*, *Indotestudo elongata* and *Malacochersus tornieri* (Das, pers com., 2006).

1.2.4 Turtles as Medicine and other Products

Turtle products have been used for cooking basins and bowls, jewellery, stepping stones, tools, pottery, musical instruments and more. Worked bones of marine turtles have been recorded from the Arabian Peninsula, South America, Pacific Island, and south-east Asia (Frazier, 2003). These bones have been worked into squares and disks, and made into a variety of implements, as well as funerary offerings (Frazier, 2003). But one of the most intriguing uses of turtles is for traditional medicinal purposes, primarily in China. The carapace of soft-shell turtles is used in powders and jellies to treat problems of the kidney, spleen, and liver (Jenkins, 1995). The plastron of hard-shell species is used for treatment of heart, liver, and kidney problems. Medicinal uses of turtle shell are widespread in India (Choudhury and Bhupathy, 1993). In Nigeria, Butler and Shitu (1985) observed the Yoruba people using the head and intestines of (*Kinixys* sp.) to treat cholera and burns and to prevent the death of children from supernatural causes.

1.2.5 Turtles in Religious Beliefs and Symbolism

Turtles have featured in religious beliefs, symbolism, and folklore. In some aboriginal cultures turtle shells are used for ceremonies such as masks made from *Pelochelys bibroni* in

Papua New Guinea (Rhodin *et al.*, 1993). The interment of marine turtle remains with human burials has been found in various coastal cultures throughout the world, indicating these animals held a special religious significance (Frazier, 2003). In India, the Kamars and Santhals believe the turtle to be their ancestor and will not eat them (Das, 1991). In some parts of Asia, turtles are protected in Muslim and Hindu sanctuaries (van Dijk *et al.*, 2000b). One of the better known is the Muslim shrine of Hazrat Bayazid Bostami in Chittagong, Bangladesh, which is inhabited by *Aspideretes nigricans*. In Buddhism a person who finds and delivers a turtle to a turtle temple is believed to be entitled to good fortune and long life (E.O. Moll, 1976; van Dijk *et al.*, 2000b). Individuals of *Batagur baska*, *Orlitia borneensis*, *Callagur borneoensis*, and other species were seen at temples in Penang and Ipoh in Malaysia. *Cuora amboinensis, Notochelys platynota, Cyclemys dentata,* and *Trachemys scripta* were observed in a Buddhist temple pond in Simunjan, Sarawak (Jensen pers obs., 2004). At least these were being fed, which is not always the case.

Turtles also feature strongly in Chinese symbolism. The Chinese character for the tortoise is considered the chief of the shelled animals. There are markings of the constellations on its shell and it features a snake head and dragon neck (Ong, 1993). The tortoise is one of four spiritual animals and is a symbol of longevity, strength and endurance. Chinese temples often keep ponds of turtles and goldfish, the turtle or tortoise symbolizing longevity and the goldfish symbolizing wealth (Ong, 1993).

1.3 Threats, the Contemporary Turtle Trade

South-east Asia has a highly diverse freshwater turtle fauna due to a combination of factors, including geological history, major mountain massifs, as well as the largest archipelago systems in the world, large tracts of lowland forests, streams and rivers, high precipitation and its tropical location (Iverson, 1992; Lovich, 1994). The turtles of this region, as in most of Asia, are threatened. As mentioned earlier, they are being collected for food, pets, traditional medicine, eggs, juveniles, adults, and body parts, and as the human population has grown, so has the use of turtles (van Dijk *et al.*, 2000a; Turtle Conservation Fund, 2002). The collection and trade affects turtle populations negatively because much of the trade involves mature adult animals (van Dijk *et al.*, 2000a; van Dijk *et al.* 2000b). While tortoises and freshwater turtles have been subjected to human predation for centuries, recent changes in Asian economics, spawned when Chinese currency became convertible, and have opened direct access to foreign markets (Behler, 1997; van Dijk *et al.*, 2000b). A highly organized turtle trade system has replaced the modest subsistence hunting for family consumption and sale in local markets (Behler, 1997).

Most of the indigenous peoples of Borneo prize soft-shell turtle meat as a delicacy (Nyanti and Bali, 2003; Rahman *et al.*, 2003). When a turtle is found in a fishing net, it is rarely returned to the wild. If it is a soft-shell turtle it is eaten or sold illegally. If it is a hard-shell animal it is often kept as a pet (Jensen pers. obs., 2002-2005). This behaviour creates a great loss of reproductively active individuals from the population. It is uncertain as to how sustainable the freshwater turtle populations are in Sarawak, Malaysian Borneo.

1.4 Prior Conservation

All turtle species currently affected by this crisis are protected in Sarawak. Commercial trade of native reptiles in Sarawak has been banned since 1998 (Sarawak Government Gazette, 1998). Additionally, the Federal Government has empowered the States with certain autonomous powers including control over turtle and riverine fishing (Anon, 2002). Under the Wildlife Protection Ordinance, *Orlitia borneensis* and *Callagur borneoensis* are listed as "Totally Protected", and *Manouria emys*, *Amyda cartilaginea*, and *Dogania subplana* are listed as "Protected" (see Table 1.1 for a complete list of Sarawak and International protections regarding non-marine turtle species found in Sarawak).

Most of the freshwater turtles and tortoises found in Sarawak are listed by the World Conservation Union (IUCN) (www.iucnredlist.org, 2004). The IUCN is the world's largest conservation network, consisting scientific experts and policy makers from more than 62 countries and 800 non-governmental organizations. The IUCN keeps a record of those species most in need of conservation attention through their 'Red List'. Listed as critically endangered

Table 1.1: Non-marine turtles of Sarawak and their status in the Sarawak Wild Life Protection Ordnance, IUCN and CITES Appendices.

Scientific Name	Sarawak Wildlife Ordnance	IUCN	CITES
FAMILY: Trionychidae			
Amyda cartilaginea	Protected	Vulnerable	Appendix II
Dogania subplana	Protected	–	–
FAMILY: Bataguridae			
Callagur borneoensis	Totally Protected	Critically endangered	Appendix II
Cuora amboinensis	–	Vulnerable	Appendix II
Cyclemys dentata	–	Lower Risk	Appendix II
Heosemys spinosa	–	Endangered	Appendix II
Notochelys platynota	–	Vulnerable	Appendix II
Orlitia borneensis	Totally Protected	Endangered	Appendix II
Siebenrockiella crassicolis	–	–	Appendix II
FAMILY: Testudinidae			
Manouria emys	Protected	Endangered	–

is *Callagur borneoensis*. Listed as endangered are *Heosemys spinosa*, *Manouria emys* and *Orlitia borneensis*. Classified as vulnerable are *Amyda cartilaginea, Cuora amboinenesis* and *Notochelys platynota*. Classified as Lower Risk is *Cyclemys dentata.* Lastly, *Dogania subplana* and *Siebenrockiella crassicollis* have not been listed by the IUCN.

Malaysia is a party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), an international agreement between 169 countries. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. The species covered by CITES are listed in three Appendices, according to the degree of protection they need. All species of freshwater turtles found in Sarawak are listed under Appendix II in Malaysia of the CITES Treaty, with the exception of *Manouria emys* and *Dogania subplana* (www.cites.org, 2004). Additionally, if a species is listed by CITES but has not been listed for protection under the Sarawak Wild Life Protection Ordinance, they shall receive local law protection (Sarawak Government Gazette, 1998).

1.5 Prior Research of Freshwater Turtles and Tortoises in Sarawak, Malaysia

No ecological research projects have been attempted in Sarawak and little is known regarding even the relatively more abundant freshwater turtle species in Sarawak. Basic information such as diet, reproduction, and in some cases, current distribution, is speculated but unknown and often the available information is from non-Bornean populations. For successful conservation and management of this important resource, an understanding of the basic ecology and life history of these species need to be obtained (Asian Turtle Trade Working Group [ATTWG], 2000; Behler, 1997; Das, 1997, Mehrtens, 1970; Turtle Conservation Fund, 2002).

Some limited surveys and research have been conducted in Sarawak, if not all of Borneo, on freshwater turtles. The first accounts on the turtles of Sarawak were authored by Edward (see Bartlett, 1894, 1895a-c, 1896), a former Curator of the Sarawak Museum, who listed species and provided locality and distributional notes. Lyons (1969) published a key to the shell bones of recent turtles of Borneo, as an aid for palaeontologists. Kiew (1984) provided a summary of the status of turtles of Malaysia. Turtles have also featured in inventory-type work in Borneo (e.g., Das, 1995b; Lloyd *et al.,* 1968) and Lim and Das (1999) published a field guide to the turtle fauna of Borneo (and Peninsular Malaysia).

Lambert and Howes (1994) conducted a field study of the Asian brown tortoise, *Manouria emys* in Sabah, Malaysian Borneo. However, only one animal was radio-tagged and monitored. Høybe-Mortensen (2004) followed up with a six month study looking at the behaviour and habitat of *Manouria emys*, again in Sabah. In 2004, Das and Jensen began a biodiversity assessment of herpetofauna in Loagan Bunut National Park (LBNP) (Das and Jensen, In press), and at the same time the second author began a broad ecological study of turtles in the Park.

1.6 *Amyda cartilaginea*: A biological review

Amyda cartilaginea, as with all other soft-shell turtles, belongs to the family Trionychidae, a distinctive group of aquatic turtles. Turtles, belonging to this family have a nearly circular carapace covered with a leathery skin. In most of the other families of turtles, the carapace is covered with horny scutes. In trionychids, the bony shell is reduced and large areas are composed of cartilage. The carapace and plastron are connected by cartilaginous and connective tissue rather than a bony connection. This formation allows for considerable volume changes inside the shell, permitting the extension and retraction of the long neck and large head, allowing longer strokes of the legs to increase burrowing efficiency, and potentially increasing speed and range of striking at prey and predators (Pritchard, 1979; Pritchard, 2001; van Dijk, 1992).

The snout is long, resembling a tube or snorkel, allowing the turtle to breathe while remaining submerged underwater. Much of their time is spent submerged under tree roots or buried in sand or mud. Aerial respiration is supplemented by pharyngeal respiration. Pharyngeal is considered important and has been noted in several soft-shell turtle species; *Apalone spinifera* (Dunson, 1960), *Trionix triunguis* (Girgis, 1961), and *Apalone mutica* (Jackson *et al*., 1976). Their eyes are placed high on their head allowing for observation above water but keeping the body submerged. All members of this family are either carnivorous or opportunistic omnivores and possess strong, powerful jaws. Large individuals can be extremely irritable and must be handled with care.

Predator avoidance is efficient by the nearly exclusive aquatic lifestyle of the animals. If discovered by a potential predator, they swiftly swim away, then with incredible speed, turn around and swim back underneath the predator. By the time the pursuer has realized what's happened, the turtle has disappeared. If the soft-shell is cornered, it will bite with amazing speed with its powerful jaws (van Dijk, 1992).

The Asian soft-shell turtle (*Amyda cartilaginea*) is the most common species of the trionychids in the lowlands of tropical south-east Asia. It was originally described as *Testudo cartilaginea* by Boddaert (1770) and is now known from north-eastern India, Myanmar, Thailand, Laos, Vietnam, Cambodia, the Malay Peninsula and Archipelago.

Amyda cartilaginea inhabits a variety of freshwater types, ranging from clear, cool swift hillstreams at elevations of 400 meters to muddy rivers, lowland peat swamps, ponds, and irrigation canals (Lim and Das, 1999). Boulenger (1912) indicated this species can be found in estuaries. Activity of *Amyda cartilaginea* appears to be crepuscular, dawn and dusk. Much of the time is spent buried in the substrate in shallow areas, like most other soft-shell turtles.

Amyda cartilaginea is a large growing species of turtle with a carapace length reaching 830 millimetres (mm) and weighing more than 35 kilograms (kg). The shape is rounded or oval, the widest part towards the posterior. They have distinct tubercles along the anterior carapace edge that extend one or two rows. Juveniles have many small tubercles and bony ridges. The snout is straight rather than down turned (as in the other locally occurring soft-shell, *Dogania subplana*). The carapace dorsum is brownish to black, the venter ranges from black to cream. The head and neck is spotted yellow. The patterns on the dorsal side vary. Males have relatively longer tails than females, other sexually dimorphic information is not known. Sex ratio in natural populations is not known. The growth rate is relatively fast; females can reach full maturity within 20 months (Lim and Das, 1999).

It is unknown exactly when the nesting season is in Sarawak, but is presumably similar to other areas. In central Thailand, nesting occurs during the end of the dry season and most of the hot season (February - July) (Nutaphand, 1979; van Dijk, 1992). The peak of the nesting season occurs around April. In northern Sumatra, nesting occurs from November to January (Heckman, in van de Bunt, 1990). Nesting takes place in late afternoon or early evening in damp areas just above high water level. Egg clutches average 5-30 eggs and three to four clutches may be laid per year. Eggs are spherical, brittle hard-shell, measuring 21-40 mm. The incubation period is between 61-140 days. Hatchlings measure 37-49 mm in carapace length (Lim and Das, 1999).

1.7 Research Constraints and Assumptions

i. Budgeting requirement very high for field research on freshwater turtles.

   Frequent field trips, a larger study area, and additional equipment was not possible with available funding.

ii. Very little funding available from grants makers for natural history and field ecology research. Little funding is available for research towards an MSc. More funding available for research towards a PhD as is post-doctoral research funding, or if I was associated with a non-government organization working on a conservation project.

iii. Choice of study sites was based on available funding.

iv. Limited number of specimens might be due to low populations, cryptic behaviour of species, or the standardized collecting methods used in North and South America, Europe, and Australia do not work locally.

v. Limited number of specimens collected, including sex and size classes, restricted the types of research questions and statistical analyses.

1.8 Thesis Objectives

Ecology of soft-shell turtles (Family: Trionychidae) may play important roles in the dynamics of freshwater ecosystems (e.g. Pritchard, 1979), but, apart from a few species from temperate regions of North America, their ecology has attracted little attention by scientists. This thesis presents information on the natural history of *Amyda cartilaginea* with notes on other freshwater turtle species found in Sarawak. This project also investigates the cultural use and level of exploitation at in Sarawak. As very little is known about the life history of most freshwater turtle species found in Borneo, the information obtained is new to science and adds to the limited knowledge of these species in the wild.

1.9 Specific Objectives

There are four research objectives stated as the following:

i. What are the species of turtles that inhabit the study areas? An assessment of the freshwater turtle biodiversity attributes of field biology, and other observations including reproductive condition and parasites.

ii. Are there similarities or differences in appearance of the turtles found in Sarawak with those from other areas? An assessment of morphometrics among the turtles of Borneo.

iii. What are the diets of the turtles under study? Includes quantitative collection and analysis of stomach contents and any observed or inferred feeding behaviour.

iv. How intense is exploitation and can the populations sustain such levels of exploitation? Is exploitation subsistence hunting or is trade, local, regional, or international also involved?

1.10 Thesis Organization

This thesis is divided into seven chapters as the following:

i. Chapter One has already provided a summary on the roles or turtles in the ecosystem, their cultural uses, and a biological review of *Amyda cartilaginea*.

ii. Chapter Two comprises two main sections, the first providing descriptions of the study areas including location, hydrology, climate, water quality, and vegetation. The second section details the general methods implemented during the field work.

iii. Chapter Three addresses aspects of biodiversity, field biology, and other observations such as reproduction and parasites.

iv. Chapter Four details morphometrics of some freshwater turtles and the colour patterns of *Amyda cartilaginea.*

v. Chapter Five addresses the diet of *Amyda cartilaginea* with dietary notes on other species.

vi. Chapter Six highlights notes of cultural and commercial use of turtles in Sarawak.

vii. The conclusion of the thesis, Chapter Seven, summarises the main findings of this study and makes recommendations for future research and management of freshwater turtles in Sarawak.

CHAPTER 2

STUDY AREA AND GENERAL METHODS

2.1 Study Areas

The primary study area was Loagan Bunut National Park (LBNP) (Figure 2.1). Field work was concentrated at LBNP but two visits were made to Balai Ringin, a fishing village located within a peat swamp to augment data collected at LBNP. Both sites are located within Bornean peat swamp forest (see photos on page 113 for view of peat swamp habitat). Information collected pertaining to cultural use and trafficking of turtles was done opportunistically throughout Sarawak and on one visit to Sabah.

2.1.1 The LBNP Study Area

2.1.1.1 Location

The LBNP study area is located between the Tinjar and Teru rivers in the upper reaches of the Baram River basin in northern Sarawak at 3°44' – 3° North and 114°09' – 114°17' East. This park was gazetted in 1990 primarily to protect the huge inland lake, the peat swamp forest, and the associated flora and fauna. It covers an area of 10,736 hectares (ha) (see Figure 2.1 for map of LBNP and its forest types).

2.1.1.2 Hydrology

The lake at LBNP is the only freshwater floodplain lake in Sarawak (Sayer, 1991), encompassing 650 ha. when at its maximum level. The lake is completely dry during prolonged drought. Annually, the lake dries up between three and six times and mostly these occur in February, May and June (Lau *et al.*, In press). The lake is fed constantly by the Bunan River and occasionally through the back flow from the Teru River through the Bunut River, which is also its main outlet. Depending on the rainfall distribution, the lake is also fed by discharge of water from the surrounding peat swamp forest.

2.1.1.3 Climate and Water Quality

The area experiences two predominant monsoon periods, i.e. the north-east monsoon which prevails from November to March and the south-west monsoon which occurs from June to September (see Box 2.1). The north-east monsoon brings the majority of precipitation to Sarawak, while this part of Borneo experiences a dry season during the south-west monsoon (Malaysian Meteorological Department, 2006). Other periods (April, May, October) are considered non-monsoon times. However, these are generalities and heavy rainstorms can be experienced during the south-west monsoon.

Box 2.1: Monsoon season times

North-east Monsoon (wet season) = November, December, January, February, March

South-west Monsoon (dry season) = June, July, August, September

Non-monsoon = April, May, October

No meteorological data have been gathered specifically for LBNP. The closest hydro-meteorological monitoring station is situated downstream of the Teru-Tinjar confluence. The average rainfall is around 3,000 mm/year (UNDP-GEF, 2003). A water quality study of LBNP and its tributaries began in 2004 (Lau *et al.*, In press). Out of 15 sampling stations, nine are within the lake. I here describe the range of water quality parameters from the nine stations averaged over a 3 month sampling period (Lau *et al.*, In press). Water depth ranged from 0.8−1.5 meters, water temperature range was 26.84−30.25°C, dissolved oxygen range was 0.31−4.27 mg/L, pH range was 5.37−6.36, turbidity was recorded at total suspended solids >1000. Measurements of turbidity using a Secchi dish yielded a range of 19cm−50cm.

2.1.1.4 Vegetation

Along the lake bank, several riparian species are dominant. Particularly *Ixora havilandii*, which grows densely closer to the Park Headquarters. There are several species of stunted

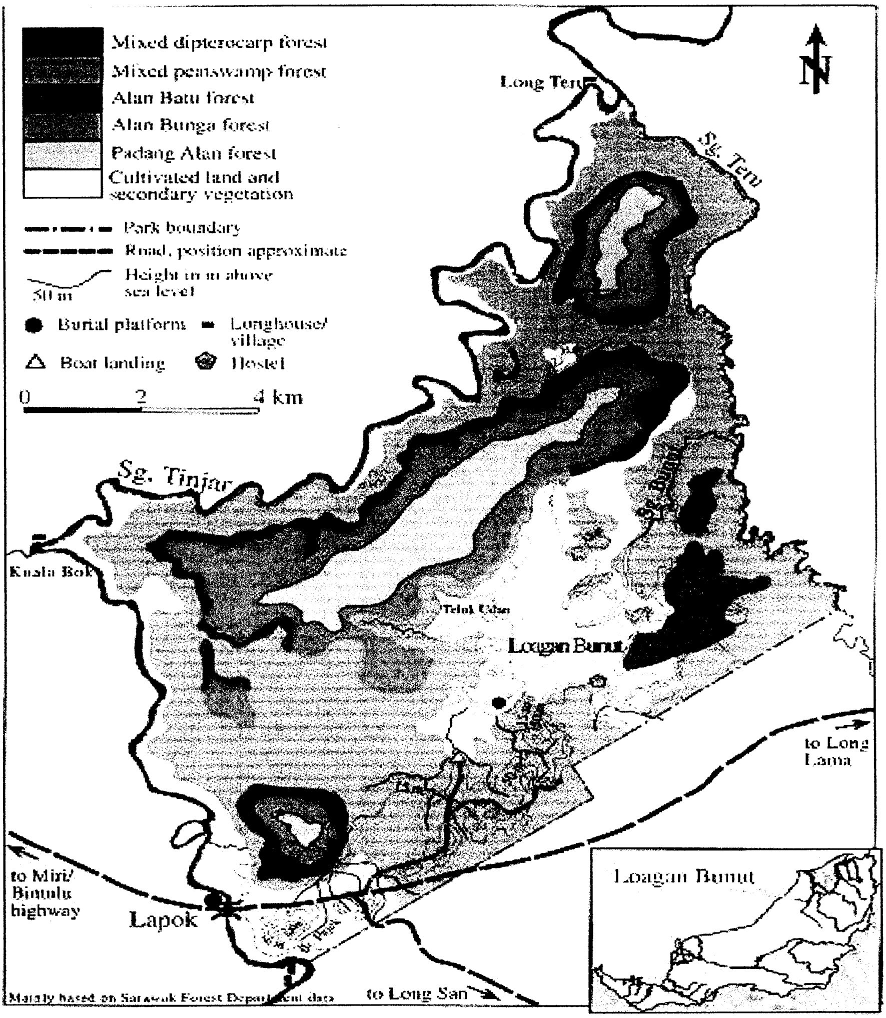

Figure 2.1: Location map of the Loagan Bunut National Park and surrounding forest types. (Source: Hazebroek and Morshidi, 2000)

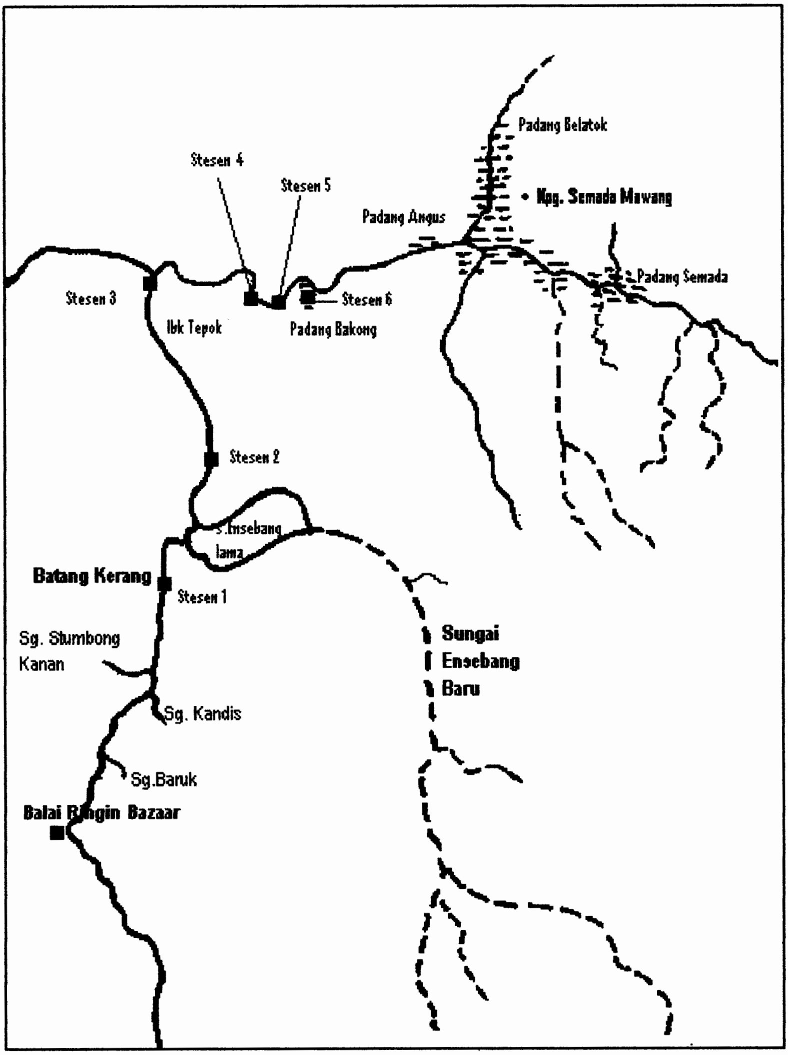

Figure 2.2: Location of study area at Balai Ringin.

treelets or shrubs of *Eugenia* species in scattered distribution. The common species growing along the river banks are *Artocarpus glaucus*, *Vatica mangachapoi*, *Sapium indica*, *Ilex cymosa* and *Eugenia* sp. The common peat swamp fern *Stenochaena palustris* is seen strangling up trees and shrubs in the open areas (Tawan *et al.*, 2004).

The bays or inlets are surrounded by mixed swamp forest which is dominated by *Dactylocladus stenostachys*, *Dryobalanops rappa*, *Dyera polyphylla*, *Shorea albida* and other common swamp species (Tawan *et al.*, 2004).

2.1.2 The Balai Ringin Study Area

2.1.2.1 Location

Balai Ringin also known as Balai Ringin Bazaar is a small fishing village on the banks of the Kerang River at 01° 03' 000" North and 110 45' 000" East. It is approximately 120 km south-east of Kuching in western Sarawak. Balai Ringin supplies the main source of freshwater fishes for the cities of Kuching and Serian (Dennis *et al.*, 2003) (see Figure 2.2 for map of Balai Ringin).

2.1.2.2 Hydrology

No published hydrology information on Balai Ringin could be located. The main river, Batang Kerang, is fed by several small streams and the surrounding peat swamp forest also discharges water into the river system. At times of heavy rainfall, the entire forest is flooded. During the south-west monsoon, most of the streams are dry.

2.1.2.3 Climate and Water Quality

The same monsoon seasons are present as in LBNP. No meteorological data have been gathered specifically for the Balai Ringin study site. The closest known hydro-meteorological monitoring station is situated in Kuching. During my surveys, I took basic water quality information from the base camp located approximately 7 km downstream from Balai Ringin. The water depth ranges from 1.5 – >3 m in the river's main channel. Water temperature ranges 25.6–26.6°C, dissolved oxygen ranges from 2.73–3.37, pH ranges from 5.8–6.4, turbidity ranges from 29cm–39cm. A Eutech Instruments Cyberscan Waterproof Series (DO300 Series) dissolved oxygen meter was used to obtain dissolved oxygen. A Cyberscan 100 (model RS232) was used to obtain pH and temperature. A Secchi dish was used to obtain turbidity. Water depth was estimated by shoving a long piece of bamboo into the main channel until it stopped, then measuring the length of bamboo that became submerged.

2.1.2.4 Vegetation

No published accounts exist regarding the vegetation lining the banks of the Kerang River. In fact, few publications exist regarding the Balai Ringin area's vegetation. The exception is some experimental work in the Balai Ringin Protected Area, a forest reserve approximately 10 km from the study site, in logged hill forest rather than peat swamp forest.

2.2 General Methods

2.2.1 Research Time Frame

A total of seven field trips were made, five to LBNP and two to Balai Ringin. The trips to LBNP averaged two weeks in length and those to Balai Ringin lasted for approximately one week each. Number of trips and length were determined by budgetary constraints. A total of 51 field days were spent in LBNP and 16 field days occurred at Balai Ringin.

2.2.2 Capture Techniques for Turtles

A variety of techniques were attempted to see which was the most effective for capturing *Amyda cartilaginea*. One method I employed was the use of hoop traps according to methods described by Frazer *et al*. (1990), Legler (1960), and Vogt (1980). The hoop traps were set in small streams flowing into the lake at LBNP. Borrowed fishing nets were attached to the hoop traps to prevent any moving aquatic animal from bypassing this trapping device. Native hoop traps called bubu were also used but found to be useless. Another local fishing device called a selembau, incidentally caught one turtle in Balai Ringin and several aquatic snakes. The most effective method of capturing soft-shell turtles was to either allow the native guides to set baited hand lines or when the water level was low, to feel in the mud for the turtles, better known as muddling (see Appendix I page 113, for and example of muddling technique).

At LBNP, five sampling trips were made, totalling 51 field days. Overall, two hoop nets attached to seine nets and 60 baited hand lines were set over 33 evenings, totalling 2,046 tap nights. At Balai Ringin, two sampling trips were made, totalling 16 field days. On the whole, 45 baited hand lines were set over 16 evenings, totalling 720 trap nights.

Manual capture was an effective yet labour intensive method of collecting turtles in the surrounding forests and streams. However, it was only effective during very low water periods. The technique consisted of wading through streams and probing areas of sand or mud and among roots with a stick, hands or feet. Other turtles were found, by either myself or LBNP personnel, as they crossed trails or other open areas. I conducted searches for turtles in forested areas by walking a 100 m stretch of forest that was 2 m wide. I looked under leaves, tree roots, and debris for any sign of turtles or tortoises.

Other standardized methods considered but rejected were pitfall traps (Lagler, 1943) and the use of trained dogs (Schwartz *et al.*, 1984). In addition, baited cage traps (rat traps, Tomahawk traps and others), and fyke traps (Vogt, 1980) basking traps and snorkelling have been used to catch aquatic turtles. There are various advantages and disadvantages associated with each of these methods. Pitfall traps are problematic in peat swamp as water level may rise or fall more than 1 m in less than 24 hours. Turtles could drown. Use of trained dogs is problematic in Sarawak due to the import and quarantine laws combined with the length of time needed to train a good tracking dog, approximately two years (Jensen, pers. experience). Baited cage traps and fyke traps were not used because of funding issues. Additionally, baited cage traps have been used in Brunei Darussalam with little success (Charles pers. com., 2005). Basking traps are probably less effective in Borneo as the turtles rarely bask. Visibility at LBNP and Balai Ringin waters is not conducive for snorkelling. Variations on the drift-fence premise might work well but the fences would sooner or later fall victim to trampling by large mammals.

With the exception of the Balai Ringin trips, traps were set for a minimum of seven days, but generally longer. The water level can rise or fall dramatically and traps were checked several times per day. If the habitat condition changed noticeably, the traps were re-located to a nearby site with at least one meter water depth. Localities of captured turtles were recorded using a Garmin III GPS, unless tree canopy prevented connection with satellites.

2.2.3 Identification of Turtles and Handling of Turtles

Turtles were identified by using guide books or monographic treatments by Lim and Das (1999), Iskandar (2000), verification with Das (pers. com., 2003-2005).

Upon capture, turtles were immediately transported to base camp where each animals was weighed, measured, and their stomachs flushed using methods developed by Legler (1977) but following the modifications developed by Fields *et al.* (2000). Tissue was collected and stored at UNIMAS, for future genetic work. External measurements such as curved and straight carapace length, carapace or shell height and width were made to the nearest mm, and turtles weight recorded to the nearest 0.1 kg. Measurements were made with vernier calipers and weighed recorded using a Chatillon scale.

All turtles were examined for presence of ectoparasites. Soft-shell turtles were given a quick 5% salt solution bath to release any unseen leeches. Turtles were kept for in plastic basins typically for a 24 hour period or until they provided a faecal sample.

Turtles were extensively photographed as well as interesting environmental features. Photographs were documented either on slide or print Kodak film (50, 100, and 400 ASA) using a Micro-Nikkor (60 mm) macro lens and a Sigma (28 – 200 mm) zoom lens.

Soft-shell turtles were tagged following the method documented by Dreslik (1997). Hard-shell turtles were tagged by attaching their catalogue number with clear epoxy to a rear marginal scute. As this was not a long term study, this identification method would last as long as the study and no animals would have their shells notched.

Sex was visually determined, if possible, and recorded for each turtle captured. Sexual dimorphism differs for the various Bornean freshwater turtle species. For *Amyda* *cartilaginea*, males have a relatively longer tail that extends to the edge or past the carapace (see Appendix I, page 114, for views of male and female *Amyda cartilaginea*). This difference in tail length between the sexes is apparently similar for *Dogania subplana*. In all but one of the Bataguridae species, *Cuora amboinensis*, *Heosemys spinosa*, *Notochelys platynota*, and *Siebenrockiella crassicollis* males have a concave plastron, and in *Notochelys platynota* and *Siebenrockiella crassicollis* males also have longer, thicker tails. The other Bataguridae species found during this study, *Cyclemys dentata*, does not exhibit any known sexual dimorphism aside from females outgrowing male turtles. Juveniles of all species were not separated by sex because these species are not known to be sexually dimorphic prior to sexual maturity.

If transport was available, turtles were taken to X-ray clinics for radiographs. This was done to determine the reproductive condition of any females. Following Gibbons and Greene (1979), turtles were x-rayed using non-screened cardboard cassettes at 200mA and 70 KV peak for 0.7 sec. at a distance of 1 m. This is equivalent to an adult human shoulder x-ray procedure. The technique is 100% accurate for determining clutch sizes and is no more disruptive to the animal than other facets of a population study. The major advantage of the technique over dissection is that individuals need not be killed. Methods specific to subjects discussed in the subsequent chapters are explained in those chapters.

CHAPTER 3

ASPECTS OF FIELD BIOLOGY

3.1 Introduction

The objective of this chapter is to present an overview of general biodiversity of turtles from the study sites and other areas, information on capture rates, environmental factors that potentially affect capture rates, and natural history notes on other observations from the field.

3.2 Methods

Capture methods and standard measurements of turtles are described in Chapter Two. Preserved and mounted specimens from museums as well as animals from longhouses, shall be discussed in Chapter Four.

Lunar phase was divided into four categories; new moon, first quarter, full moon, and last quarter. The moon is defined as the new moon when the un-illuminated side is facing the Earth. At this time, it is not visible, except during a solar eclipse. First quarter moon is the phase when one half of it appears to be illuminated by direct sunlight. During this phase, the fraction of the moon's disk that is illuminated is increasing. Full moon is the phase when it appears completely illuminated by direct sunlight. Last quarter moon is the phase when one half of it appears to be illuminated by direct sunlight. During this phase, the fraction of the moon's disk that is illuminated is decreasing. Moon phases were obtained from the U.S. Navy Astronomical Applications Department website (U.S. Navy, 2003: http://aa.usno.navy.mil/faq/docs/moon_phases.html) and defined in Box 3.1. The hard-shell species were pooled together due to their presumed similar behaviour, capture method, and habitat use.

Lunar phase was recorded at the time of capture to test for possible differences in activity level during the different phases of the lunar cycle. Turtles that were captured while physically active were used in this analysis. This includes any animals that were caught with baited lines or other traps as they must swim or walk to the traps to be caught. Three *Amyda* *cartilaginea* were found by muddling (= feeling in the mud), and one *Cyclemys dentata* was also found buried near the trunk of a tree. Obviously these animals were inactive and were not used or considered in the analysis.

Box 3.1: Definitions of Moon Phases.

New Moon = The Moon's non-illuminated side is facing the Earth. The Moon is not visible (except during a solar eclipse).

First Quarter = One-half of the Moon appears to be illuminated by direct sunlight. The fraction of the Moon's disk that is illuminated is increasing.

Full Moon = The Moon's illuminated side is facing the Earth. The Moon appears to be completely illuminated by direct sunlight.

Last Quarter = One-half of the Moon appears to be illuminated by direct sunlight. The fraction of the Moon's disk that is illuminated is decreasing.

To investigate if weather effected capture success, the weather condition at time of collection was divided into three categories as clear, overcast, and raining. Overcast is defined as times when the sky was completely cloudy and grey, clear weather could have some white cumulus clouds but blue sky was visible (Box 3.2).

Box 3.2: Definitions of Weather Phases

1. Overcast = when the sky was completely cloudy and grey.
2. Clear = includes white cumulus clouds and/ or blue sky.
3. Rain = any precipitation event

In this exercise only wild caught animals that were physically active (= moving) at the time of capture were used. It was apparent that the four animals - three *Amyda cartilaginea* and one

Cyclemys dentata - that were found buried could have been potentially located during any weather condition.

Seasonality was divided into the north-east monsoon (wet season), south-west monsoon (dry season), and the non-monsoon times. These seasons are described in greater detail in Chapter Two. During the north-east monsoon, 22 days were spent searching for turtles. During the south-west monsoon, 15 days were spent searching for turtles. In the non-monsoon times, 30 days were spent searching for turtles.

3.3 Results

3.3.1 Species Richness

A total of 34 individual turtles from two families and four species were found from the study sites and two other localities. For a breakdown on this information, see Table 3.1. Although turtles were marked (described in Chapter Two) and released, no animals were caught a second time. See Appendix I pages 113 - 115, for some of the species captured during the course of this study.

3.3.1.1 LBNP

Over 51 field days and 2,046 trap nights, were spent searching for turtles and a total of five freshwater turtle species were recorded at LBNP. In all, 14 *Amyda cartilaginea* were captured during this study. Six males, six females and two juvenile turtles were examined. Six *Cyclemys dentata* were collected. One female, four juveniles, and one carcass. Three juvenile *Cuora amboinensis* were collected. One adult female *Cuora amboinensis* and one adult *Notochelys platynota* were provided by Park personnel from their longhouse, for examination. One juvenile *Heosemys spinosa* recorded was based on a photograph by a UNDP-GEF employee.

Table 3.1: Total number of individuals for each species caught during this project. Asterisk refers to the numbers in parenthesis as unsexed individuals

Family	Species	LBNP	Balai Ringin	Matang Wildlife Centre	Mulu Area	Total
Trionychidae	*Amyda cartilaginea*	**14**	**5**	**0**	**1**	**20**
	Adult males	6	0	0	1	7
	Adult females	6	4	0	0	10
	Juveniles	2	1	0	0	3
Bataguridae	*Cuora amboinensis*	**3**	**0**	**0**	**0**	**3**
	Adult males	0	0	0	0	0
	Adult females	0	0	0	0	0
	Juveniles	3	0	0	0	3
Bataguridae	*Cyclemys dentata*	**6(1)***	**1**	**0**	**0**	**6**
	Adult males	0	0	0	0	0
	Adult females	1	1	0	0	2
	Juveniles	4	0	0	0	4
Bataguridae	*Heosemys spinosa*	**1**	**1**	**3**	**0**	**5**
	Adult males	0	0	1	0	1
	Adult females	0	1	1	0	2
	Juveniles	0	0	1	0	1

3.3.1.2 Balai Ringin

Over 16 field days and 720 trap nights, were spent searching for turtles and a total of three freshwater turtle species were seen at Balai Ringin. Only five *Amyda cartilaginea* were caught and examined at Balai Ringin. There were four females, and one juvenile. Additionally, one female *Cyclemys dentata* and one female *Heosemys spinosa* was collected.

3.3.1.3 Additional Species

An additional five turtle species were found incidentally. One *Dogania subplana* was found by Das on the banks of Sungei Bayur, at the base of Gunung Penrissen, in the Borneo Heights area. Two *Pelodiscus sinensis*, an introduced soft-shell turtle species, were incidentally collected in Kuching. One *Amyda cartilaginea* was caught while on at Mulu. Three *Heosemys spinosa* were found by various UNIMAS personnel in Matang Wildlife Centre, and examined.

3.3.2 Trapping Success of *Amyda cartilaginea*

3.3.2.1 LBNP

Each night, a minimum of 60 traps and baited, hand-lines were set, representing 60 trap nights. As mentioned in Chapter Two, sampling at LBNP was conducted in the form of 2,046 trap nights. Out of 14 *Amyda cartilaginea* captured at LBNP, only 11 were caught out of all these trap nights. The other three individuals were found by muddling. No two animals were caught on the same night. This represents a success of 11 trap nights out of 2,046 or 0.54% trapping success.

3.3.2.2 Balai Ringin

At Balai Ringin, all five turtles obtained for examination were caught via traps or baited handlines. At least 45 traps and hooks were set over 16 evening totalling 720 trap nights. Since all five animals were caught by trapping, this represent a success of 0.69% or five trap nights out of 720 trap nights.

It is interesting to note that the trapping success of Balai Ringin, a predominately Malay fishing village is slightly higher than at LBNP a protected area.

3.3.3 Capture Success

3.3.3.1 Effects of Lunar Phase on Capture Success

During the new moon phase, two adult *Amyda cartilaginea* (one male, one female), representing 11.80% of the soft-shell turtles, were captured. During the first quarter moon phase, five adult turtles (one male, four females) (29.4%), were captured. During the full moon phase, five turtles were captured (29.4%) (four females, one juvenile). During the last quarter phase, five turtles were captured (29.4%) (two males, one female, two juveniles) (Figure 3.1).

Other turtle species captured while physically active during this study were *Heosemys spinosa* (four individuals), *Cuora amboinensis* (three individuals), and *Cyclemys dentata* (six individuals). All but one *Cyclemys dentata* of these 13 turtles were found while they were physically active. During the new moon lunar phase, two juveniles (one *Cuora amboinensis*, one *Cyclemys dentata*), representing 16.7%, were captured. During the first quarter lunar phase, only one female *Heosemys spinosa* (8.3% of the total) was captured. During the full moon lunar phase, six hard-shell turtles were located and examined. This represents 50% of the total. They were one female and one juvenile *Heosemys spinosa*, one juvenile *Cuora amboinensis*, one female and two juvenile *Cyclemys dentata*. During the last quarter lunar phase, three hard-shell turtles were captured representing 25% of the total of these turtles found to be active during capture. These included one male *Heosemys spinosa*, one juvenile *Cuora amboinensis*, and one juvenile *Cyclemys dentata*. Results for both soft-shell and hard-shell turtles indicate that lunar phase may not have an influence on their activity patterns. However, only a larger sample size of at least one species combined with radio-tracking movement may provide a better answer to this question (Figure 3.2).

3.3.3.2 Effects of Precipitation on Capture Success

Three individuals of *Amyda cartilaginea* were collected during clear weather, three individuals were collected (one male, two juveniles), representing 18% of the total sample. During overcast weather, 53%, or nine individuals, of soft-shell turtles were captured, represented by three males and six females. During rain events six animals (29%) were captured, represented by four females and one juvenile (Figure 3.3).

For hard-shell turtles a total of 12 individuals (Figure 3.4) were located while they were walking in the forest floor or on forest trails. During rain events a total of four (34%) animals were found. These were one female, one male and one juvenile *Heosemys spinosa* and one female *Cyclemys dentata*. During overcast times, eight hard-shell turtles (66%) were found. These were one female *Heosemys spinosa*, three juvenile *Cuora amboinensis*, and four juvenile *Cyclemys dentata*.

3.3.3.3 Effects of Seasonality on Capture Success

As might be expected, the water levels of both the lake and its tributaries at LBNP and the riparian habitats in Balai Ringin are lower during the dry season and higher during the rainy season. In examining *Amyda cartilaginea*, I was interested in knowing if capture success was higher during a particular season. Therefore, the three turtles found buried in the mud were included in this data set for a total of 20 individuals captured. During the wet season, six female *Amyda cartilaginea* were captured representing 30% of the total (Figure 3.5). During the dry season seven soft-shell turtles (three males, two females, two juveniles), representing 35%, were captured. During the non-monsoon seasons, seven soft-shell turtles (four males, two females, one juvenile) were captured representing 35%.

When examining the effect of seasonality on the activity level of *Amyda cartilaginea*, then the total animals captured would be 17. Only three male *Amyda cartilaginea* were found buried in the mud and these individuals were all found in the dry season. Therefore the total animals captured during the dry season changed from seven to four individuals representing 24% of the total. Soft-shell turtles captured during the wet season remained at six individuals

(35%), and animals caught during the non-monsoon times remained at seven individuals representing 41% of the total (Figure 3.6)

Hard-shell turtles totalled 13 individuals (Figure 3.7). One female *Cyclemys dentata* was found buried in the hollowed trunk of a tree. Although she was inactive at the time of capture, she is included in this data set as I am looking at overall effects of capture and seasonality. During the wet season, six hard-shell turtles were located and examined. This represents 46% of the total hard-shell turtles captured. They were one female *Heosemys spinosa*, two juvenile *Cuora amboinensis*, and three juvenile *Cyclemys dentata*. Turtles found during the dry season were three, one juvenile *Heosemys spinosa*, one juvenile *Cuora amboinensis*, and one juvenile *Cyclemys dentata*. This represents 23% of the total hard-shell turtles captured. There were four hard-shell turtles captured during the non-monsoon times representing 31% of the total hard-shell turtles captured. These were one male and one female *Heosemys spinosa*, and two female *Cyclemys dentata*.

When examining the effect of seasonality on the physical activity of hard-shell turtles, then only one turtle is removed from the total. The female *Cyclemys dentata* found buried under the tree at Balai Ringin is taken out and the new total of turtles is 12. Totals for turtles caught during the dry season and wet season remain the same but the percentage of animals captured changes to 50% and 25%, respectively (Figure 3.8). The number of turtles captured during the non-monsoon times changes from four to three individuals and is 25% of total animals caught while physically active based on seasonality.

Certain aspects of the various seasons, as in the dry season, may create access into areas otherwise inaccessible due to the reduced water level. All four cases of locating and capturing turtles that were buried in mud or in a tree, took place during the dry season. During these times, turtles were found in localities that during the northeast monsoon were covered by at least 2 meters of water.

3.3.4 Reproductive Biology

Ten *Amyda cartilaginea* (five males, two females, three juveniles), seven *Cyclemys dentata* (two adult females, five juveniles), three *Heosemys spinosa* (one male, two females), and four *Cuora amboinensis* (one female, three juveniles) were radiographed. Only one *Cyclemys dentata* from Balai Ringin was found to be gravid with two eggs that had not yet developed shells. One egg measured 39 x 20 mm, while the second egg measured 48 x 28 mm. The average egg size for this species is 57 x 30–35 mm (Lim and Das, 1999; Ernst and Barbour 1989). One *Heosemys spinosa* from Matang was gravid with one egg measuring 70 x 34 mm. This species is known to have a clutch of one elongated egg and the female has a slightly hinged plastron that allows passage of this large egg. Little published information exists on the reproduction of *Heosemys spinosa*, but others have found their eggs to be 63–35 mm (Offermann, pers. com., 2005). Another turtle, a *Dogania subplana*, found dead and presumably killed and decapitated by an otter, was found to be gravid with 11 eggs ranging in diameter from 0.8–2.1 mm. The average clutch size of this species is 3–7 (Lim and Das, 1999), indicating that this turtle may have been carrying two clutches. These spherical eggs ranged in diameter size from 22–31 mm.

3.3.5 Parasites

Both ecto- and endoparasites were found on wild-caught turtles throughout the study. Leeches were found on *Amyda cartilaginea*, but only from Balai Ringin; they were attached to the skin in the folds of the limbs. They were identified by Fredric R. Govedich, Monash University, as most likely of the genus *Placobdelloides* from the (Family Glossiphoniidae). This is a genus commonly found on turtles in the region (Govedich, pers. com., 2005).

Heosemys spinosa, one male and one female, incidentally found at Matang had many ornate ticks on their bodies. They were confirmed to belong to the genus *Amblyomma*, identified by Reuben Sharma, Universiti Putra Malaysia. Ticks were attached to the skin in most of the folds on all four limbs and around the anal area.

Nematodes were found from both study sites LBNP and Balai Ringin. Four *Amyda cartilaginea* (one female and three males) were found to have nematodes. One *Cyclemys dentata* and one *Heosemys spinosa*, both from Balai Ringin, had nematodes. No nematode specialists of Asian turtles could be found to identify these animals.

3.3.6 Injuries and Scarring

Among the wild caught *Amyda cartilaginea,* four adult females had long scars along their carapace and plastrons. See Appendix I, page 114, for an example of a female with these scars. These were thin, long scarring, that could have been from getting in and out of vegetation or possibly obtained from males during copulation. One juvenile had four small, rounded, lesions across its carapace, less than 1 cm in diameter.

One *Cyclemys dentata* appeared to have been burned on one side of its carapace. The scutes had a melted appearance. This animal came from LBNP near the Park's border with a large oil palm plantation. I kept the animal for a few days and although shy, appeared to be healthy and readily ate some banana pieces prior to release. Fire scarring has been noted in other Asian turtle species such as *Siebenrockiella crassicollis* (Mitchell *et al.*, 2005,), and proposed that these turtles may spend some time buried in leaf litter, dead grass, possibly during times when local residents burn this vegetation.

3.4 Discussion

Capture rates for both *Amyda cartilaginea* and hard-shell turtles were extremely low, 0.54% and 0.69%, respectively, indicating the populations of these species may be at a crisis level. In common with much of south-east Asia and Borneo in particular, historical data are unavailable in order to assess past abundance and compare with current trends among the turtle species.

Turtle capture rates were tested against three environmental factors; lunar phase, weather, and seasons. In the analysis of effects of lunar phase, clearly a new moon has an effect on movement of *Amyda cartilaginea.* At a capture rate of 11.8% compared to 29.4%

with the other phases, the darkness of the sky may have an effect on the foraging capabilities of these animals. Other predatory species, common poorwills and tropical nightjars, both nocturnal birds, have been noted as having increased foraging activity with increased moonlight (Brigham and Barclay, 1992; Jetz *et al.*, 2003). Regarding hard-shell turtles, with a capture rate of 50% during the full moon phase, this indicates that some lunar illumination is necessary for foraging activity.

The effects of lunar phase on changes in animal behaviour are well known. Tigar and Osborne (1997) hypothesized that fewer predaceous arthropods were active during full moons than new moons, possibly because of the increased risk of vertebrate predation. Álvarez-Castañeda *et al.*, (2004), concluded that fewer rodent remains were present in owl (*Tyto alba*) pellets collected during full moons, indicating fewer rodent activity during this lunar phase. Church (1960a), found that ovulation of the common Asian toad (*Bufo melanostictus*) was correlated with the lunar cycle in Java. Church (1960b) also found this to be the case with the crab-eating or mangrove frog (*Fejervarya cancrivora*) in Java.

With 53% of the *Amyda cartilaginea* captured during overcast weather and 66% of hard-shell turtles captured during the same weather condition, thus it appears that all turtles favoured overcast weather for moving and foraging. Seasons did not have a dramatic affect on the capture rate of turtles. However, more information is necessary to determine any patterns of behaviour and significance of environmental factors. Tracking animals via radio or satellite would be necessary. Clearly, a large effort is required for studies that examine the behaviour in turtles, as well as other animals, especially when conducted across multiple seasons, lunar phases, weather conditions, and over a period of several years.

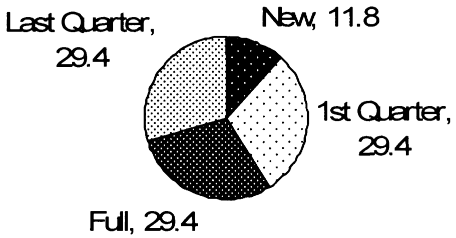

Figure 3.1: Percentage of *Amyda cartilaginea* found physically active during various lunar phases.

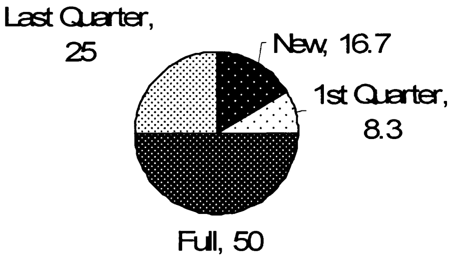

Figure 3.2: Percentage of hard-shell turtles found physically active during various lunar phases.

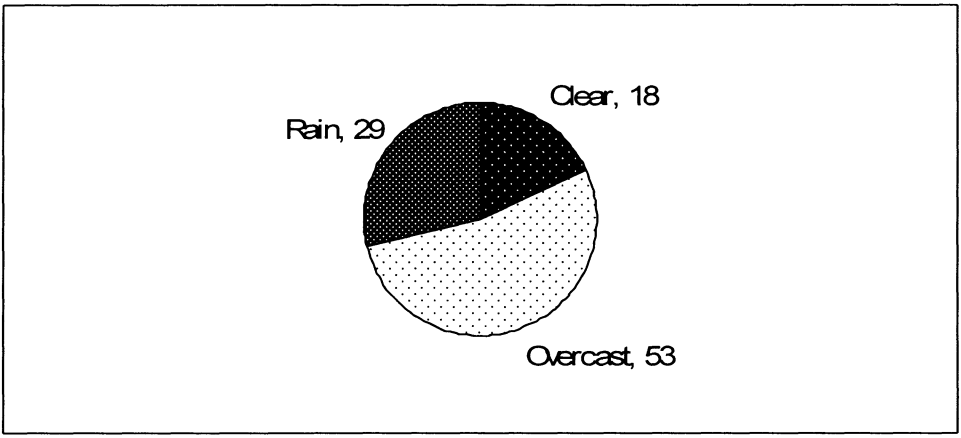

Figure 3.3: Percentages of *Amyda cartilaginea* found during different weather conditions.

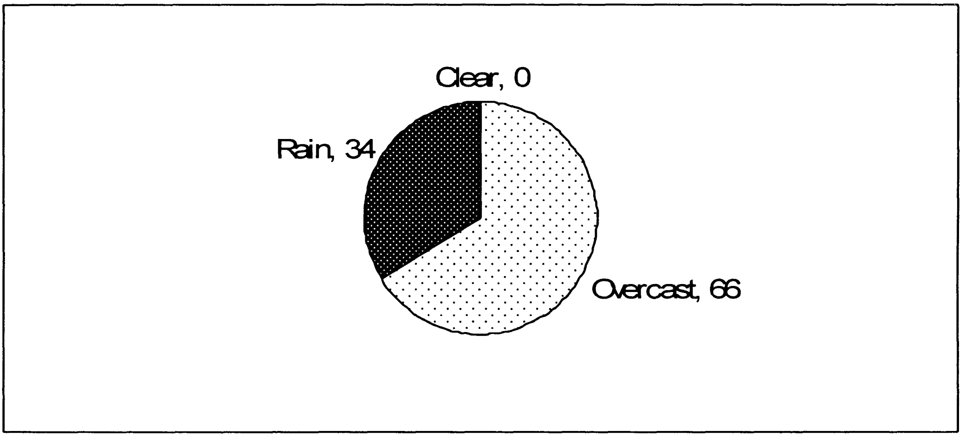

Figure 3.4: Percentages of hard-shell turtles found during different weather conditions.

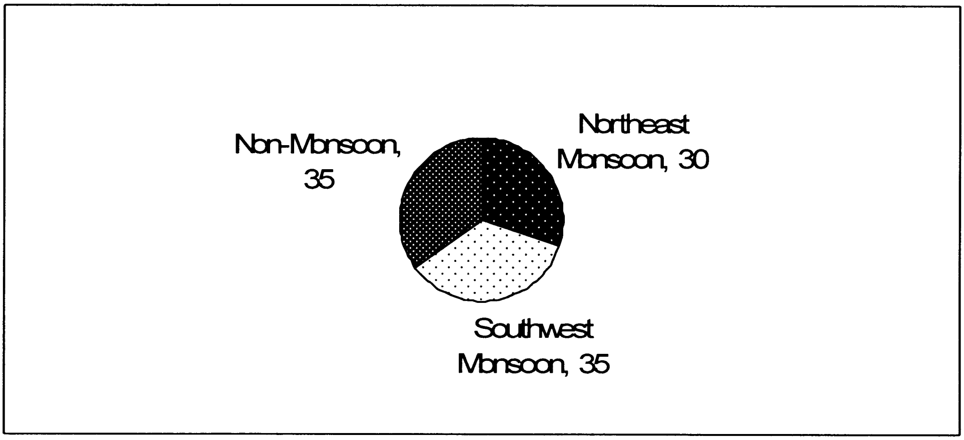

Figure 3.5: Percentages of all *Amyda cartilaginea* caught based on seasonality.

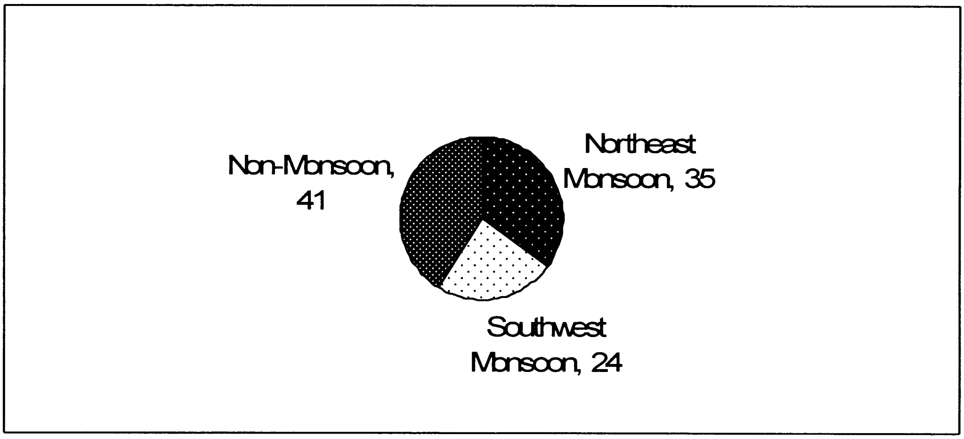

Figure 3.6: Percentages of *Amyda cartilaginea* found based on being physically active during different seasons.

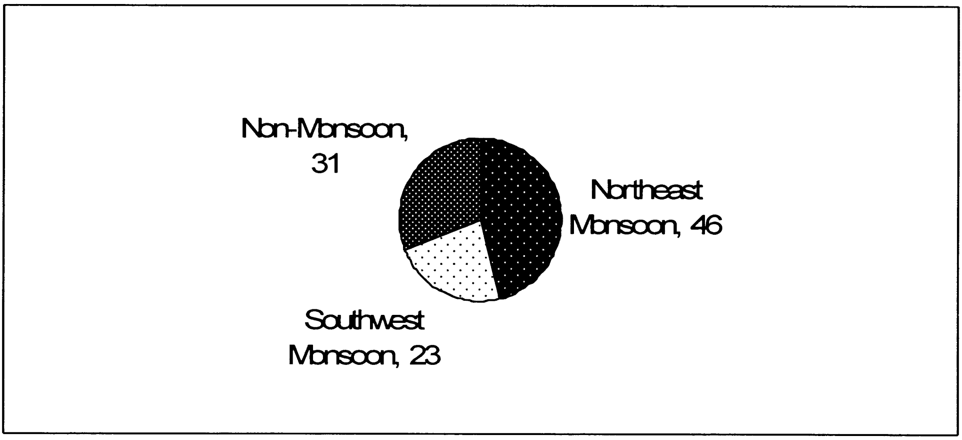

Figure 3.7: Percentages of all hard-shell turtles caught based on seasonality.

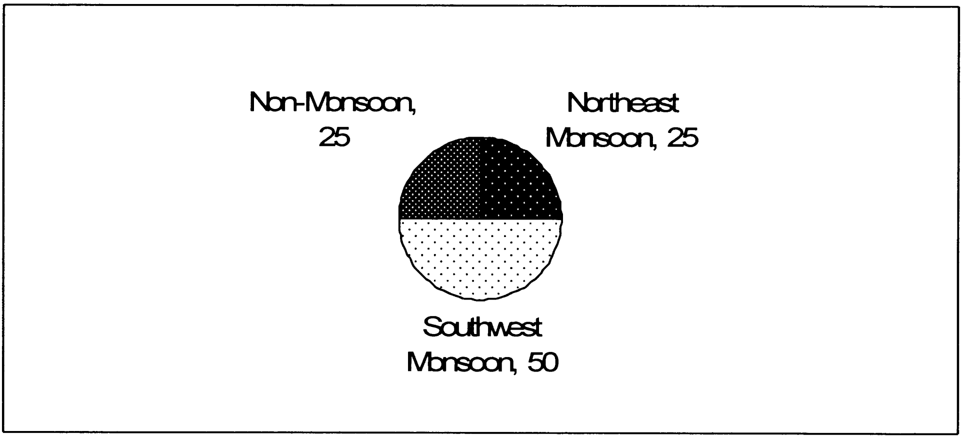

Figure 3.8: Percentages of hard-shell turtles found based on being physically active during different seasons.

CHAPTER 4

MORPHOMETRICS AND COLOUR PATTERNS

4.1 Introduction

Turtles have been the subject of numerous morphometric and growth studies. Morphometrics are commonly used to aid in identification of sex as well as age, growth, and other characteristics of turtles such as colour variation (Berry and Shine, 1980; Claude, 2003; Lovich *et al*., 1986; Lovich *et al*., 1990). The objective of this study was to record standard morphometrics and colour variation of *Amyda cartilaginea* found during the study, along with additional information gathered on the non-target species.

4.2 Methods

For this investigation, I used wild turtles located during the field component of this study, animals measured from longhouse visits throughout Sarawak, and information gathered from preserved specimens from the Sarawak Museum and the Raffles Museum of Biodiversity Research, Singapore. Only animals known from Borneo localities were used. Many of the museum specimens were juveniles, therefore sex could not be identified.

External measurements were taken of all live turtles located and a more detailed description of this process can be found in Chapter Two. Straight carapace length (SCL), straight carapace width (SCW), and carapace depth or shell height (SH) were measurements used in this chapter. In a few cases, all from captive turtles, SH was not recorded because the animals were kept in barrels, jars, or other containers where I was unable to manoeuvre the animals to obtain this measurement.

Sexual size dimorphism was tested on *Amyda cartilaginea* as this was the only species having a sample size with enough males and females measured. A Mann-Whitney U-test was employed on 10 adult male, and 19 adult female turtles to investigate if there was a significant difference ($p =$ or < 0.050) in the SCL, SCW, and SH between the sexes.

To examine allometric growth, I used a linear regression (ANOVA) to investigate if the width of the turtles changed in relation to length as they became larger and also if carapace depth became greater as the carapace lengthened during ontogeny. The first analysis compared the relationship of the ratio of SCW/SCL to SCL. The ratio of SCW/SCL was calculated to minimize skewing of the distribution points. In the second calculation, SCL was log transformed to satisfy assumptions of normality and analyzed to determine a relationship or correlation with SCW/SCL. Lastly, an arcsine of SCW/SCL was calculated and a linear regression tested with SCL. Another series of regression tests were run using SH as a variable in relation to SCL. These three separate regression analyses were used for turtle species where measurement data was collected for at least five individuals to maintain statistical validity. The program Minitab™ ver. 13 was used for analysis. In Minitab™, results for the correlation coefficient (r) are obtained by taking the square root of R^2 expressed as a proportion not as the percentage provided in the test results. Individual test results can be seen in Appendix I.

Amyda cartilaginea individuals were photographed to capture any colour patterns and variation. Only animals from Sarawak, live (n = 26) and preserved (n = 9), were used for this purpose. Colour variation from preserved specimens is not always reliable. Mounted specimens and those preserved in spirit lose all reliable signs of colouration; however, specimens preserved in spirit usually retain their pigmentation pattern although the original base colour may have changed (van Dijk, 1992). Therefore, I recorded the carapacial patterns for the museum specimens. Base colouration of carapace was assigned colour names following Smithe (1975). With the exception of one animal, base colouration of the plastron did not fit any descriptions within Smithe's (1975) colour guide.

4.3 Results

4.3.1.1 Sizes of Turtles: *Amyda cartilaginea*

Male *Amyda cartilaginea* averaged slightly larger in body size than females. Mean male SCL was 280.4 mm, while the mean female SCL was 257.0 mm. The largest turtle, a male, had a SCL of 664 mm, SCW of 524 mm and SH of 182 mm. This animal resides at the Sarawak

Museum and was found near the Museum, in the Sarawak River (Leh pers. com., 2005). The smallest male, was from Simunjan, with a SCL of 151 mm, SCW of 143 mm, and SH was not recorded. In fact, out of a total sample size, (n = 48), five animals did not have SH recorded. The smallest *Amyda cartilaginea* was a juvenile, from the Gunung Mulu area, with a SCL of 47 mm and SCW of 45 mm. Again the SH was not recorded. This animal was found in a longhouse, placed in a small-mouthed bottle. The turtle had attained such a size that I was unable to remove the animal to measure SH without breaking the bottle. The largest female turtle, from Balai Ringin, with a SCL of 526 mm and SCW of 370 mm, had a SH of 110.5 mm. The largest SH measurement came from a mounted female specimen (SH = 145) in the Sarawak Museum that was collected in Kuching. The smallest female, a preserved specimen from the Sarawak Museum and collected in Kuching, had a SCL of 125 mm, SCW of 112 mm, and SH of 37 mm. Other measurements and numerical data, including the means and standard deviations of each category of this species (male, female, all turtles) are presented in Table 4.1. Figure 4.1 shows the size classes of all Bornean *Amyda cartilaginea* measured with respect to SCL. Figures 4.2 and 4.3 show size classes of male and female individuals.

4.3.1.2 Other Turtle Species

Dogania subplana

Only three *Dogania subplana* were measured. Two, including a juvenile collected in Kuching and an adult male collected in Bario, came from the Sarawak Museum. The third animal, an adult female, came from the Bayur River, a stream at the base of Borneo Heights in Penrissen area. The measurements of the male were SCL = 151 mm, SCW = 109 mm, SH = 34 mm. The female's measurements were SCL = 185 mm, SCW = 122, SH = 46 mm. The juvenile's measurements were SCL = 52 mm, SCW = 41 mm, SH = 18 mm.

Table 4.1: Size measurements for *Amyda cartilaginea.* Range of measurements is followed by mean and standard deviation ($\bar{x} \pm$ SD) in parenthesis, followed by number of individuals measured.

	SCL	SCW	SH
Known adult male	151-664 (280.4+143.6) n=10	143-524 (241.9+106.4) n=10	51-182 (80.3+39.6) n = 9
Known adult female	125-526 (257.0+105.2) n=19	112-370.4 (215.2+71.0) n=19	37-145 (59.6+27.2) n = 17
All *Amyda cartilaginea*	47-664 (227.7+139.8) n=48	45-524 (192.3+106.6) n=48	16-182 (64.0+37.3) n = 43

Table 4.2: Size measurements for other turtle species. Range of measurements is followed by standard deviation (mean ± SD) in parenthesis, followed by the mean, followed by number of individuals measured. Species with a sample size of less than five individuals are dealt with in the text only.

Species	SCL	SCW	SH
Cuora amboinensis	54 – 187 (121.1 + 49.0) n = 20	45 – 145 (98.5+36.6) n = 20	24 – 84 (52.7+20.8) n = 19
Cyclemys dentata	50 – 292 (111.0 + 65.4) n = 36	44 – 223 (93.2 + 48.6) n = 36	19 – 114 (42.6 + 25.9) n = 34
Heosemys spinosa	72 – 217 (165.6 + 47.1) n = 8	76 – 168 (136.8 + 28.7) n = 8	33 – 88 (71.7 + 20.1) n = 7
Notochelys platynota	141 – 217 (176.8 + 27.6) n = 6	120 – 205 (147.7 + 31.1) n = 6	58 – 93 (66.6 + 14.9) n = 5

Callagur borneoensis

One mounted, adult male of this species was found at the Sarawak Museum. The SCL = 269 mm, SCW = 238 mm, and SH = 129 mm. This animal came from an unspecified Sarawak locality.

Cuora amboinensis

A total of 20 animals were measured, but only 19 had their SH recorded (Figure 4.4). This included the three wild caught juveniles from LBNP, and the one female from Long Teru near LBNP. The remaining animals came from either other longhouses or the Sarawak Museum. Three animals, two males and one female, were from the Mulu area. From the Bintulu area, four. adults were measured, three females and one male. From the Sarawak Museum seven

preserved animals were measured, nine juveniles and two adults of unknown sex. This breaks down to 10 juveniles, five females, three males, and two adults of unknown sex. The smallest turtle measured, a juvenile from the Sarawak Museum collection and collected from Kuching, had a SCL of 54 mm, SCW of 45 mm, and a SH of 24 mm. The largest turtle was also from the Sarawak Museum and collected from Kuching, with a SCL of 187 mm and SH of 84 mm. But it was not the widest turtle which was the female from Long Teru which had a SCW of 145 mm. Additional information concerning measurements of *Cuora amboinensis*, are in Table 4.2.

Cyclemys dentata

A total of 36 animals from Borneo localities were measured but only 34 animals had their SH recorded. One wild caught animal, a female, came from Balai Ringin. Five wild caught animals, one female and four juveniles came from LBNP, along with a carcass retrieved from a barbeque pit. From Mulu, two adults were measured. From Bintulu, five adults were measured. From the Sarawak Museum, 15 juveniles and two mounted adults were measured. All had been collected from the Kuching area. From the Raffles Museum of Biodiversity Research, six animals from Borneo localities were measured. One specimen came from

Brunei, one from Bako, one from Sungei Sadong, two from Pontianak, and one from the Sambas River in West Kalimantan. This species does not exhibit obvious sexual dimorphism, so I was unable to sex adult animals. The smallest specimen came from the Sarawak Museum with a SCL = 50 mm and SH = 19 mm. The animal with the smallest SCW of 44 mm also was a preserved animal at the Sarawak Museum. The largest animal with a SCL = 292 mm and SCW = 223 mm was the burnt carcass from LBNP. This animal may likely have had the largest SH measurement as well, but the plastron was removed. The animal with the largest measured SH of 114 mm, was from Mulu. For more information concerning measurements of *Cyclemys dentata*, see Table 4.2, and for information on size classes see Figure 4.5.

Heosemys spinosa

A total of eight animals were measured, but only seven of these animals had their SH recorded. Of these, four were wild-caught animals, one male from BR, and one female, one male, and one juvenile from Matang. From Bintulu, three animals, one juvenile and two females were measured. The remaining specimen was a mounted animal from the Sarawak Museum. The smallest animal with a SCL = 72 mm, SCW = 76 mm, and SH = 33 mm was the juvenile from Matang. The largest animal with a SCL = 217 mm and SCW = 168 mm was the mounted specimen from the Sarawak Museum. However, the animal with the greatest shell depth was the adult male from Matang.

Notochelys platynota

A total of six animals were measured, but only five had their SH recorded. From Mulu, three animals were measured. One adult from LBNP and one from Bintulu were also measured as well as one mounted specimen from the Sarawak Museum. The smallest animal with a SCL = 141 mm and SH = 58 mm was from Mulu, while the animal with the most narrow carapace width was from Bintulu. The largest animal with a SCL = 217 mm, SCW = 205, and SH = 93 mm, was the animal at the Sarawak Museum.

Orlitia borneensis

One adult with a SCL = 334 mm, SCW = 227 mm, and SH = 128 mm, was a mounted specimen at the Sarawak Museum. No wild or live captive animals of this species were seen.

Siebenrockiella crassicollis

One individual of this species was seen and measured during this project. The SCL = 179 mm, SCW = 142 mm, and SH 69 mm. It was from Long Terawan near Mulu and had been a pet for over ten years.

Manouria emys

Only one individual of this species was seen and measured. It was a mounted specimen at the Sarawak Museum and the SCL = 369 mm, SCW = 263, and SH = 143 mm.

4.3.2 Sexual Size Dimorphism in *Amyda cartilaginea*

The arithmetic mean for male and female SCL were 280.4 mm and 257.0 mm respectively, indicating that male *Amyda cartilaginea* have a longer SCL. However, when analyzed using a Mann-Whitney U-test, even though the medians for male and female SCL were 245 mm and 223 mm respectively, $P > 0.05$, indicating there is no significant difference between male and female SCL. The same test was performed for SCW and SH. Results were similar with $P > 0.05$, indicating no significant difference between SCW and SH between male and female turtles.

4.3.3 Allometry

4.3.3.1 *Amyda cartilaginea*

A total of six linear regressions (ANOVA) were run and all resulted within a 95% confidence interval. All six of these fitted line regression plots exhibited negative allometry and the $P < 0.05$ for all equations investigating the relationship between SCW and SCL, which infers that with growth, the proportion of the carapace width in relation to carapace length changes.

Similarly, as the carapace lengthens the deepening of the shell slows down. Regression analysis for SH and SCL resulted in $P < 0.05$. Table 5.3 contains the results for these tests as well as results of similar regression analysis for other species listed below. Figures 4.6 to 4.11 are the fitted line regression plots for these calculations.

4.3.3.2 Other species

Cuora amboinensis

This species also exhibited negative allometry in three tests of linear regression. The P values for linear regressions of SCW/SCL based on SCL; SCW/SCL based on the logarithm of SCL; and the arcsine of SCW/SCL based on the logarithm of SCL were all below 0.05 ($P < 0.05$) indicating that as the carapace lengthens, the growth of the carapace width is not the same. However, P values for similar linear regressions for SH/SCL based on SCL were different. Not one of the P values was less than 0.05 ($P > 0.05$) indicating that deepening of the carapace continues as the carapace lengthens. These turtles have a high domed carapace compared to shell length. Table 4.3 presents the results of the analysis and Figures 4.12 to 4.17 for the fitted line regression plots.

Cyclemys dentata

Results for this species were interesting. Although the three linear regressions testing the relation of widening of the carapace with lengthening of the carapace were within the 95% confidence interval, P values were less than 0.05 ($P < 0.05$), none of the regressions investigating relation of deepening of the carapace (SH) to lengthening of the carapace (SCL) had a sufficient P value to be significant. Table 4.3 summarises P values and other results and Figures 4.18 to 4.23 for the fitted line regression plots for these calculations.

There were two outlying points in the fitted line regression plots comparing SH and SCL. The first of these outliers, KJ-9, came from Mulu and had a carapace height of 114 mm, and carapace length of 154 mm. It's SH/SCL ratio was 0.74, but in fact, the average SH/SCL

Table 4.3: Results of the tests for allometry using ANOVA.

Parameters	*Amyda cartilaginea*	*Cuora amboinensis*	*Cyclemys dentata*	*Heosemys spinosa*	*Notochelys platynota*
SCW/SCL vs. SCL	0.924 - 0.000	0.914 - 0.000	1.010 - 0.001	1.213 - 0.002	0.749 + 0.000
r	0.81	0.59	0.60	0.97	0.16
P	0.000	0.006	0.000	0.000	0.756
SCW/SCL vs. log10 SCL	1.148 - 0.124	1.163 - 0.164	1.504 - 0.314	2.303 - 0.660	0.519 + 0.140
r	0.59	0.54	0.60	0.97	0.12
P	0.000	0.014	0.000	0.000	0.822
arcsine SCW/SCL vs. log10 SCL	1.617 - 0.245	1.546 - 0.276	2.313 - 0.598	5.125 - 1.844	0.079 + 0.410
r	0.58	0.50	0.62	0.93	0.18
P	0.013	0.025	0.000	0.002	0.729
SH/SCL vs. SCL	0.296 - 0.000	0.508 - 0.000	0.403 + 0.000	0.497 - 0.000	0.340 + 0.000
r	0.37	0.41	0.21	0.47	0.21
P	0.013	0.079	0.807	0.224	0.737
SH/SCL vs. log10 SCL	0.395 - 0.051	0.681 - 0.111	0.374 + 0.019	0.621 - 0.080	0.223 + 0.072
r	0.42	0.42	0.21	0.40	0.14
P	0.004	0.076	0.826	0.377	0.821
arcsine SH/SCL vs. SCL	0.403 - 0.053	0.725 - 0.123	0.419 + 0.005	0.656 - 0.088	0.215 + 0.081
r	0.42	0.42	0.00	0.39	0.11
P	0.004	0.074	0.959	0.380	0.816

ratio was 0.41. The second outlier, KJ-78, was a preserved specimen from the Sarawak Museum. Its SH was 44 mm, and SCL was 50 mm. It's SH/SCL ratio was 0.88.

Because the scaling of the regression plots examining correlation between SH/SCL to SCL had a different trajectory than the other turtles, i.e., weakly allometric, I removed the two outliers to examine if they were creating this difference. Results of these calculations can be seen in Table 4.4 and in Figures 4.24 to 4.26. The removal of the outliers improved the regression plots and the P values. However, only one regression looking at the relation of the arcsine of SH/SCL and the logarithm of SCL was statistically significant with P = 0.053. The interpretation being that as the turtle grows, the shell does not attain as great a depth as it does length.

Heosemys spinosa

Results for the linear regressions looking at the relationship of SCW and SCL all had P values < 0.050 indicating that as the turtle grows, it does not attain as great a width as it does length. Results for the regression looking at the relationship of SH and SCL were different. P values were greater than 0.050 for all three calculations. Refer to Table 4.3 for results of these regressions and Figures 4.27 to 4.32 for fitted line regression plots of these analyses. Due to the small sample size (n = 8, for SCW and SCL; n = 7, for SH and SCL), I investigated if there might be a correlation between these variables. I used a Pearson Correlation and the results for SCW and SCL were significant (P = 0.988) indicating a high correlation between the two variables at the 0.010 level. Similarly, results for SH and SCL (P=0.960) were significant at the 0.010 level.

Notochelys platynota

Not one of the six linear regressions for this species, either looking into the relationship between lengthening and widening of carapace or lengthening and deepening of carapace, resulted in P values less than 0.05 (P > 0.050). Of course the sample size was quite small (n = 6 for SCW and SCL; n = 5 for SH and SCL), so this may be a considerable factor to the results. A Pearson

Table 4.4: Results of linear regressions for *Cyclemys dentata* after removing outlying points.

Parameter	Results
SH/SCL vs. SCL	0.370050 + 0.0001666
r	0.28
P	0.099
SH/SCL vs. log10 SCL	0.289476 + 0.0499749
r	0.33
P	0.054
arcsine SH/SCL vs. SCL	0.291039 + 0.0546174
r	0.59
P	0.053

Correlation was used to see if there was any correlation between these variables. The results for SCW and SCL resulted in a significant correlation between these two variables (P = 0.874) at the 0.05 level. Results for the Pearson Correlation looking at SH and SCL also resulted in a significant correlation between these two variables (P = 0.889) at the 0.050 level. See Table 4.3 for results of these regressions and Figures 4.33 to 4.38 for fitted line regression plots of these analyses

4.3.4 Colour variation in *Amyda cartilaginea*

In all but one specimen, the ventral side, including the plastron, the underside of the legs and tail, and the ventral side of the posterior cartilaginous flap of the carapace were all off-white in colour. A female from LBNP (KJ-86) had an unusually brown plastron, corresponding with Cinnamon Drab #219C from Smithe's (1975) colour guide. Some animals had grey splotches (spots with undefined borders) on their plastrons (n = 14), while some had no markings at all (n = 12). The splotches varied from just a few near the margins, to being covered in these grey speckles.

The base colour of the head and carapace is usually brown, but varies in tone from a brownish black (Sepia #119) to a basic brown (Army Brown #219B). Only one animal did not have brown carapace colour. A juvenile from LBNP (KJ-33), had a carapace of a light grey (Glaucous #80). All animals had distinct tubercles along the anterior edge of their carapace.

All except three of the 26 live specimens photographed had a saddle shape of black spots on the forward area of the carapace. Those with saddles also had a medial, black streak near the posterior of the carapace and circles or blotches near the margins made of smaller black spots. These varied in number for each individual. One animal, KJ-18, from Simunjan, was so dark, almost black (Sepia #119), that no markings could be identified. The other two animals, KJ-7 from Mulu, and KJ-67, a preserved animal at the Sarawak Museum. both had black and grey spots all over their carapace and legs. These were also the largest animals measured during this study, KJ-67 had a SCL of 664 mm., and KJ-7 had a SCL of 601 mm.

These patterns could also be seen on the preserved specimens from the Sarawak Museum. All but one of these animals had the black saddle, black streak near the posterior of the carapace and the circles of blotches on the carapace. This animal a juvenile, KJ-67, was collected in Kuching and had no distinctive markings at all.

Yellow spotting also featuring prominently on many animals. All but two of the live animals had spots on their head, sometimes their throat as well, and in one case over the entire body. The animals with yellow spots all over was KJ-25 from Simunjan. Two animals did not have any yellow spotting at all. They were KJ-7 from Mulu, and KJ-31 from Balai Ringin. A total of 16 animals had the spotting on their head and throat, six had spotting on their head only, and two had spotting on the head, throat and front legs.

A few animals had either yellow or off white splotches on their throats. These ranged from circular with irregular borders to an off white band around the entire throat. One animal, KJ-23 from Balai Ringin had blackish irregular lines on its head.

4.4 Discussion

4.4.1 Sizes of turtles

Size classes of *Amyda cartilaginea* between 400 and 500 mm SCL, are few in both males and females indicating that possibly animals are not living long enough to attain the sizes and that the few animals greater than 500 mm SCL are very old individuals. *Cuora amboinensis* and *Cyclemys dentata* also have a missing size class. However, it is possible more animals from Borneo should be measured to determine a true range of sizes and determine if there indeed is a lack of recruitment into the largest size classes. More research is needed on this subject.

4.4.2 Sexual Size Dimorphism *Amyda cartilaginea*

Analysis of SCL, SCW, and SH for a difference between male and female turtles resulted in no significant difference between the sexes albeit the arithmetic means were different. This may be an artefact of sample size (males, n = 10; females, n = 19), or the possibility that trapping methods targeted smaller turtles among other circumstances as most turtle species favour either larger male or larger females.

Many reviews of sexual size dimorphism in turtles have shown that adult females are larger than adult males (Gibbons and Lovich, 1990; Lovich *et al.*, 1990; Ernst *et al.*, 1994). Instances of the reverse, males being larger than females, are unusual but not unreported. In fact, Pritchard (2001), summarized that large soft-shell turtle species of Asia, including *Amyda cartilaginea* have larger males than females. This is a trend not only found in Trionichidae, but in Testudinidae and Kinosternidae, termed "female size conservatism" (Pritchard and Trebbau, 1984). In the smaller species of these families, females are larger than males, in the larger species males are the larger ones. The rationale being that among these smaller species, those constrained by their environment to be small, females have to attain an adequate shell volume to contain a clutch of adequate size and number of eggs. In larger species, even moderate sized females may have adequate shell volume and enormous size may be disadvantageous during nesting excursions. Additionally, Berry and Shine (1980) hypothesized that smaller male size evolved to increase mobility and hence, the ability to locate females.

4.4.3 Allometry

Linear regression between SCW and SCL as well as SH and SCL for *Amyda cartilaginea* demonstrated that the relative growth of these two dimensions were negatively allometric indicating strong proportional changes with growth. In observations of juveniles and adults, juveniles appear almost circular while adults have lengthened into an oval carapace with length greater than width.

Cuora amboinensis have a high domed shell which may account for the results of linear regressions for SH and SCL.

As for *Cyclemys dentata*, the carapace outline of juveniles is circular and becomes progressively narrower, until in older adults the outline is oval in shape. In height, this species show great variation. Some animals are flattened in shape while others are high domed.

4.4.4 Colour variation of *Amyda cartilaginea*

Older descriptions of *Amyda cartilagina's* colour were vague at best. Boulenger (1912) stated that they were olive brown above, and de Rooij (1915), in reviewing illustrations by Boddaert (1770), mentioned that specimens have black sports or a black transverse band on the back. Lim and Das (1999) mentioned that occasionally animals have dark markings. Ernst and Barbour (1989) stated the species has numerous yellow-bordered black spots and yellowish dots in younger individuals, but they were reviewing animals from Indochina. Nuthaphand (1979), described animals that possess a carapace covered with yellow dots as well as the head and legs as *Amyda nakornsrithammarajensis*. However, Meylan (1987), stated that this pattern is a variation found in *Amyda cartilaginea*. I only found one animal exhibiting this variation in the yellow spotting.

In van Dijk's thesis (1992), museum specimens were examined and he specified that a very distinct version of black spots were seen on animals from Borneo. Auliya (2000) was the first to examine live specimens in the West Kalimantan state of Indonesian Borneo. Animals examined in West Kalimantan have similar colouration and patterns to those found in Sarawak. They both have the distinct saddle across the carapace along with some indistinct black markings close to the margins. Auliya (2000) also found that in extremely large animals, the saddle was lost. Two animals I examined that had a SCL greater than 600 mm, they too did not have these distinct black markings on their carapace. The systematic status of populations found in Sarawak and likely all of Borneo needs to be verified through phylogenetic analysis.

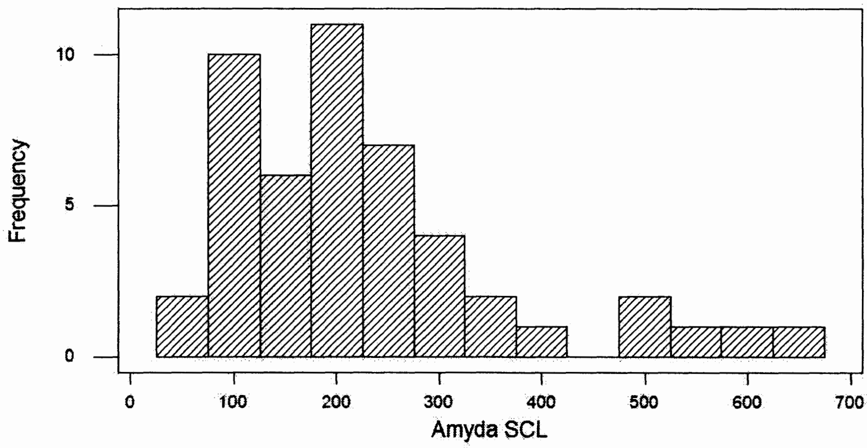

Figure 4.1: Size classes of all Bornean *Amyda cartilaginea* SCL measurements.

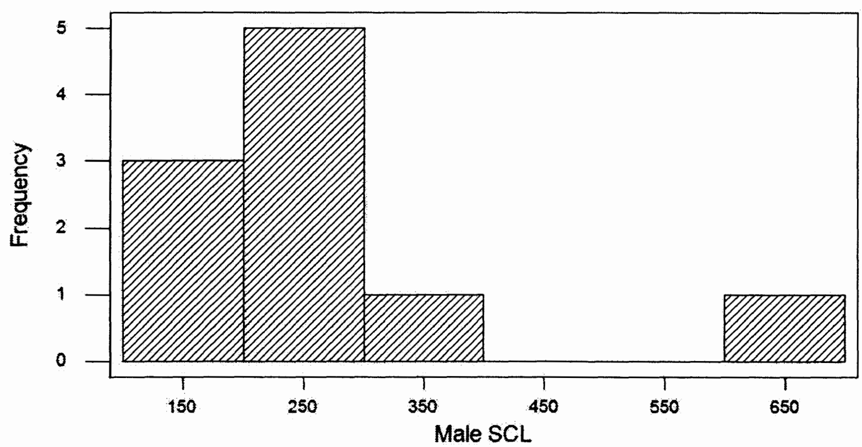

Figure 4.2: Size classes of Bornean *Amyda cartilaginea* males.

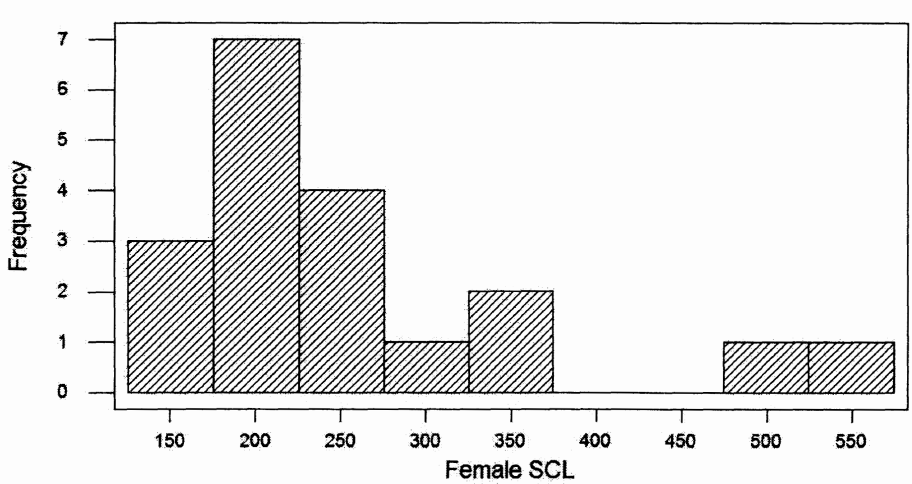

Figure 4.3: Size classes of Bornean *Amyda cartilaginea* females.

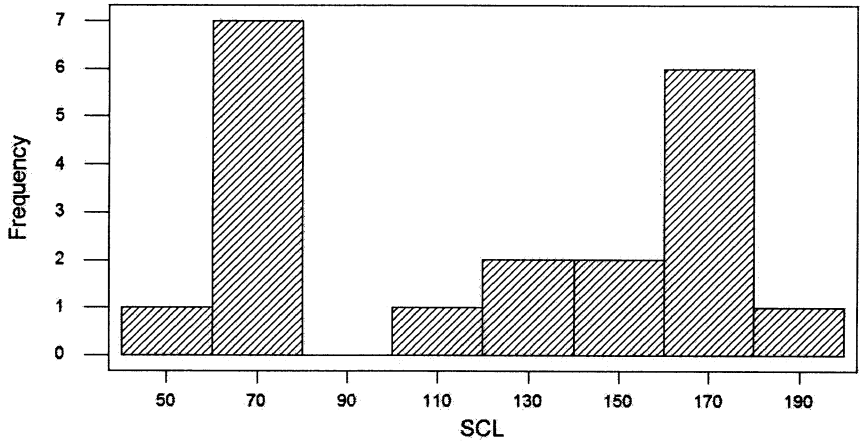

Figure 4.4: Size classes of Bornean *Cuora amboinensis* measured.

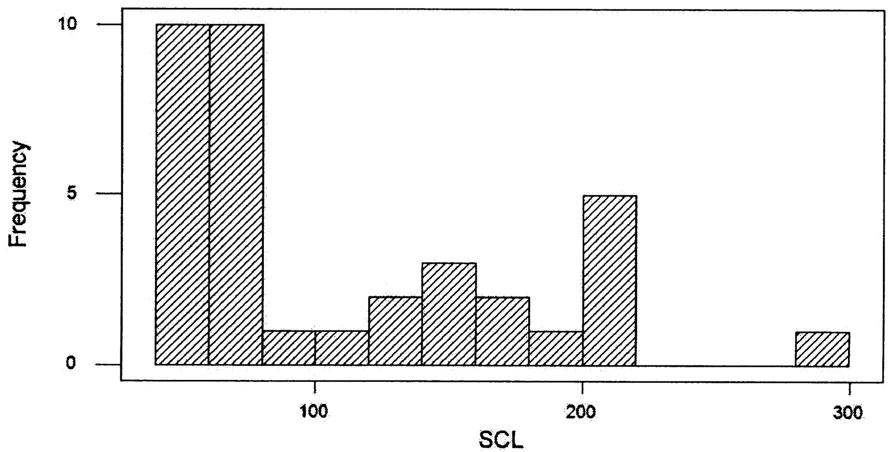

Figure 4.5: Size classes of Bornean *Cyclemys dentata* measured.

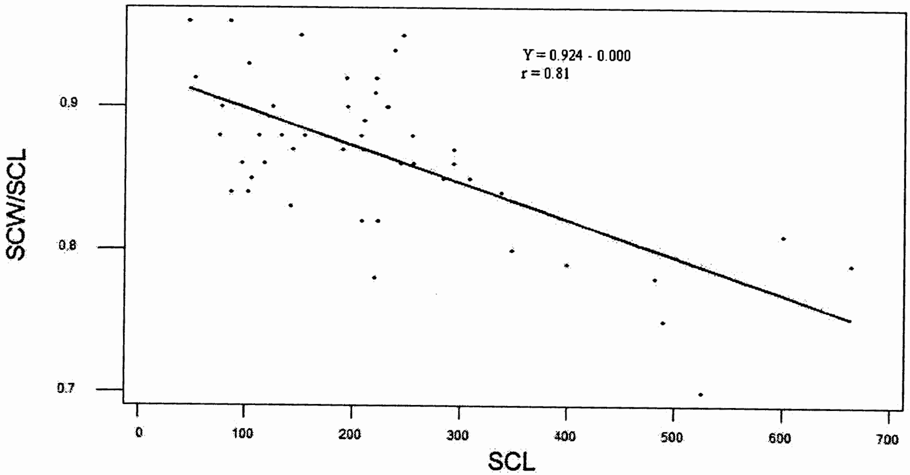

Figure 4.6: Linear regression of SCW/SCL based on SCL for *Amyda cartilaginea.*

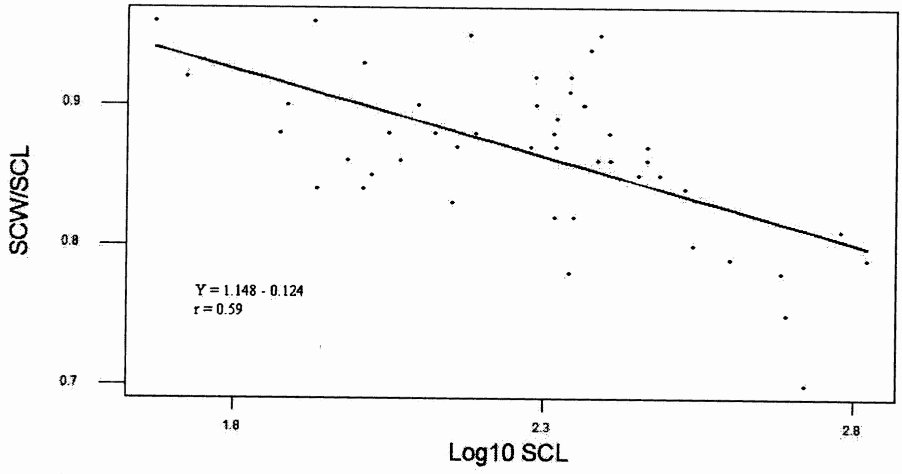

Figure 4.7: Linear regression of SCW/SCL based on the logarithm of SCL (Log10 SCL) for *Amyda cartilaginea.*

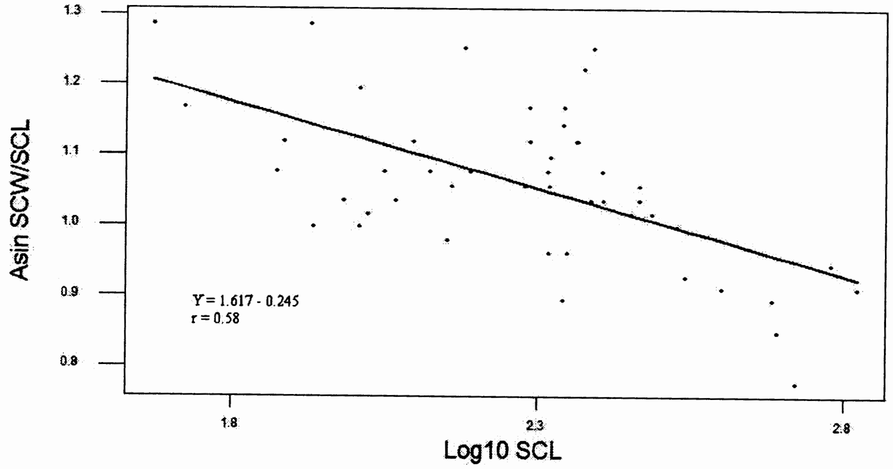

Figure 4.8: Linear regression of the arcsine (Asin) of SCW/SCL based on the logarithm of SCL for *Amyda cartilaginea.*

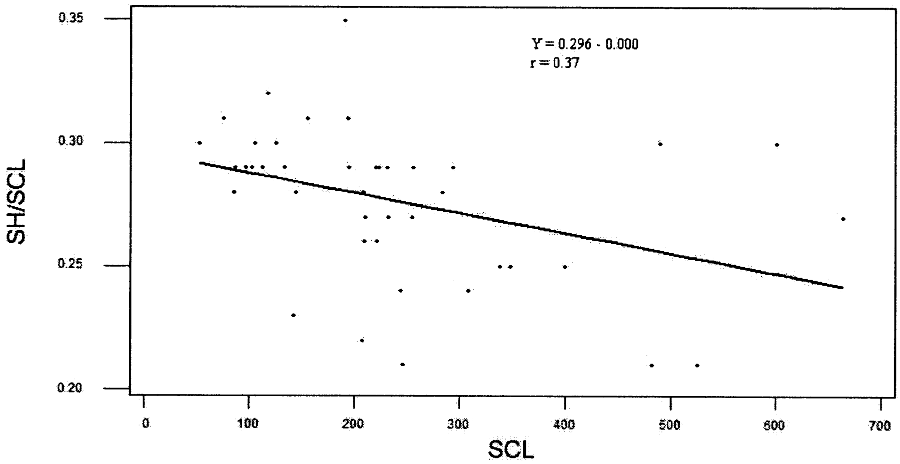

Figure 4.9: Linear regression of SH/SCL based on SCL for *Amyda cartilaginea.*

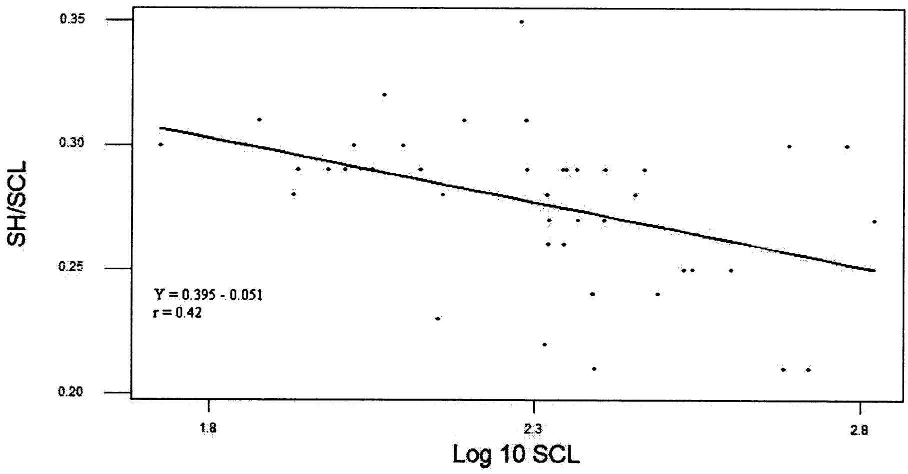

Figure 4.10: Linear regression of SH/SCL based on the logarithm of SCL (Log 10 SCL) for *Amyda cartilaginea.*

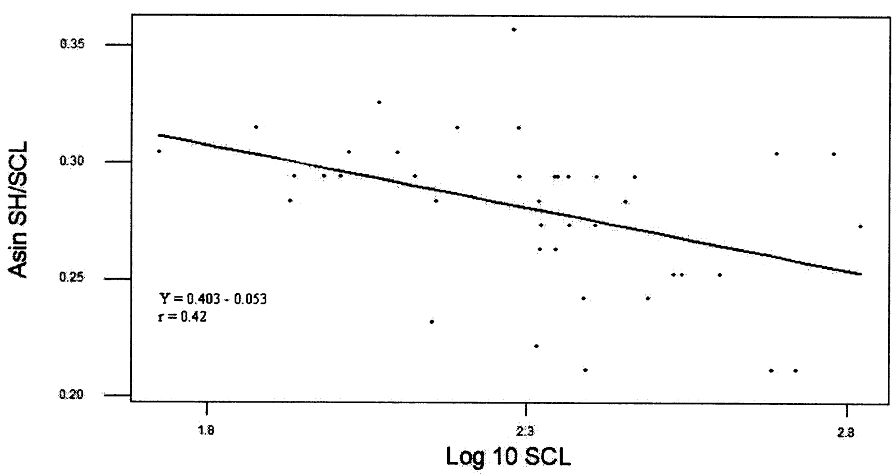

Figure 4.11: Linear regression of the arcsine (Asin) of SH/SCL based on the logarithm of SCL for *Amyda cartilaginea.*

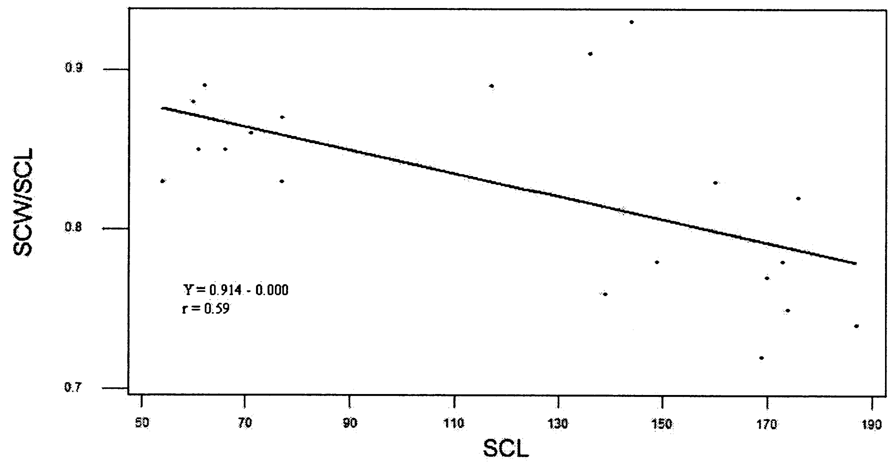

Figure 4.12: Linear regression of SCW/SCL based on SCL for *Cuora amboinensis*.

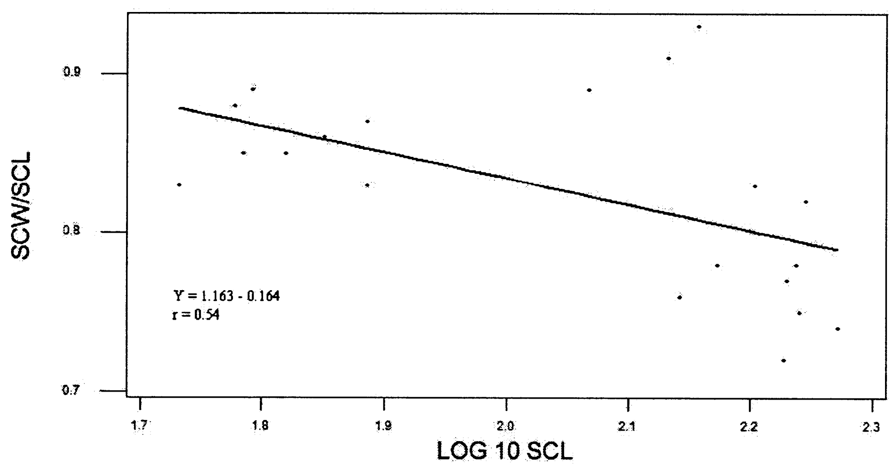

Figure 4.13: Linear regression of SCW/SCL based on the logarithm of SCL (LOG 10 SCL) for *Cuora amboinensis*.

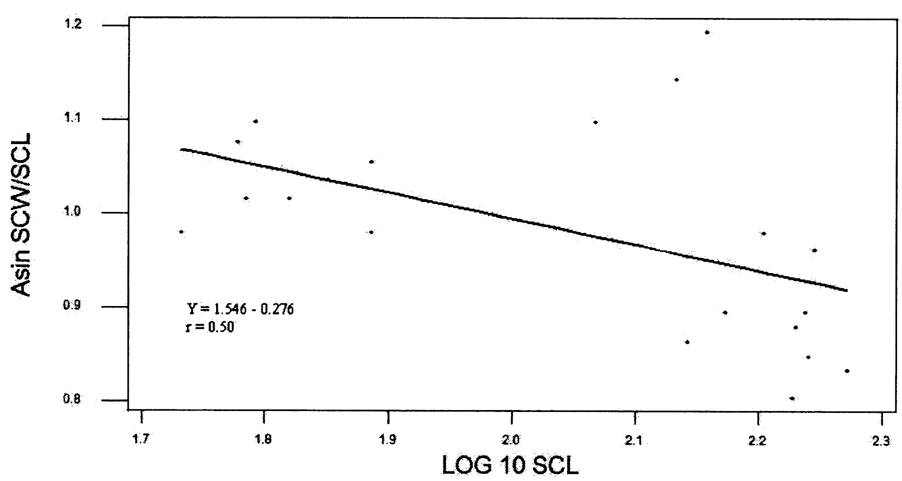

Figure 4.14: Linear regression of the arcsine (Asin) of SCW/SCL based on the logarithm of SCL for *Cuora amboinensis*.

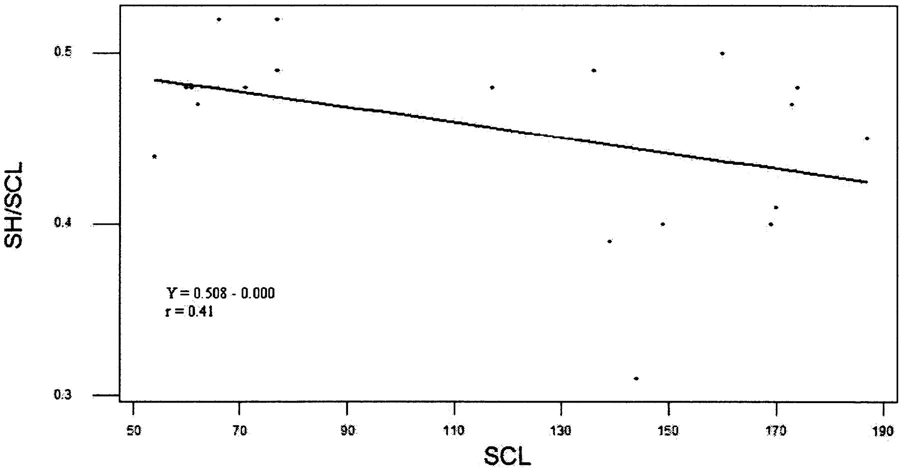

Figure 4.15: Linear regression of SH/SCL based on the SCL for *Cuora amboinensis*.

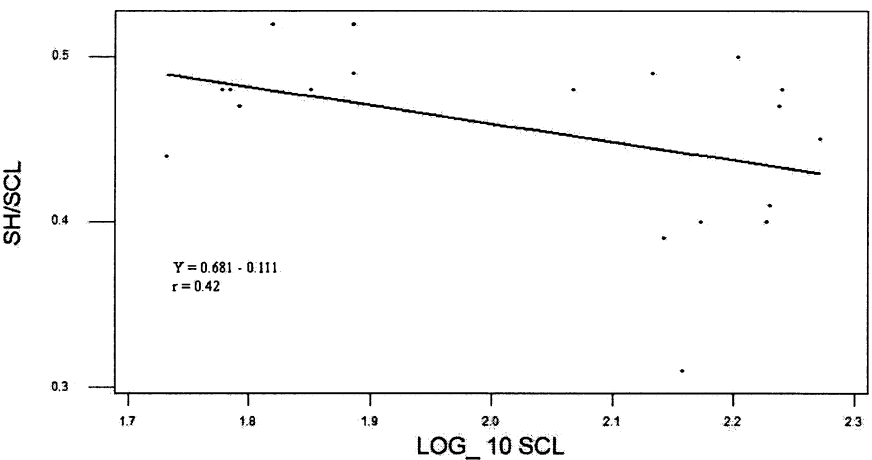

Figure 4.16: Linear regression of SH/SCL based on the logarithm of SCL (LOG_10 SCL) for *Cuora amboinensis*.

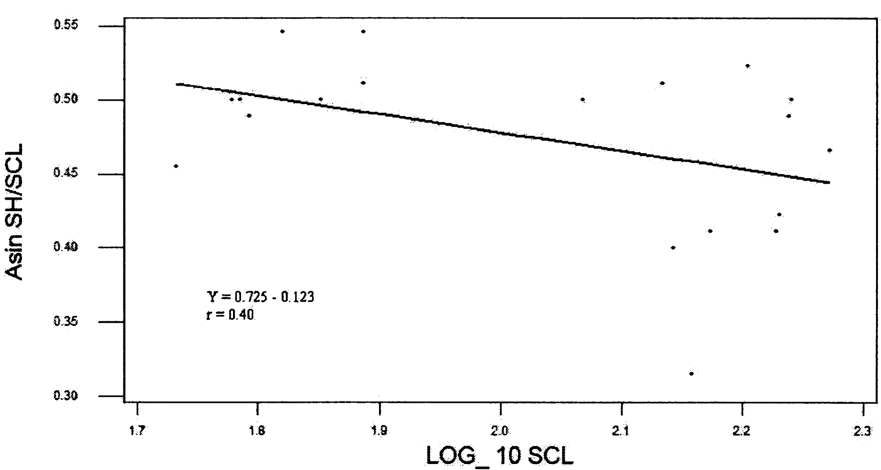

Figure 4.17: Linear regression of the arcsine (Asin) of SH/SCL based on the logarithm of SCL for *Cuora amboinensis*.

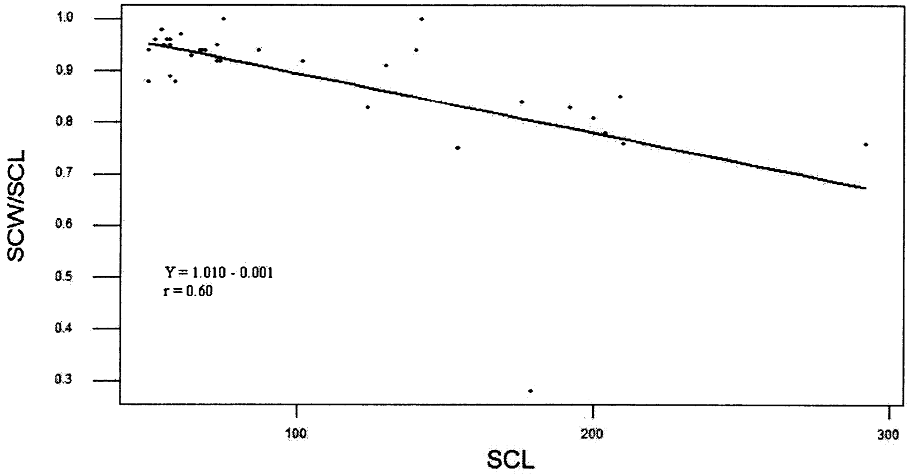

Figure 4.18: Linear regression of SCW/SCL based on SCL for *Cyclemys dentata*.

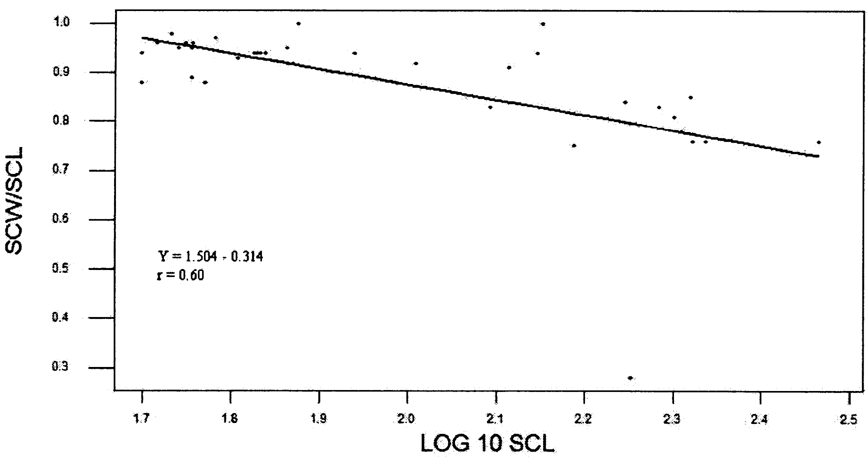

Figure 4.19: Linear regression of SCW/SCL based on the logarithm of SCL (LOG 10 SCL) for *Cyclemys dentata*.

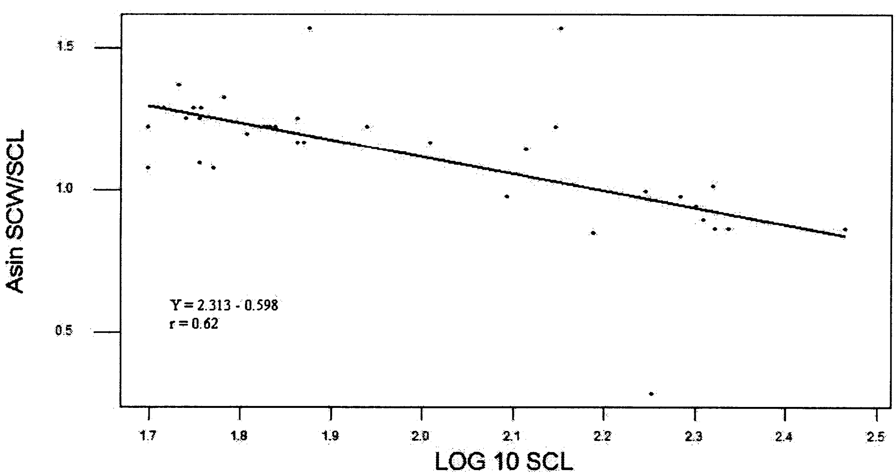

Figure 4.20: Linear regression of the arcsine (Asin) of SCW/SCL based on the logarithm of SCL for *Cyclemys dentata*.

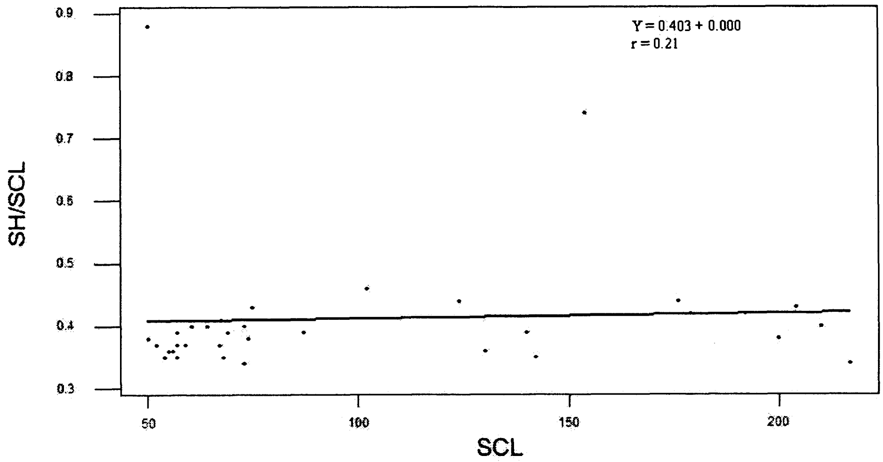

Figure 4.21: Linear regression of SH/SCL based on SCL for *Cyclemys dentata.*

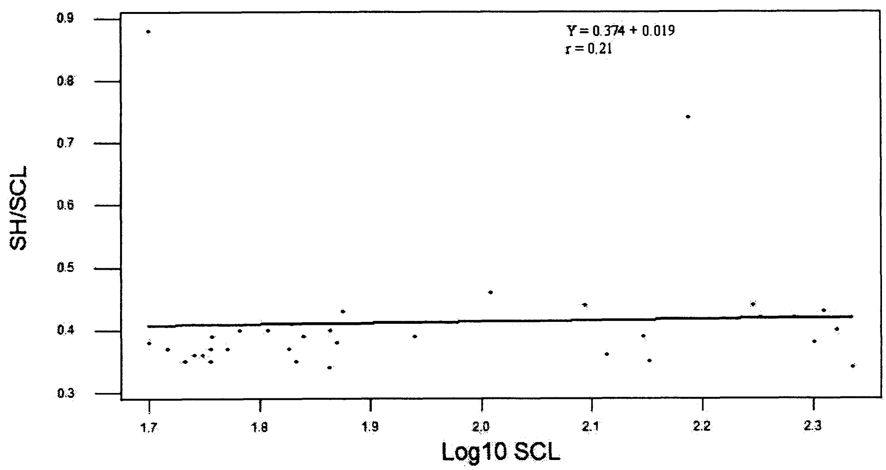

Figure 4.22: Linear regression of SH/SCL based on the logarithm of SCL (Log10 SCL) for *Cyclemys dentata.*

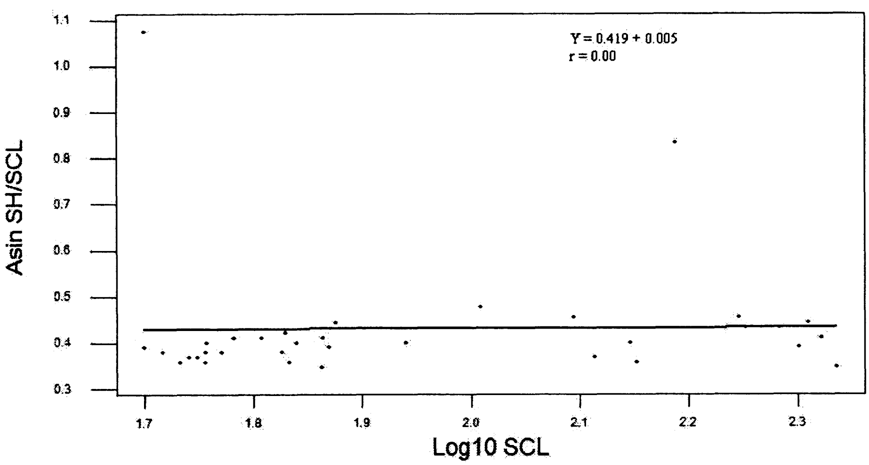

Figure 4.23: Linear regression of the arcsine (Asin) of SH/SCL based on the logarithm of SCL for *Cyclemys dentata.*

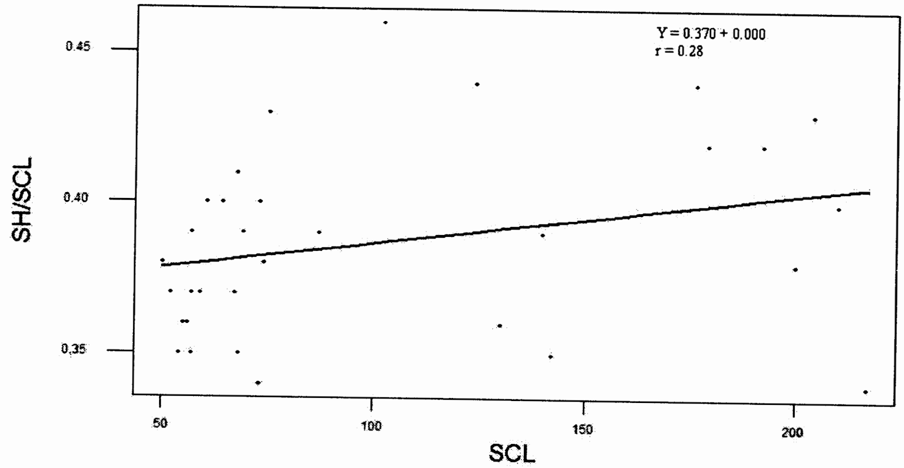

Figure 4.24: Linear regression of SH/SCL based on SCL for *Cyclemys dentata* after removing outliers.

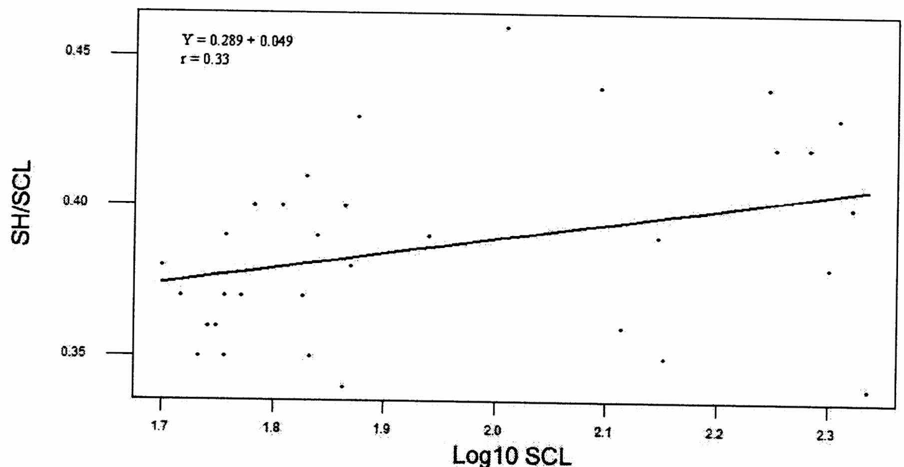

Figure 4.25: Linear regression of SH/SCL based on the logarithm of SCL (Log10 SCL) for *Cyclemys dentata* after removing outliers.

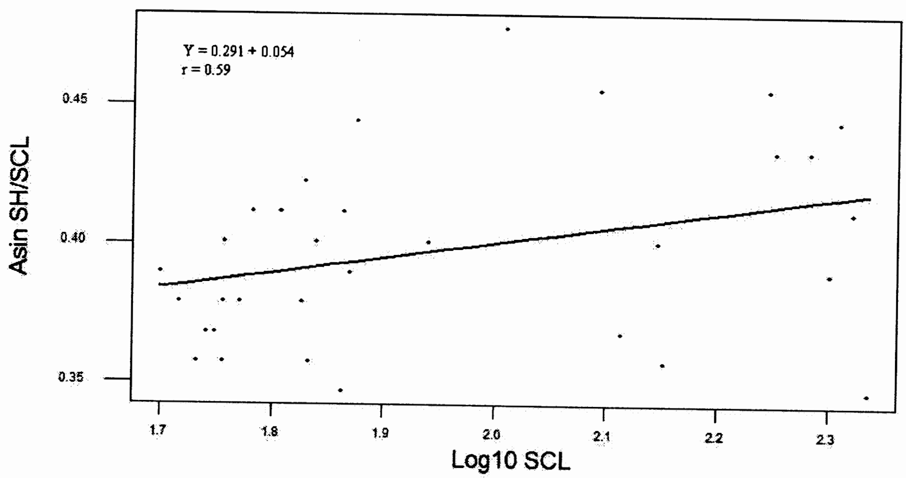

Figure 4.26: Linear regression of the arcsine (Asin) of SH/SCL based on the logarithm of SCL for *Cyclemys dentata* after removing outliers.

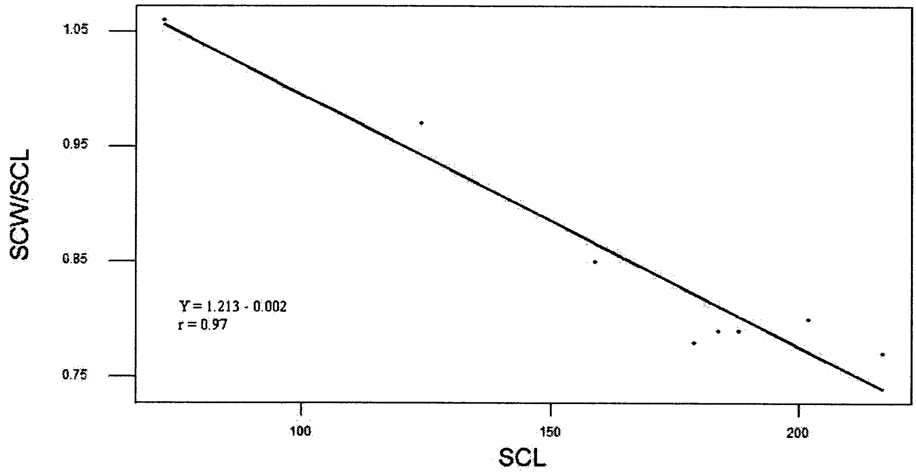

Figure 4.27: Linear regression of SCW/SCL based on SCL for *Heosemys spinosa*.

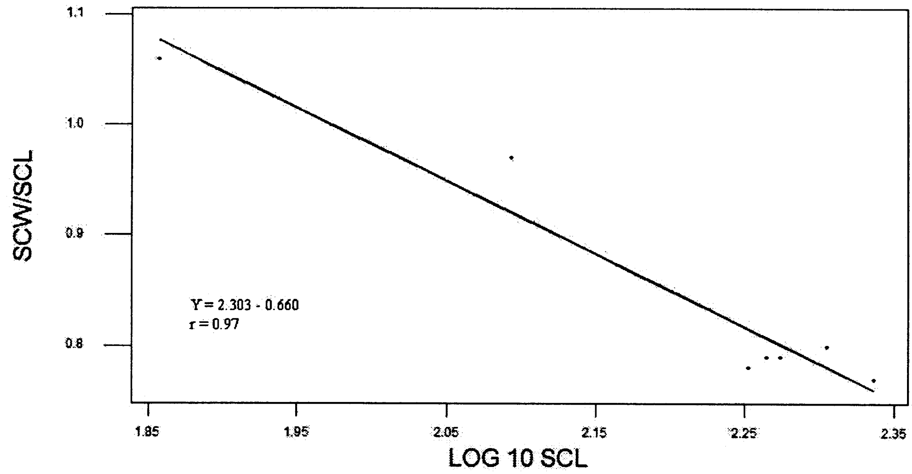

Figure 4.28: Linear regression of SCW/SCL based on the logarithm of SCL (LOG 10 SCL) for *Heosemys spinosa*.

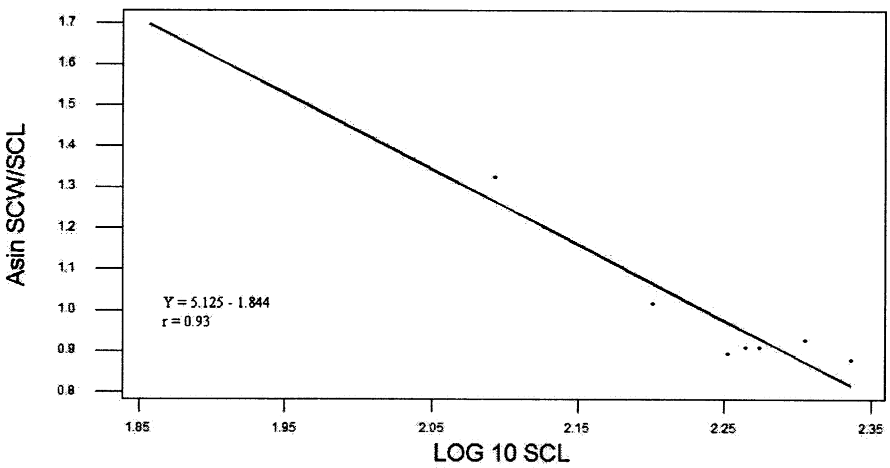

Figure 4.29: Linear regression of the arcsine (Asin) of SCW/SCL based on the logarithm of SCL for *Heosemys spinosa*.

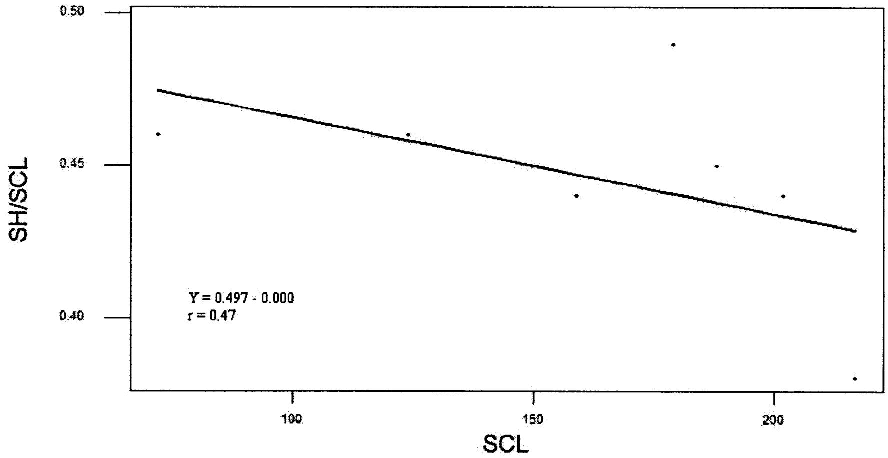

Figure 4.30: Linear regression of SH/SCL based on SCL for *Heosemys spinosa.*

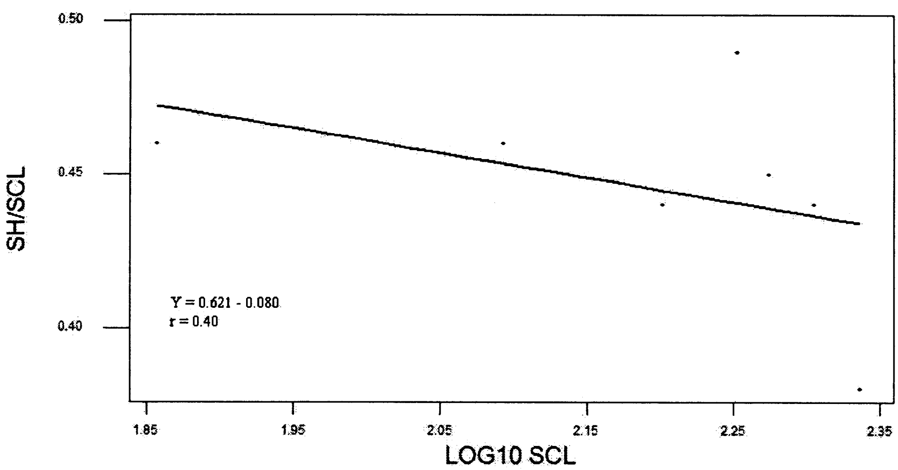

Figure 4.31: Linear regression of SH/SCL based on the logarithm of SCL (LOG10 SCL) for *Heosemys spinosa*.

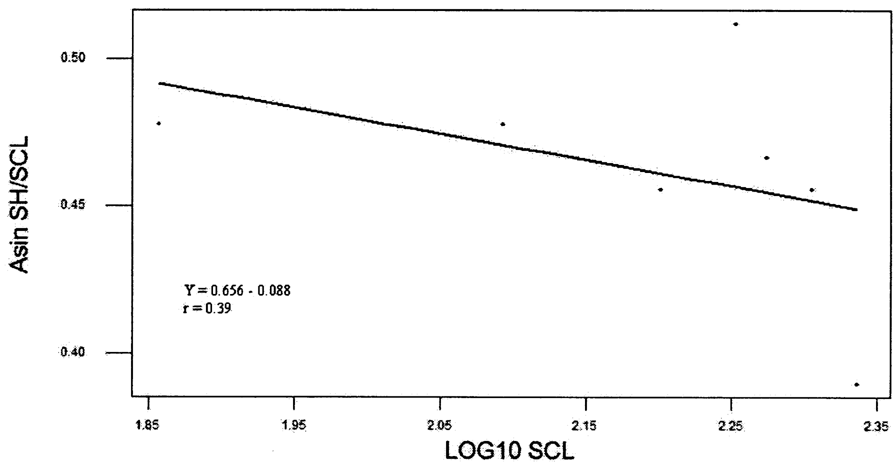

Figure 4.32: Linear regression of the arcsine (Asin) of SH/SCL based on the logarithm of SCL for *Heosemys spinosa*.

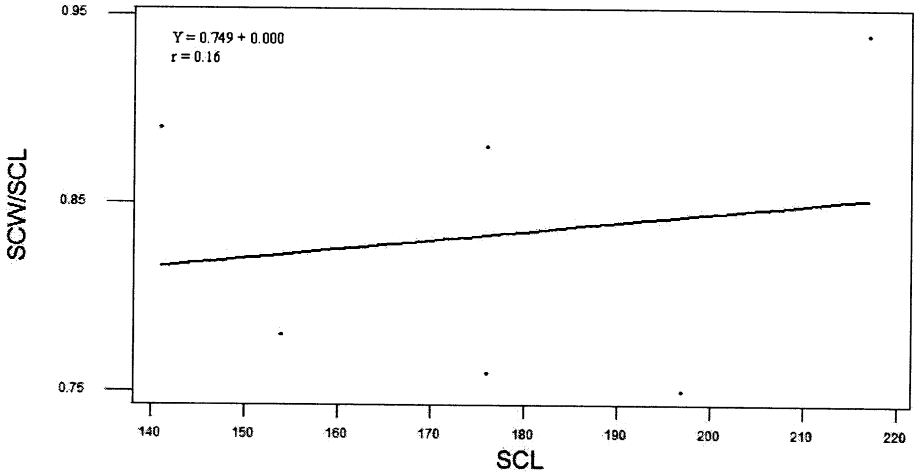

Figure 4.33: Linear regression of SCW/SCL based on SCL for *Notochelys platynota.*

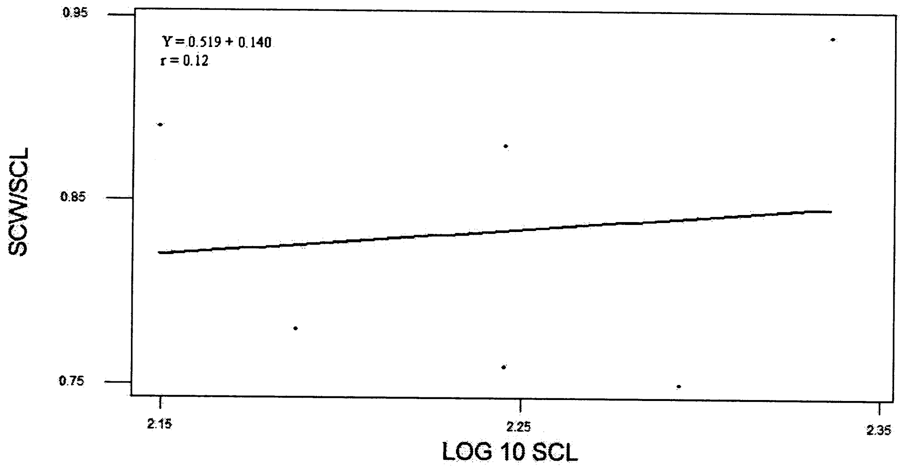

Figure 4.34: Linear regression of SCW/SCL based on the logarithm of SCL (LOG 10 SCL) for *Notochelys platynota.*

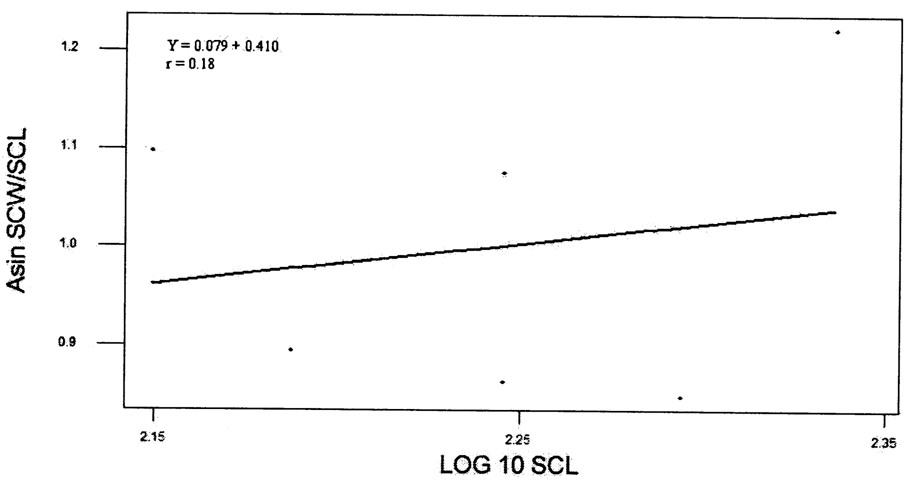

Figure 4.35: Linear regression of the arcsine (Asin) of SCW/SCL based on the logarithm of SCL for *Notochelys platynota.*

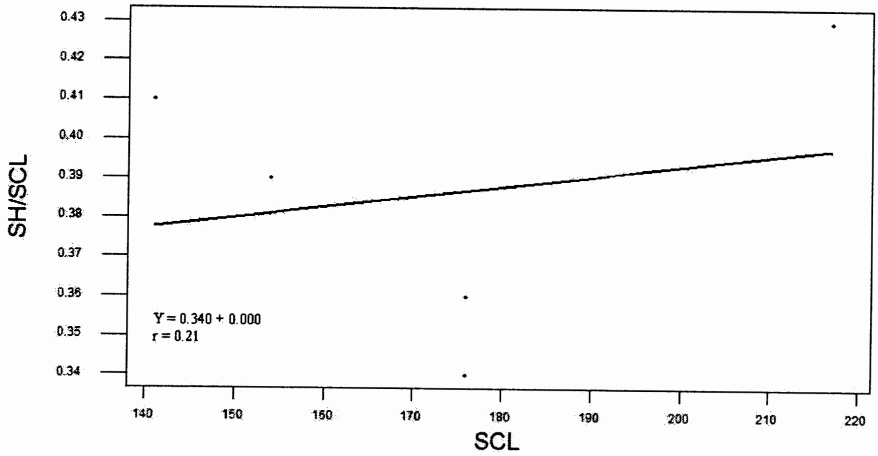

Figure 4.36: Linear regression of SH/SCL based on SCL for *Notochelys platynota*.

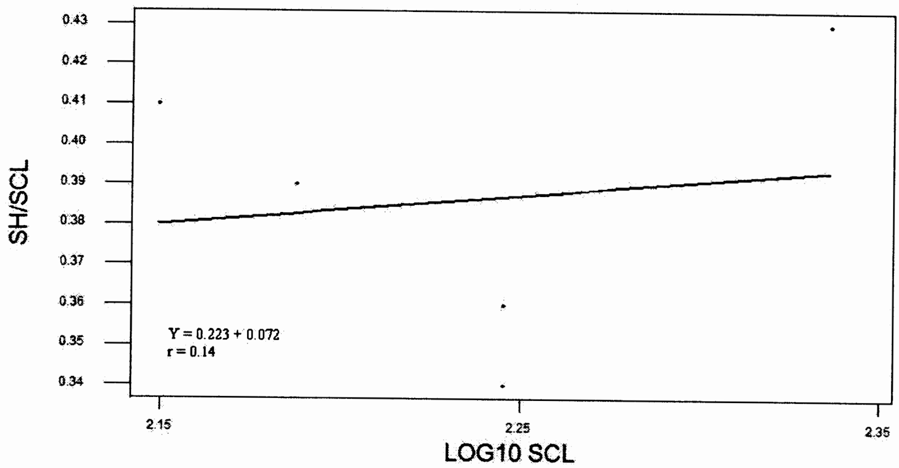

Figure 4.37: Linear regression of SH/SCL based on the logarithm of SCL (LOG10 SCL) for *Notochelys platynota*.

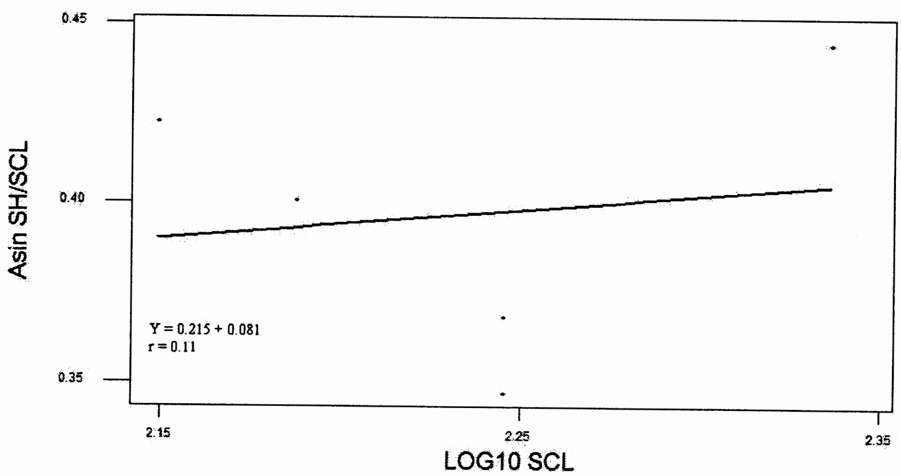

Figure 4.38: Linear regression of the arcsine (Asin) of SH/SCL based on the logarithm of SCL for *Notochelys platynota*.

CHAPTER 5

DIETARY ANALYSIS

5.1 Introduction

The objective of this chapter presents is to investigate the diet of *Amyda cartilaginea* captured from the two study sites, LBNP and Balai Ringin, with additional dietary notes from other wild-caught turtle species.

5.2 Methods

Dietary analysis was conducted based on both stomach analysis and faecal analysis of living specimens. Dissection of stomachs to examine contents was not possible in this study, as all turtles are protected under the Sarawak Wild Life Protection Ordinance (Sarawak Government Gazette, 1998). Approximately one hour after returning from the field, stomachs were flushed using the method developed by Legler (1977), incorporating the modifications created by Fields *et al.* (2000). Additionally, due to the relatively remote field conditions and limited budget, I was unable to install a water pump which would allow for constant water pressure during the stomach flushing procedure. Instead I used a 30 cc syringe for supplying the water for flushing the alimentary canal.

Turtles were provided a dose of Ketamine, a dissociative anaesthetic, to minimize stress and prevent damage to the mouth and oesophagus. Ketamine was used because it has replaced barbiturates as the more popular drug for aquatic turtles on account of its supportive cardiovascular profile and larger margin of safety (see for instance, Moon and Foerster, 2001; ULAM, 1998). The anaesthetic was administered on the left front limb of all subjects intramuscularly. The recommended dosage range was 22 to 44 mg/kg of body weight (Moon and Foerster 2001; ULAM, 1998). I began by administering the minimum dosage, 22 mg/kg. Response to the drug was determined by checking the reflexes on the limbs and with the eyelids. If there was no response to the Ketamine after 15 minutes, another dose of 22mg/kg was administered. This would add up to be the maximum recommended dosage. Out of 15 animals which received Ketamine, 13 required the maximum recommended dosage before any observable effect was noted. Even at the maximum dosage, most individuals did not completely relax. I was uncomfortable with administering more than the recommended dosage of Ketamine for reasons of safety of the study subjects. Performing stomach flushing on a soft-shell turtle which was not completely relaxed thus presents its own challenges.

Turtles were held in plastic basins of 60 cm diameter and 30 cm depth to allow recovery from the effects of the anaesthetic and to collect faecal samples. Typically, this occurred after a 24-hour period. After turtles started moving in the basin, enough water was placed in the basin to cover the turtle and a towel was placed over the top of the basin to minimize stress. However, there were instances of animals not defecating for up to five days. Each sample (stomach and faecal) was washed in water, using a mesh strainer of 0.2 mm mesh size. These samples were immediately preserved in 70% ethanol for study.

Contents of the stomach and faecal samples were examined separately for each turtle. Types of food were sorted under low magnification using an Olympus SZX9 dissecting microscope. The presence of each dietary group was recorded to the lowest identifiable taxon, in this study, typically to ordinal level of classification. Additionally, two categories were used, namely, unknown arthrodpods and unknown vertebrates. Any unidentifiable part of an insect or any other arthropod, i.e., wing, claw, etc., was grouped in the first category. The unknown vertebrates category represents any part known to be from a vertebrate, i.e., bone fragments, but unclassifiable further. The volume of each kind was determined by the displacement of water in a either a 25 ml or 5 ml graduated cylinder, as described by Moll and Legler (1971). Descriptive analysis of data pertaining to contents of stomachs and faecal samples were expressed in two ways:

$$\textit{Percent Frequency of Occurrence} = \frac{\textit{Number of turtles in which a given food item was found} \times 100}{\textit{Number of individuals that provided samples}}$$

$$\textit{Total percentage of food volume} = \frac{\textit{volume of diet category x over all individuals}}{\textit{of the volume of all diet categories over all individuals}}$$

I tested to investigate if there was a correlation between body size and the different food categories using the Pearson correlation test. I again used the Pearson correlation test to examine if body size was correlated with the volume found of either stomach contents or faecal matter. I analyzed all data in SPSS for Windows ver. 10.1® or in Microsoft Excel ver. 2003® spreadsheets.

5.3 Results: General

Amyda cartilaginea

In total, 18 animals were obtained, comprising three juveniles, nine females and six males. Stomach flushing was not attempted on the juveniles due to their small size, and they yielded little in terms of faecal matter. Therefore they are not included as part of the dietary analysis. Only nine adult animals provided stomach contents (four males and five females), while 13 animals provided (five males and eight females) faecal samples. Parasitic nematodes were found in one female and two male turtles, all from LBNP. Furthermore, sand or gravel type substrate was found in all faecal samples. It is assumed that these items were not intentionally ingested and consequently were excluded from further analysis.

All 15 turtles that provided either stomach samples, faeces, or both, were captured evenly during the different seasons. Five animals, all female, were caught during the end of the north-east monsoon (wet season) which extends from November to March. All five had eaten plants, four had also eaten unknown vertebrates, and three had taken various arthropods and had fish parts in either their stomach or faecal samples. Five animals (three male; two female) were captured during the south-west monsoon (dry season) which occurs from June to September. Four had plants in their stomach or faecal samples, three had fish and unknown vertebrate material, and only one provided arthropod parts. In the non-monsoonal period (April; October), five animals (three male; two female) were also caught. All animals had plant material and fish parts in either their faecal or stomach samples, four had insect parts and of an unidentifiable vertebrate.

5.3.1 Results: Stomach

In total, 60% of turtles obtained in this study provided stomach contents. In all, 66% of male *Amyda cartilaginea* provided stomach contents, while 55% of the females provided stomach contents. They consisted of both aquatic and terrestrial plants, invertebrates, and remains of fish. Muscle tissues and bone fragments from unidentifiable vertebrate species also occurred in stomach contents. Seven of the nine samples contained plant material (77%) while only five samples contained animal parts (55%). Frequency of occurrence of animals found in the stomach contents includes unknown arthropods (11%), dragonflies (Odonata) (11%), spiders (Arachnida) (11%), teleost fishes (Pisces) (22%), and unknown vertebrate remains (55%). These data are also presented in Table 5.1. Percent frequency of occurrence for food items found in male and female stomachs are represented in Figures 5.1 and 5.2, respectively. The percent frequency of occurrence of food items found in stomachs of both male and female *Amyda cartilaginea* is represented in Figure 5.3.

Percentage of volume within stomach contents is presented in Table 5.1. Plant material was present in 33% of the stomach samples, while unknown vertebrate parts represented 48% of the total volume of stomach contents. The remaining percentages are teleost fishes (7%), unknown arthropod remains (4%), Odonata and Arachnida, each comprising 4% of total volume.

No notable differences were found in the dietary resource type ingested by males and females. Of the seven samples containing plant material, three came from females and four from males. Two samples, one from each sex, contained invertebrate material. One sample from a female contained unknown vertebrate bone fragments.

A Pearson Correlation test was used to determine the relationship between body size and the number of identifiable prey types in the stomach. This calculation is plotted in Figure 5.4. No correlation ($r = -0.313$; $P = 0.412$) was observed between these contents and body mass indicating that larger turtles would not necessarily take a greater type of dietary resources. The largest mass of an individual providing stomach contents was 4 kilograms. Turtles contained food from one to

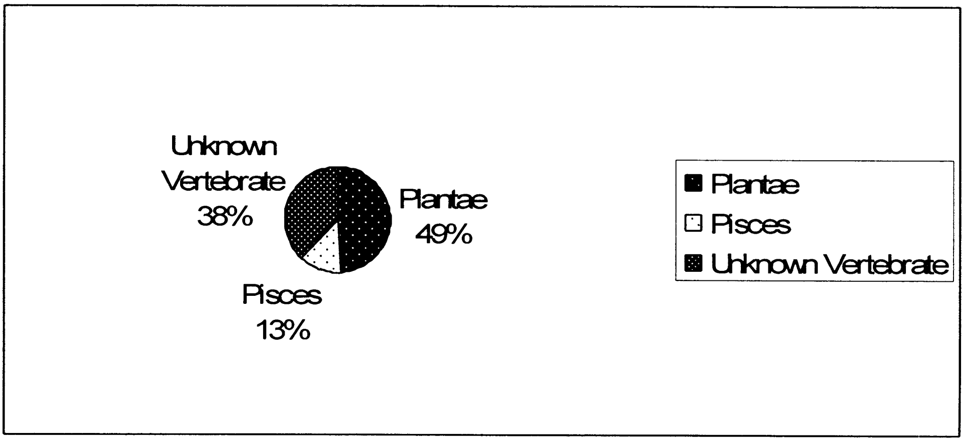

Figure 5.1: Percent frequency of food items found in stomachs of male *Amyda cartilaginea*

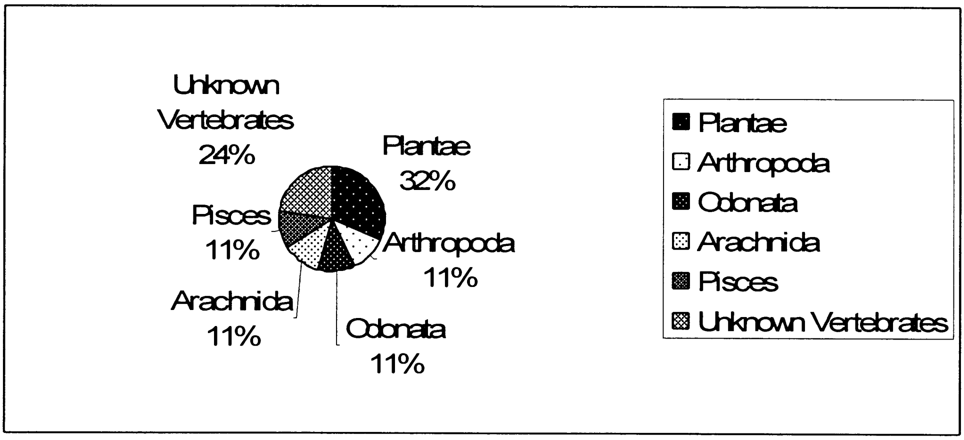

Figure 5.2: Percent frequency of food items found in stomachs of female *Amyda cartilaginea*

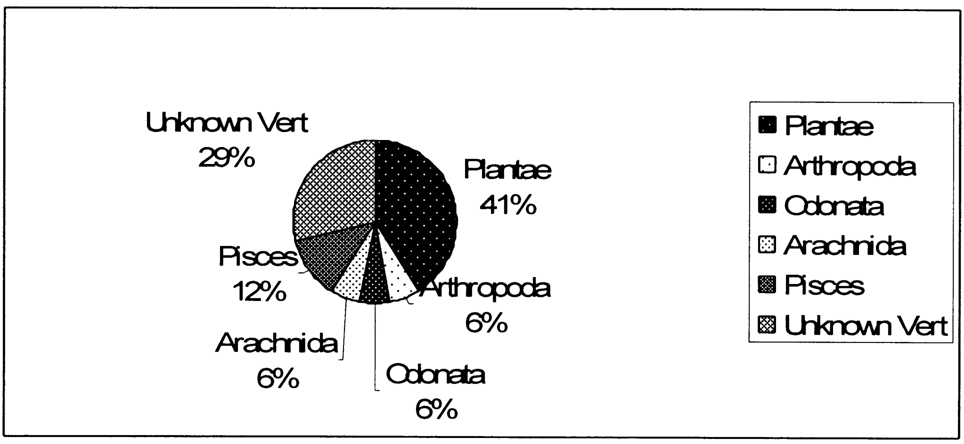

Figure 5.3: Total percent frequency of occurrence food items in stomachs of both male & female *Amyda cartilaginea.*

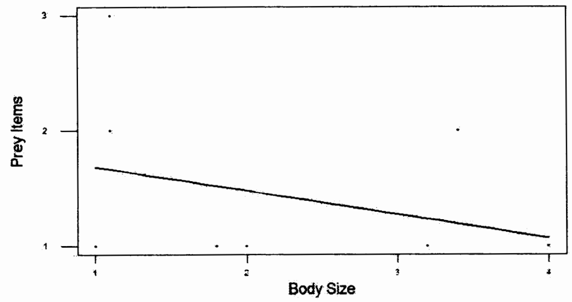

Figure 5.4: The relationship between the number of prey items found in the stomachs of *Amyda cartilaginea* and body size.

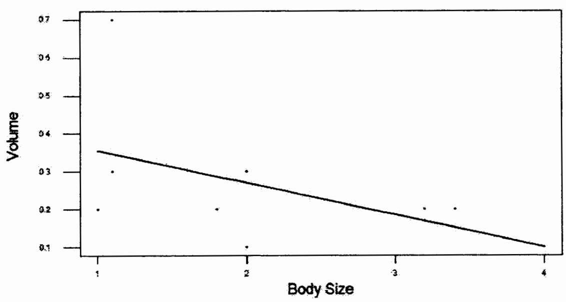

Figure 5.5: The relationship between the volume of items found in the stomachs of *Amyda cartilaginea* and body size.

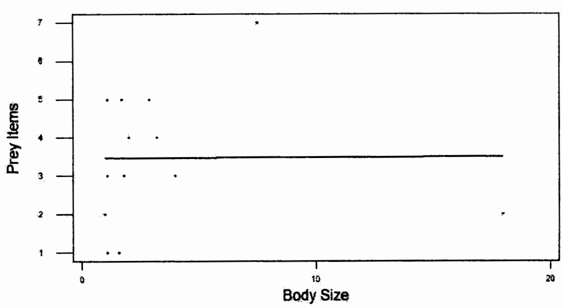

Figure 5.6: The relationship between the number of prey items found in the faeces of *Amyda cartilaginea* and body size.

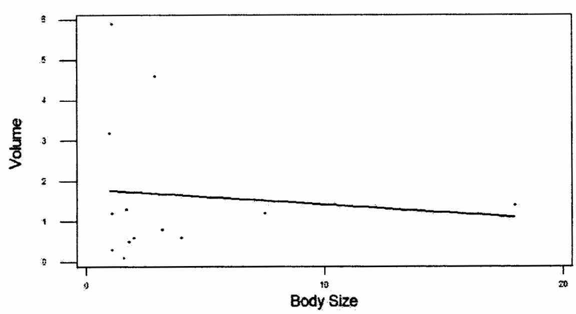

Figure 5.7: The relationship between the volume of items found in the faeces of *Amyda cartilaginea* and body size.

three prey items in their stomachs. A Pearson Correlation test was also used to check for any relationship between body size and the volume of stomach contents. There was no correlation ($r = -0.518$; $P = 0.153$) between these two variables (Fig. 5.5).

5.3.2 Results: Faecal

Of the 18 turtles obtained, 86% provided faecal samples. Eighty-three percent of male *Amyda cartilaginea* provided faecal samples while 88% of the females provided faecal samples. Items found in faecal samples and representing the frequency of occurrence are summarized in Table 5.2. They consisted of plant material (100%), arthropod remains (62%), flies (Diptera) (7.7%), beetles (Coleoptera) (7.7%), ants (Hymenoptera) (23%), dragonflies (Odonata) (7.7%), snails (Gastropoda) (7.7%), teleost fish (Pisces) (69%), birds (Aves) (7.7%), and unknown vertebrates (84%). Percent frequency of occurrence of prey items found in faeces is summarized for males in Figure 5.8; females, Figure 5.9; and all *Amyda cartilaginea*, Figure 5.10.

The percentage of volume of total contents in the faecal samples is presented in Table 5.2. Plant material had a total percentage volume of 56%, followed by teleost fish at 16%. Unknown vertebrates followed at 14% of the total volume, with unknown birds at 6%, unknown arthropods at 4%, Hymenoptera at 1%, and Diptera, Coleoptera, Odonata, and Gastropods each at < 1%. The small sample size does not permit statistical testing, but there seems to be no difference between the dietary preferences between males and females. All males and females provided faecal samples containing plant materials. Three of the five males provided had insect parts, while five of the eight females had the same. Four of the five males provided unknown vertebrate material, while six of the eight females did the same. Interesting items recovered were the bird feathers and bones found in a single adult male (Field Number: KJ-126).

A Pearson Correlation test was used to determine the relationship between body size and the number of identifiable prey types in faecal contents. Similar to the results of the stomach contents, no correlation ($r = 0.005$; $P = 0.987$) was found between body mass and the number of

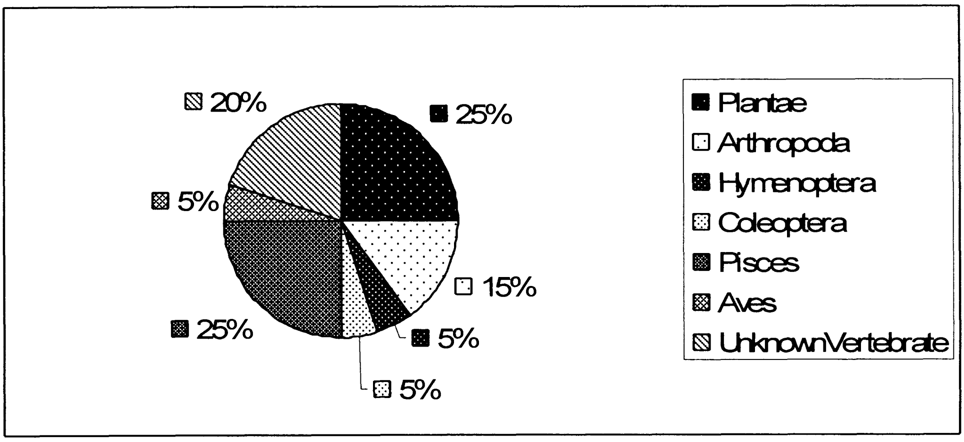

Figure 5.8: Percent frequency of food items found in faeces of male *Amyda cartilaginea.*

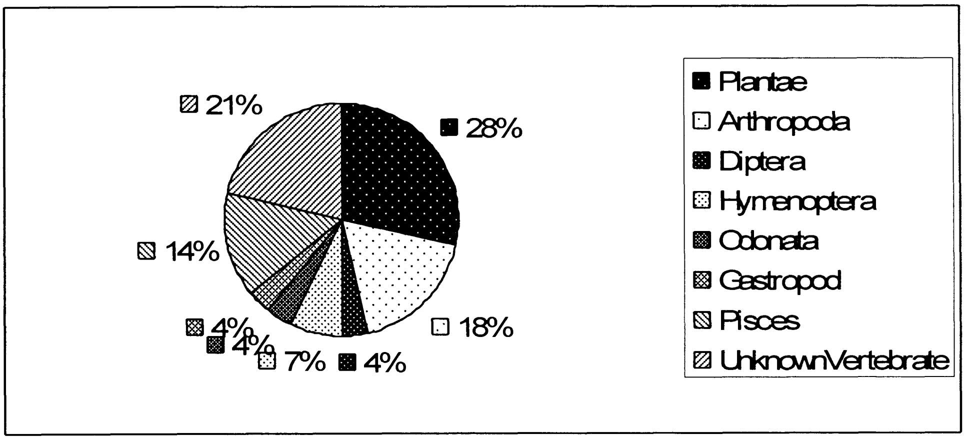

Figure 5.9: Percent frequency of food items found in faeces of female *Amyda cartilaginea.*

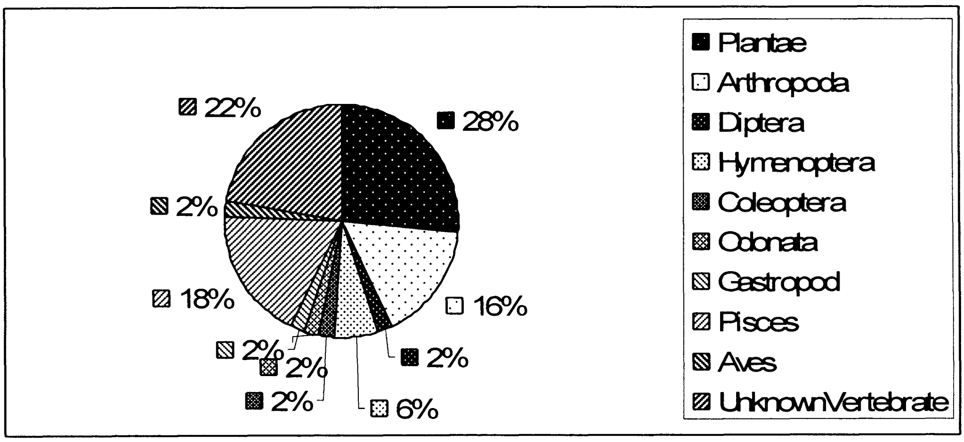

Figure 5.10: Total percent frequency of occurrence food items in faeces of both male & female *Amyda cartilaginea.*

identifiable prey items indicating that larger animals would not necessarily harvest a greater number of prey resource types (Fig. 5.6). The largest animal that provided faecal matter for analysis was a female (Field Number: KJ-031) weighing 18 kg. Similar to the results of the stomach contents, there was no correlation ($r = -0.101$; $P = 0.742$) between body size and the volume of faecal matter. The calculation is represented in Fig. 5.7.

5.4 Discussion

Collection of large sets of field data on *Amyda cartilaginea* is difficult in Sarawak where this species is actively hunted for food by nearly all indigenous peoples. and the species is consequently not easily captured. Additionally, it appears to be an extremely elusive animal. Although it may not move great distances, it cannot be seen from above or in the water, which is highly turbid (19 – 50 cm at LBNP; 29 – 39 cm at Balai Ringin) and hence with low or no visibility, the colour being either chocolate milk or motor oil, apparently does not bask, at least on land, and does not enter hoop nets (two hoop nets were used at LBNP for a total of 33 evenings). Therefore obtaining large data sets for this species is difficult and costly.

The dominant foods found in both stomach and faecal analysis are plant materials, followed by unknown vertebrates, indicating that *Amyda cartilaginea* is an omnivore. Tendencies towards omnivory have been reported for another trionichid turtle, *Trionix triunguis* (see Branch, 1988; Ernst and Barbour, 1989), and the tendency to feed upon carcasses is known from other soft-shell species: *Trionyx triunguis* (Akani *et al.*, 2001), *Aspideretes gangeticus* and *Aspideretes hurum* (Das, 1995a), and *Rafetus euphraticus* (Taskavak and Atatür, 1998,). Identifiable terrestrial vertebrates were found in one faecal sample in this study. Several white feathers, along with bone and muscle tissue belonging to an indeterminate bird were recovered from an adult male (Field Number: KJ-126). These remains may have come from an intermediate egret (*Egretta intermedia*), as this is the only bird species found at LBNP with completely white plumage. Turtles have been known to take birds off the water surface for food. In the USA, Pryor (1996), observed a *Chelydra* *serpentina* taking a semi-palmated sandpiper (*Calidris pusilla*) from the water's surface. In this same paper, Pryor (1996), also reviewed other accounts of *Chelydra serpentina* predation on birds; laughing gull (*Larus atricilla*), lesser yellowlegs (*Tringa flavipes*), and possibly Forster's tern (*Sterna forsteri*), all migratory sea or shore-birds. It is possible that this individual did take the intermediate egret off the water's surface as it was foraging. Intermediate egrets are migratory birds, coming to the wetlands of Borneo seasonally and at LBNP when water and fish are plentiful in the lake. This may represent a larger variety of food sources for these turtles, during certain periods. Whether *Amyda cartilaginea* is preying upon terrestrial birds as well as animal carcasses, it could be considered a keystone species in its contribution to recycling nutrients in the peat swamp ecosystem.

Result of the Pearson Correlation test indicate there was no correlation between body size and the number of identifiable prey items in the stomach and again in looking at body size and the volume of retrieved stomach contents. Although the sample size was small (n = 9), these results may be related to problems with the stomach flushing technique. It could be a safe assumption that larger turtles consume larger amounts of food. However this is not the case. In fact, the largest sample (0.7 ml) was provided by a turtle weighing 1.1 kg (Field Number: KJ-128). Stomach flushing success is often inversely proportional to the size of turtle and the volume of water injected with a hand-operated syringe may be insufficient for large animals (Demuth and Buhlmann, 1997; Legler, 1977). Without dissection, it is impossible to know whether failure to dislodge food from the stomach means the stomach is empty or the technique is ineffective.

Sexual and ontogenetic differences in diet in the species remain unknown and appear to be negligible, but the sample in this study does not permit appropriate statistical testing. In addition, data were unavailable for juvenile turtles. Such differences have been highlighted in other trionychids, such as *Apalone mutica* by Plummer and Farrar (1981). In other freshwater turtle species, there is a well documented shift from carnivory to herbivory with increasing body size: *Trachemys scripta* (Clark and Gibbons, 1969), *Emydura krefftii* Georges, 1982), *Trachemys* *scripta* (Hart, 1983), *Pangshura tentoria* (Das, 1985), *Chelonia mydas* (Bjorndal, 1985). Further sampling with a wide range of size classes is needed to answer these questions.

There was no correlation between body mass and the number of prey items as well as no correlation between body mass and volume of faecal matter. The sample size does not permit quantitative analysis of any seasonal differences. Seasonal differences in rainfall and water availability may influence the diet and behaviour of turtles, especially in places where streams dry out completely and turtles may be forced to aestivate or perhaps burrow and remain underground in a quiescent state. Changes in the water level may influence feeding behaviour especially in areas where many of the streams dry out completely. During these periods, turtles were found buried in mud. All three individuals located in mud were found at LBNP in small streams, buried 0.3 – 0.5 m depth of wet mud in previously submerged stream banks. A smaller number of turtles may have had insects in their diet during the dry season because aquatic insects tend to breed during the wet season, and consequently are less likely to be available during this period. Conversely, as the water levels decrease, fish are confined to smaller areas, making them more easily harvestable prey for turtles (Jensen, pers. obs. 2004, 2005). Additionally, during the dry season, there is a large die-off of fish at Loagan Bunut, therefore some of the fish intake may be from scavenging (Jensen pers. obs. 2004, 2005). Although the samples were small, these data are a noteworthy addition to the knowledge of the ecology of this species.

5.5 Other Turtle Species

Dogania subplana

One *Dogania subplana* was collected by Das. It was found dead, likely killed by an otter. Upon examination of the gut, the stomach was full of the remains of a freshwater crab and one aquatic snail.

Cuora amboinensis

Only five animals were found during this study, three females and two juveniles. One female and both juveniles provided faecal samples. All three samples contained plant material and both juvenile samples contained unknown insect parts. This is consistent with published information on the diet of this species which is known to be largely herbivorous (Lim and Das, 1999; Pritchard, 1979).

Cyclemys dentata

A total of seven wild specimens were found during this study, two adult females and five juveniles. One female and three juveniles provided faecal samples. All five samples contained plant material and two of the three juvenile samples contained parts of unknown insects. This is consistent with known information categorizing this species as omnivorous (Lim and Das, 1999; Pritchard, 1979), and possibly, juveniles ingest relatively more animal matter than the adults.

Heosemys spinosa

A total of four individuals were located during this study, two females, one male, and one juvenile. All four provided faeces for examination. All three animals (1 male, 1 female, 1 juvenile) came from the same general location, Kubah National Park. All three had the same type of seeds and other plant material in their samples along with unknown insect parts. The fourth animal was from Balai Ringin and her faeces contained plant material, unknown insect parts, vertebrae from an unknown fish species, in addition to several phalanx bones from a monkey, identified as either a macaque (*Macaca* sp.) or langur (*Presbytis* sp.) by the Earl of Cranbrook (pers. comm., 2004). *Heosemys spinosa* has been noted as an herbivorous species (Lim and Das, 1999; Pritchard, 1979), therefore the presence of vertebrate remains in the faeces of a wild-caught individual is noteworthy.

Germination was attempted with the seeds obtained from the *Heosemys spinosa* individuals. They were placed in a sterile planting medium and misted several times per day but after 45 days, there was no germination. Germination was attempted for a full 90 days, but without success.

Table 5.1: Stomach contents of nine individuals of *Amyda cartilaginea* from Sarawak, collected between May 2004 through April 2005.

Dietary Resource Type	% Frequency of occurrence	Total percentage of volume
Plants	77	33
Unknown Arthropoda	11	4
Odonata	11	4
Arachnida	11	4
Pisces	22	7
Unknown Vertebrata	55	48

Table 5.2: Faecal samples of 13 individuals of *Amyda cartilaginea* from Sarawak, collected between May 2004 through April 2005.

Dietary resource type	% Frequency of occurrence	Total percentage of volume
Plants	100	56
Unknown Arthropoda	62	4
Diptera	7.7	<1
Hymenoptera	23	1
Coleoptera	7.7	<1
Odonata	7.7	<1
Gastropoda	7.7	<1
Pisces	69	16
Aves	7.7	6
Unknown Vertebrata	84	14

CHAPTER 6

USE OF TURTLES IN SARAWAK

6.1 Introduction

The objective of this chapter is to summarize information on the use of, and trade in tortoises and freshwater turtles in Sarawak. Certain species such as *Amyda cartilaginea*, are assumed to be declining range wide, yet there is no published information highlighting current exploitation in Sarawak. In this chapter, I discuss observed prices of turtles at wet markets. However, no turtles were actually purchased from any individual in Sarawak.

6.2 Methods

The main methods of data collection were to interview people from longhouses and survey wet markets around the two main study sites in Sarawak. For dates and markets visited, see Table 6.1. For dates and longhouses/ camps visited, see Table 6.3. However, other opportunities arose to visit additional areas. These were the longhouses along the Tutoh River and surrounding Mulu National Park (the Penan settlement at Mulu, Long Iman, Long Terawan, and Long Panai). Wet markets were visited in Kuching (Satok Market, Tabuan Jaya, and Batu 7), some longhouses and camps in the Bintulu area (Rumah Biol, the Log Pond logging camp, Rumah Suran, Rumah Ngumbang, and the Gabung Camp), two longhouses surrounding LBNP (Long Teru and Long Meran), an isolated visit to Long Sukang, and wet markets in Serian, Balai Ringin, Bako, Lundu, Sematan, Sarekei, Simunjun, Daro, Miri, Mukah, Bintulu, and the Indonesian border markets of Tebedu and Serikin. Information on turtles seen at the Sibu wet market including photographs were provided by Mohd. Azlan (pers. com., 2006).

I recorded recent prices of animal products used for food, including chicken and pork parts found at the Satok, Kuching wet market. In examining the prices of fish, I only recorded fish species that are also found along with *Amyda cartilaginea* in my main study sites. These were ikan haruan (*Channa striatus*), ikan toman (*Channa micropelites*), ikan baong (*Hemibagrus nemurus*), and ikan kali (*Clarius prophagorus*). Beef or lamb products, while consumed in Sarawak, are generally imported from overseas and the prices reflect this, therefore I chose not to included these animal products.

Pet shops were visited for other purposes and if turtles were seen for sale, the information was recorded. However, this was not the focus of the project.

6.3 Results

Turtles seem to be used primarily for food and on a smaller scale for pets or socio-religious purposes and the most desirable species seems to be *Amyda cartilaginea.* Prior to the passing of Sarawak's Wildlife Protection Ordinance, many species of wildlife could be seen for sale along border areas such as Serikin. Das (pers. com., 2006) stated that up to 2002, a variety of wild mammal, bird and reptile species, including turtles (*Cuora amboinensis*), were sold at the Serikin market on the weekends. On two visits I made during 2004 and 2005, no wildlife was for sale, at least not openly. There were numerous Sarawak law enforcement vehicles and uniformed men patrolling the market.

Turtles at wet markets may be for sale, but not obviously. Only at a few markets would they show me any turtles for sale. *Amyda cartilaginea* was found for sale as a food item at Balai Ringin and Serian. I was offered *Amyda cartilaginea* for RM 10.00/ kg from fishermen, but it was considerably more from fish mongers at RM 25.00/ kg. Although in other markets (Bintulu, Daro), soft-shell turtles were priced at RM 24.00/ kg. In talking with a few individuals not connected with the sale of turtles who wish to remain anonymous, the soft-shell turtle will generally cost a minimum of RM 24.00/ kg and sometimes more. Chicken prices were RM 6.50/ kg; pork at RM 5.00/kg; ikan haruan at RM 8.00/ kg; ikan toman at RM 8.00/ kg; ikan baong at RM 12.00/ kg; and ikan kali at RM 12.00/ kg. Clearly, soft-shell turtle is the most expensive animal product (Table 6.2).

Occasionally I would find other turtle species for sale in "pet" sections of wet markets, alongside puppies, rabbits, and tropical fishes. These were often *Trachemys scripta*, native to North America and popular in the local pet trade, and also *Cuora amboinensis*. I observed these animals at the Satok, Kuching wet market along with the Daro wet market, and confirmed from photographs taken at the Sibu wet market in 2005, that *Cuora amboinensis* was being sold at that location. These animals were being sold between RM8.00 and RM10.00 per animal.

Turtles were also seen for sale in Kuching pet and aquarium shops. Species seen were *Cuora amboinensis*, *Pelodiscus sinensis*, *Carretochelys insculpta*, *Trachemys scripta*, and *Geochelone elegans*. In aquarium shops in Miri and Daro, I observed *Trachemys scripta* for sale. Other species noted in Sarawak pet shops have been *Chelydra serpentina*, *Indotestudo elongata* and *Malacochersus tornieri* (Das, pers com., 2006).

Interviews with turtle hunters and fishermen at longhouses indicate that *Amyda cartilaginea* is a prized food item. Some people, especially the Penan interviewed, use both the eggs and meat of the soft-shell turtles. In the more remote areas of Sarawak, hunting practices are generally traditional and have a long history. The most frequently used methods of catching turtles are either by baited hooks or by muddling for them during the dry season. I was told that muddling during the dry season may yield more turtles, although the effort is labour-intensive. I did not find anybody using dogs to locate forest turtles as they are known to do in the Indochinese countries (Espenshade III and Le, 2002; Holloway, 2003). Turtles are opportunistically taken in fishing nets, bubu, and selambau, and targeted along with fish by using hooks. Bait used varied across Sarawak, from chicken parts or pig parts to various fish. However, most turtle hunters agreed that the best bait was ikan kali. Other reptiles incidentally caught were water monitor lizard (*Varanus salvator*), elephant trunk snake (*Acrochordus javanicus*), puff-faced water snake (*Homalopsis buccata*), and the mangrove snake (*Boiga dendrophila*). The monitor lizards and elephant trunk snakes would always be kept for personal consumption or for sale. However, at least in Balai Ringin, mangrove snakes were disliked and were impaled on tree branches and left to rot. The only dog-faced water snake I saw, was on one of my sampling trips to Balai Ringin. It was found alive in the catch of a selembau and my guide wanted to sell it at the wet market, but I convinced him to let me release it downstream of the selambau.

Turtles in remote areas are used mainly for subsistence and in some cases, localized trade. I did not observe any evidence of medicinal or religious importance of turtles in Sarawak culture, but occasionally saw skeletal remains of turtles hanging in longhouses. See Appendix I, page 115 for a photo of soft-shell turtle skeletal remains from a longhouse and butchering of a turtle. In some cases, along the Tutoh River, soft-shell turtles are saved and sold to buyers from restaurants in Miri. In Balai Ringin and Serian, buyers from Kuching restaurants were seen purchasing soft-shell turtles.

Although this project focuses on Sarawak, it is interesting to note that consumption of freshwater turtles also occurs in Sabah. Hoybye-Mortensen (pers comm. 2005), stated that turtles were not hunted in Sabah. However, while on a trip in June 2005, I conducted three interviews that indicated just the opposite. In all three interviews, the people pointed out that labi-labi was a sought after item and one person stated that they also ate eggs of the labi-labi.

6.4 Discussion

Turtles appear to be a cash crop if caught and this may indicate market pressure on the animals. With a market price of RM24.00 to RM25.00/ kg, a small adult *Amyda cartilaginea* at 2 - 3 kg could be sold for RM48.00 to RM75.00. A study of wildlife use from 1995 (Abdullah, 1996), indicated that soft-shell turtles were being sold in Kuching for RM14.00 to RM16.00/ kg. It is interesting to note that in peninsular Malaysia, Sharma (1999) recorded *Amyda cartilaginea* was being sold at wet markets for RM 5.00 to RM 8.00/ kg. This increase in price in Sarawak, from between 36% to 41% in 10 years may be an indication of the increased rarity of the animal combined with the soft-shell turtles now being protected by law.

In addition to their monetary value, *Amyda cartilaginea* are attractive from a market perspective because they stay alive for days without food. Many people will place an opportunistically caught turtle in a basin or tank or water until there is a time to eat or sell. This is important in rural communities without refrigeration, or for fishermen on multi-day fishing trips and for shipping turtle to towns from upriver. Also, these turtles are a luxury item for those who have relocated to urban areas and may live more than a day's journey away from their rural homes but maintain cultural and dietary preferences from home. They continue to eat wild meat even when they have easily available alternatives (Bennett and Robinson, 2000). During interviews with residents from longhouses in the Bintulu area, some folks stated that it was easier to drive to Bintulu or Miri and purchase a soft-shell than to hunt them.

There are no records of the volume of the turtle trade in Sarawak and no historical records of population abundance of any non-marine turtle species. However, given the life history and ecology of most turtle species, it is doubtful whether present levels of exploitation are sustainable. Congdon *et al.* (1993) demonstrated that long-lived organisms such as turtles have life history traits that severely constrain the ability of populations to respond to disturbances such as overexploitation. These traits include delayed sexual maturity and often high and variable nest mortality. Population stability of turtles was most sensitive to changes in adult or juvenile survival and less sensitive to changes in age at sexual maturity, nest survival, or fecundity. They concluded that the concept of sustained harvest could not be applied to populations of long-lived animals.

Extirpation of these animals from the ecosystem also have negative effects on the biodiversity. These animals serve roles as seed dispersers, scavengers, predators, and prey in the forest and wetlands. Removal of a faunal or floral component from an ecosystem can disrupt its functioning (Gunderson and Holling, 2002; Odum, 1993).

Multiple studies around the world have pointed out the negative effects of hunting practices on wildlife (Alvard, 1994; Bennett and Robinson, 2000; Murray, 2003; Redford and

Robinson, 1991). Hunting wildlife to extirpation negatively effects human populations that depend on it and the resource must be replaced if people are to maintain familiar lifestyles.

Freshwater turtles and tortoises are clearly an important part of the local culture in Sarawak. Comprehensive surveys of the turtle trade in Sarawak is needed to determine the level of exploitation and if there is also export to the international wildlife market.

Table 6.1: Wet markets and dates of visits

Market	Date of Visit (dd/mm/yy)	Market	Date of Visit (dd/mm/yy)
Miri	25/10/03	Lundu	01/08/04
Satok, Kuching	08/11/03	Sematan	01/08/04
Sarikei	05/12/03	Satok, Kuching	12/09/04
Daro	06/12/03	Batu 7, Kuching	26/09/04
Mukah	06/12/03	Satok, Kuching	10/10/04
Bako	21/12/03	Batu 7, Kuching	24/10/04
Serikan	11/01/04	Miri	24/11/04
Serian	04/02/04	Lopok	26/11/04
Balai Ringin	04/02/04	Satok, Kuching	12/12/04
Simunjan	04/02/04	Tabuan Jaya, Kuching	16/12/05
Serian	08/02/04	Satok, Kuching	16/12/05
Balai Ringin	08/02/04	Miri	16/02/05
Tebedu	08/02/04	Lopok	26/02/05
Lopok	04/04/04	Bintulu	23/03/05
Balai Ringin	24/04/04 to 30/04/04	Miri	06/04/05
Balai Ringin	29/05/04 to 02/06/04	Lopok	17/04/05
Miri	06/07/04	Serikan	12/05/05
Lopok	12/07/04	Satok, Kuching	08/06/05

Table 6.2: Recent prices of animal products for food.

Animal Product	Price
Soft-shell Turtle	RM 24.00/ kg
Ikan Haruan	RM 8.00/ kg
Ikan Toman	RM 8.00/ kg
Ikan Baong	RM 12.00/ kg
Ikan Kali	RM 12.00/ kg
Chicken	RM 6.50/ kg
Pork	RM 5.00/ kg

Table 6.3: Longhouses/ camps and dates of visits.

Longhouse	Date of Visit (dd/mm/yy)
Penan Settlement, Mulu	29/10/03
Long Iman	29/10/03
Long Terawan	30/10/03
Long Panai	30/10/03
Long Sukang	13/11/03
Long Meran	16/04/04
Long Teru	18/07/04
Rumah Biol	20/03/05
Rumah Suran	20/03/05
Rumah Ngumbang	20/03/05
Gabung Camp	20/03/05
Long Pond Camp	21/03/05

CHAPTER 7

SUMMARY AND CONCLUSION AND RECOMMENDATIONS

7.1 Summary of Findings

All four specific objectives of the study have been achieved. This chapter presents and overview of results and recommendations.

7.1.1 Aspects of Field Biology

Capture rates for *Amyda cartilaginea* were extremely low. Out of 2,046 trap nights at LBNP, 14 *Amyda cartilaginea* were captured, representing a success rate of 0.54%. Out of 720 trap nights at Balai Ringin, five *Amyda cartilaginea* were captured, representing a success rate of 0.69%. Populations of this species may be at a crisis level in Sarawak. Very few hard-shell turtles were found during the course of the study. At LBNP, three *Cuora amboinensis* and seven *Cyclemys dentata* were captured. At Balai Ringin, one *Cyclemys dentata* and one *Heosemys spinosa* were captured.

In the analysis of effects of lunar phase, clearly a new moon has an effect on activities or movements of the turtles. Hard-shell turtles had the greatest capture rate during the full moon phase, indicating that some lunar illumination is necessary for foraging activity. Both *Amyda cartilaginea* and the hard-shell turtles favoured overcast weather versus clear skies or rain, for moving and foraging. Seasons did not have a dramatic affect on the capture rate of turtles. However, because capture rates were so low, it is unknown whether these correlations are significant. A larger and longer study using radio-telemetry is recommended.

Observations of reproductive biology, parasites, or scarring and injuries, was recorded. Three turtles were found to be gravid with eggs; one *Dogania subplana*, one *Cyclemys dentata*, and one *Heosemys spinosa*. Both ecto- and endoparasites were found among wild caught turtles. Leeches were found only on *Amyda cartilaginea* from Balai Ringin. *Heosemys spinosa* individuals from Matang were covered with ornate tick. Nematodes were found in some but not all turtles and not limited to locality. Of interesting note, is the one *Cyclemys dentata* who appeared to be scarred from a fire.

7.1.2 Morphometrics and Colour Patterns

Size classes of three species; *Amyda cartilaginea, Cuora amboinensis*, and *Cyclemys dentata* were represented in Chapter 4 by bar graphs (Figures 4.1 – 4.5). In each case, there was at least one size class of medium sized adults with no individuals. These results possibly indicate that animals are not living long enough to attain large size. However, it is possible more animals from Borneo should be measured to determine a true range of sizes and determine if there indeed is a lack of recruitment into the largest size classes.

Sexual size dimorphism exists in *Amyda cartilaginea*, with males being larger than females. This trait is also found in other large Asian soft-shell turtles. However, sexual size dimorphism was not statistically significant, perhaps an effect of skewed size of captured animals (equipment and techniques used biased towards medium-sized animals and the largest individuals trap-shy, or perhaps a result of past exploitation).

All allometric analyses indicate strong proportional changes with growth of all species. However, *Cyclemys dentata* stands out in that this species shows great variation among individuals. Some animals are flattened in shape while others are high domed.

Amyda cartilaginea from Borneo have a distinct series of black splotches and a black saddle band over a brown base colour on the carapace, unique from other patterns found on this species on the Asian continent.

7.1.3 Dietary Analysis

Dietary analysis of *Amyda cartilaginea* indicates that they an opportunistic omnivore. Those of *Cuora amboinensis* and *Cyclemys dentata* indicate that, indeed, they are herbivorous. Most interesting was the presence of primate phalange bones in the faeces of one *Heosemys spinosa*, although they are known for being predominately herbivorous in the wild. This information suggests that freshwater turtles play an important part in the food webs within peat swamp forests, through energy flow and nutrient cycling (omnivory, scavenging, and herbivory); dispersal of seeds (omnivory, scavenging, and herbivory) and maintaining water quality (scavenging).

7.1.4 Cultural and Commercial Use

Amyda cartilaginea is a prized food item in Sarawak culture. Surveys suggest that cultural use of turtles is high although they are protected by State legislation, but the level of commercial use for food is unclear. Pet trade in local and exotic turtles is active in Sarawak. Comprehensive surveys of the turtle trade in Sarawak are needed along with an assessment of current law enforcement effectiveness for future management and conservation decision making.

7.2 Conclusion

There have been no ecological studies prior to this on any freshwater turtles species on Borneo. This study provides baseline knowledge on some basic ecological attributes of *Amyda cartilaginea*. Additional notes on ecological attributes of nine other species from two families were opportunistically collected and also contribute new knowledge towards the ecology of turtles on Borneo.

As an opportunistic omnivore, *Amyda cartilaginea* plays an important role in the peat swamps of Borneo by cycling energy from both animal and plant material. The other species analysed for diet also contribute to the ecosystem by breaking down cellulose material into energy and also in seed dispersal. Scavenging behaviour, likely from *Amyda cartilaginea* and *Heosemys spinosa* is one of the more important aspects of nutrient cycling for both the wetlands and for human populations. Without scavengers, wetlands would become overloaded with nutrients and the subsequent eutrophication.

The colour patterns of *Amyda cartilaginea* found in Borneo are different than those found on the Asian continent. The current taxonomy groups animals from north-eastern India eastward across Asia and into the Malay archipelago as *Amyda cartilaginea.* It is believed that more than one species may exist within what is currently classified as one species. Phylogeographic research and additional ecological field research is needed to examine differences between animals found in Borneo and separated from the Asian continent to see if these are possibly different species as suspected. Also with *Cyclemys dentata*, some animals found in Sarawak have a high domed shell, differing from those purported to be the same species that have a flattened shell. Historically across Asia, what may be several species was grouped together as *Cyclemys dentata* by some basic morphometric and morphological attributes. With the advances in genetic analysis techniques, this species has been recommended to be reclassified as the *Cyclemys* complex until phylogeographic analysis is conducted.

The consumptive use of *Amyda cartilaginea* appears to be high in the rural areas and among the non-Muslim populations. The harvest rate of turtles in Sarawak along with any trafficking needs to be investigated.

7.3 Recommendations

Continued research is necessary for all species of freshwater turtles and tortoises found in Sarawak. Future studies of freshwater turtles should include population estimates for each species in Sarawak. This would require an extensive amount of time, as the best way to accomplish this would be with capture-mark recapture in a subset of different habitat types and then extrapolate this data to habitats across Sarawak. Information on reproductive biology from wild populations, for all species is still needed. Information on habitat use, home range and other life history requirements is needed and necessary for proper wildlife and reserve management.

Once a base-line inventory is established a long-term monitoring program should be implemented. Development of monitoring programs not only for freshwater turtles but for other keystone natural and physical resources should be a standard operation for resource managers. Long term monitoring provides early warning signals that indicate changes that could impair the long-term health of natural systems. Early detection of potential problems allows resource managers to take steps to restore ecological health of natural and physical resources before serious damage can happen. Long-term monitoring also notes positive trends, such as the case in the United States with the California gray whale (*Eschrichtius glaucus*). This species had been hunted to the brink of extinction. After creating legal protection, a long-term monitoring program began for the populations along the eastern Pacific. Recent results indicated that this species had recovered in numbers sufficient to allow native American tribes from this region, to restore traditional hunting practices of this species.

Effective conservation of freshwater turtles and tortoises in Sarawak will first require an understanding of the level of use and any trafficking. An involvement of various groups can work for increased law enforcement and the development and productions of substitutes to wild-caught turtles such as farming. Community education is needed to influence the attitudes of consumers and the provision of knowledge and methods for those hunting and eating turtles to convert to a more sustainable form of development and production.

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Leven in Zeer Kundig Artz, Lid van het Koninglijk Genoodschap te London, en van het Zeeuwsche Genoodschap der Wetenschappen te Vlissingen/Petri Boddaert, Medicinae Dosctoris, Urbis Flissingae exconsiliarii, Societatis Zeelandicae scientiarum, quae Flissingae est, Socii, Epistola ad virum amplissimum W. Roëll, Medicinæ Doctorem, urbis Amstelodami Commissarium, Societatis Indicae Occidentalis Moderatorem, Societatis Surinamensis Directorem Sagacissimum de testudine cartilaginea, descripta atque accuratissima icone illustrata ex Museo viri Celeberrimi Johannis Alberti Schlosseri, dum in vivis esset Medicinæ Doctoris expertissimi, Societatis regiæ Londinensis, atque Societatis Zeelandicæ quæ Flissengæ est, Socii. Cornelium van Tongerlo, Amstelodami (= Amsterdam). (4) + 39 (+ 1 = errata) pp; 1 pl. (*Testudo cartilaginea.*) Note: This is a bilingual work, with the title appearing in both languages (Dutch and Latin) on separate pages.

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APPENDIX I
Photographs

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Upper left: Muddling for turtles in the peat swamp forest.

Lower left: Typical habitat for *Amyda cartilaginea.*

Right: An adult *Amyda cartilaginea.* Note the black saddle and splotches over a dark brown carapace. Unique to Borneo.

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Upper left: Female *Amyda cartilaginea.* Note the tail length, shorter than that of a male. Also, note the dark brown plastron and scratches. This plastron colour is atypical for an *Amyda cartilaginea* found in Sarawak.

Lower Left: Male *Amyda cartilaginea.* Note the long tail, distinctive for a male of this species. Also, note the typical off-white plastron colouration with grey speckling.

Upper right: A juvenile *Cuora amboinensis.*

Lower right: A juvenile *Cyclemys dentata.*

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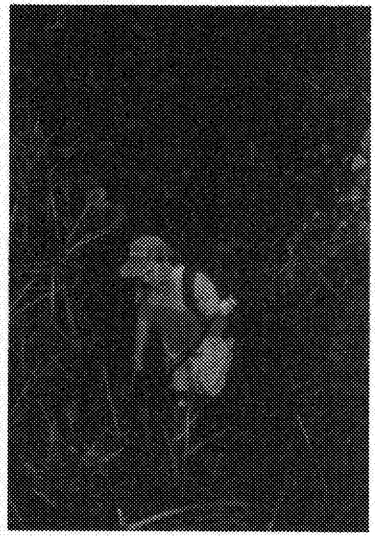
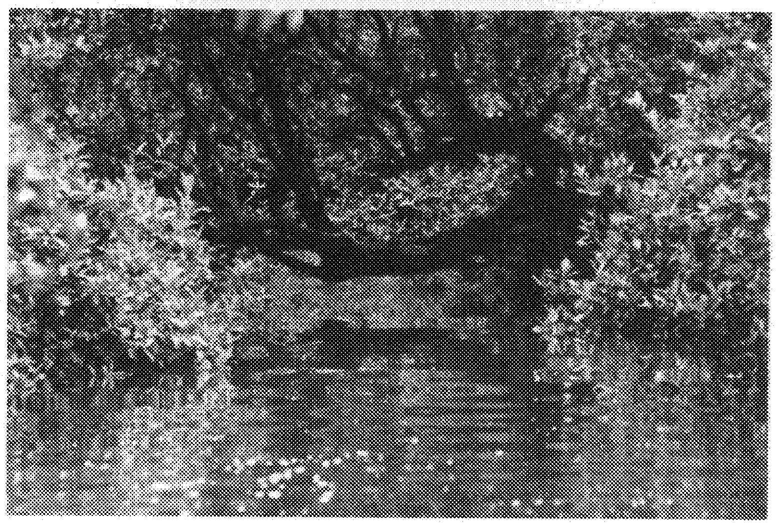
Upper left: A juvenile *Heosemys spinosa*

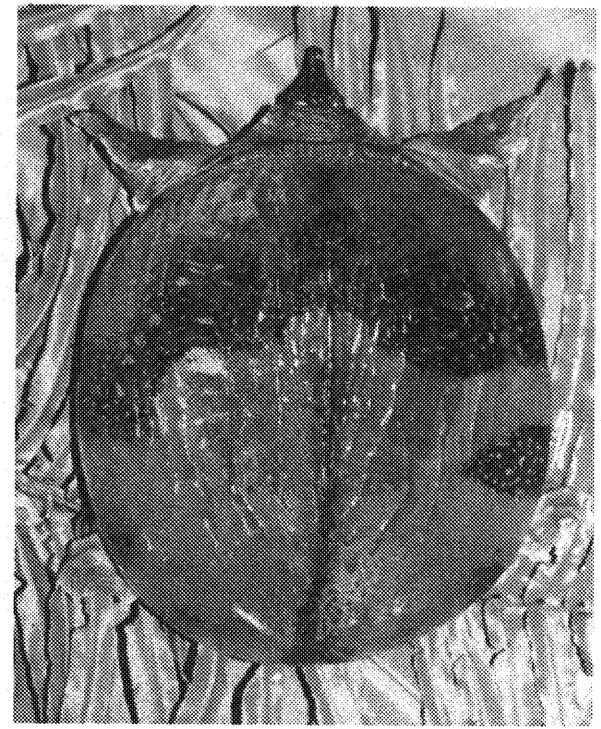
Lower left: An adult *Notochelys platynota.*

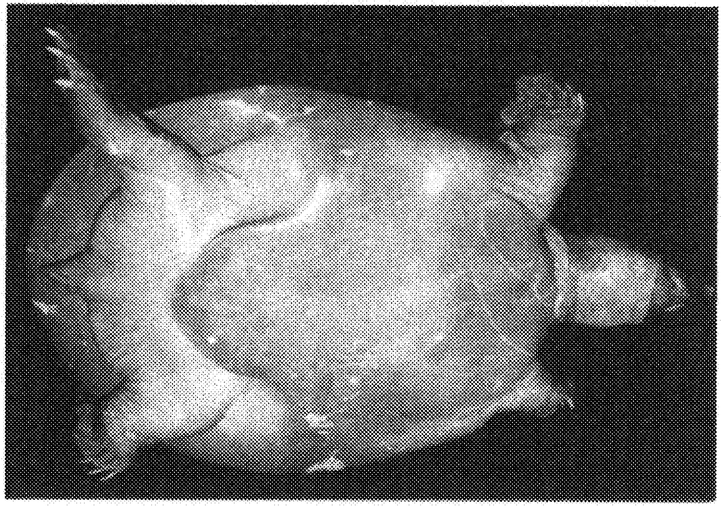
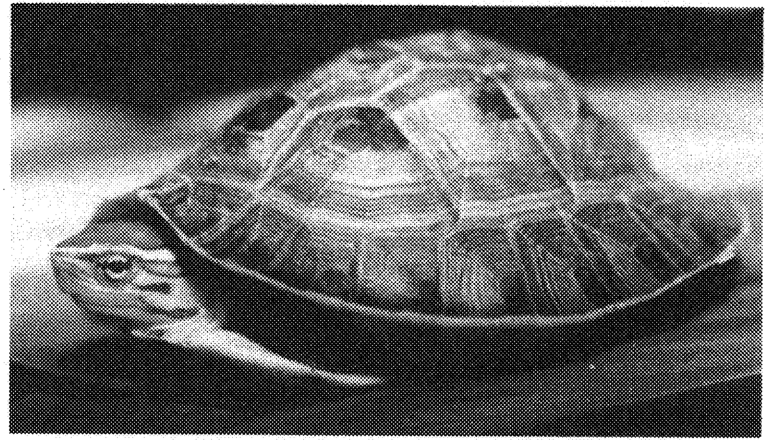
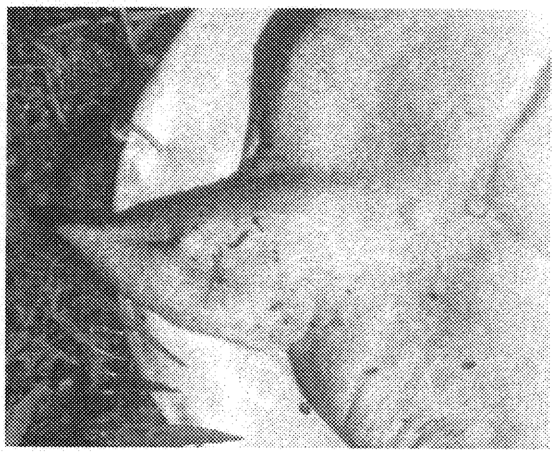
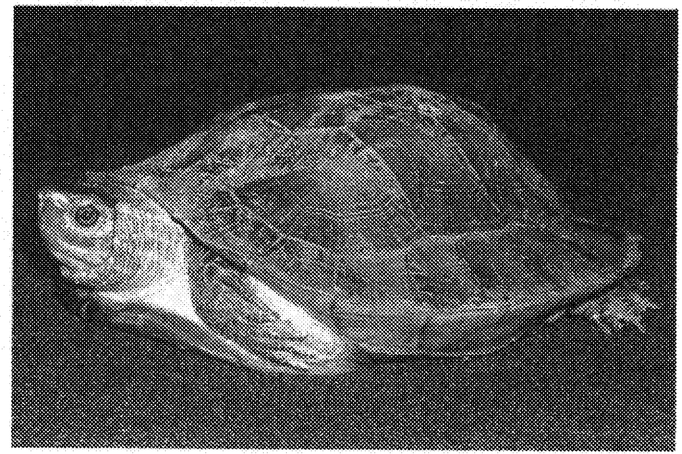
Upper right: The remains of an adult *Amyda cartilaginea* found behind a longhouse in Sarawak.

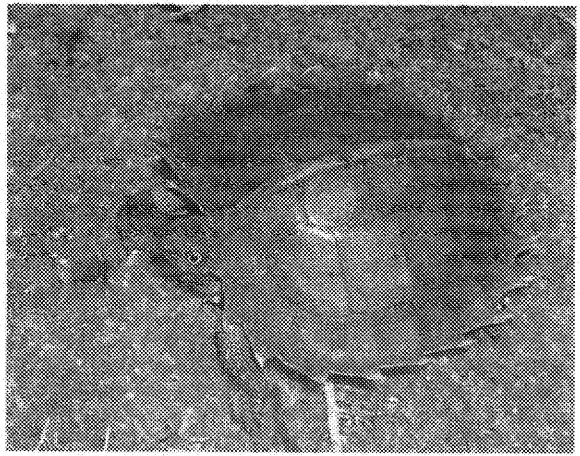
Lower right: At a longhouse somewhere in Sarawak. Turtles are a prized food source.

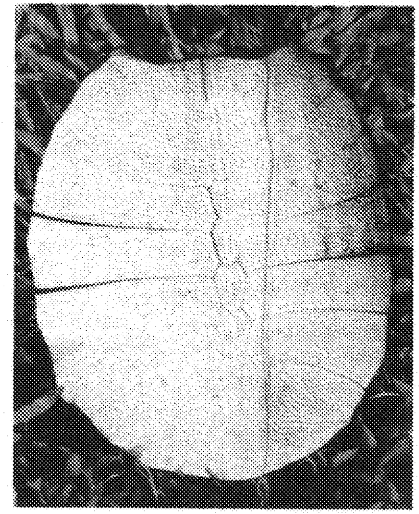


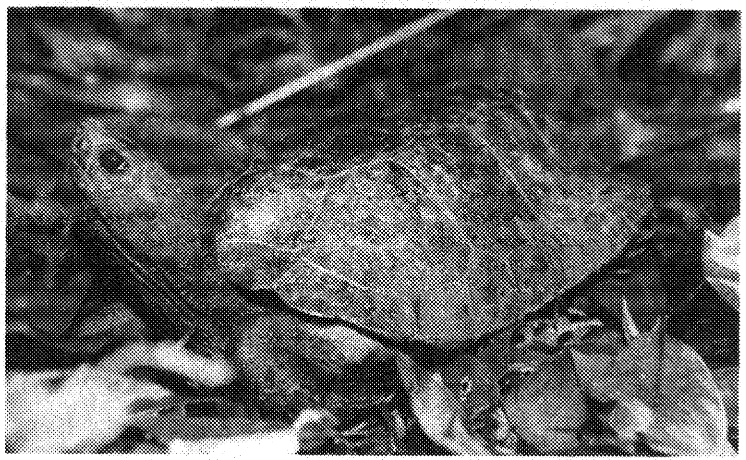


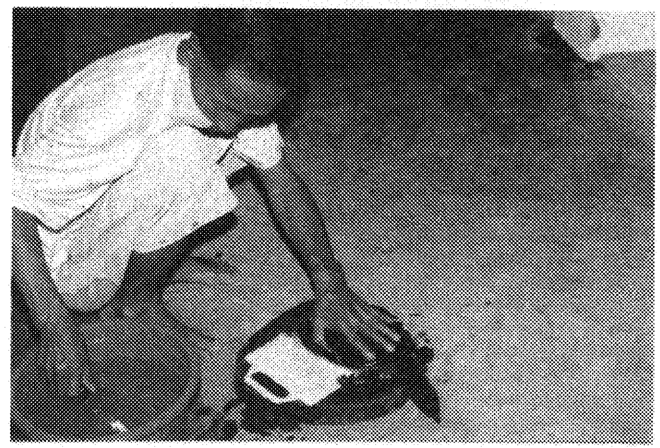










APPENDIX II

MORPHOMETRIC ANALYSIS

Mann-Whitney U-Test: *Amyda cartilaginea* male SCL and female SCL
male SCL N = 10 Median = 245.0
female S N = 19 Median = 223.0
Point estimate for ETA1-ETA2 is 18.0
95.4 Percent CI for ETA1-ETA2 is (-49.0,75.1)
W = 159.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.6796
The test is significant at 0.6796 (adjusted for ties)

Cannot reject at alpha = 0.05

Mann-Whitney U-Test: *Amyda cartilaginea* male SCW, female SCW
Male SCW N = 10 Median = 222.5
Female S N = 19 Median = 201.0
Point estimate for ETA1-ETA2 is 20.0
95.4 Percent CI for ETA1-ETA2 is (-39.0,65.0)
W = 164.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.5356
The test is significant at 0.5356 (adjusted for ties)

Cannot reject at alpha = 0.05

Mann-Whitney U-Test: *Amyda cartilaginea* male SH, female SH
Male SH N = 9 Median = 68.00
Female S N = 17 Median = 63.00
Point estimate for ETA1-ETA2 is 5.00
95.4 Percent CI for ETA1-ETA2 is (-10.99,22.01)
W = 137.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.4188
The test is significant at 0.4186 (adjusted for ties)

Cannot reject at alpha = 0.05

Regression Analysis: *Amyda cartilaginea* SCW/SCL versus SCL
The regression equation is
SCW/SCL = 0.924677 - 0.0002593 Amyda SCL

S = 0.0420170 R-Sq = 43.2 % R-Sq(adj) = 42.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.061772	0.0617717	34.9897	0.000
Error	46	0.081210	0.0017654		
Total	47	0.142981			

Regression Analysis: *Amyda cartilaginea* SCW/SCL versus Log10 SCL

The regression equation is
SCW/SCL = 1.14877 - 0.124107 Log10 SCL

S = 0.0447738   R-Sq = 35.5 %   R-Sq(adj) = 34.1 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.050765	0.0507654	25.3233	0.000
Error	46	0.092216	0.0020047		
Total	47	0.142981			

Regression Analysis: *Amyda cartilaginea* AsinSCW/SCL versus Log10 SCL
The regression equation is
ARCSine = 1.61705 - 0.245436 Log10 SCL

S = 0.0919520   R-Sq = 33.8 %   R-Sq(adj) = 32.4 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.198543	0.198543	23.4818	0.000
Error	46	0.388937	0.008455		
Total	47	0.587480			

Regression Analysis: *Amyda cartilaginea* SH/SCL versus SCL
The regression equation is
SH/SCL = 0.296033 - 0.0000813 Amyda SCL_1

S = 0.0289235   R-Sq = 14.1 %   R-Sq(adj) = 12.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0056449	0.0056449	6.74769	0.013
Error	41	0.0342993	0.0008366		
Total	42	0.0399442			

Regression Analysis: *Amyda cartilaginea* SH/SCL versus Log10 SCL
The regression equation is
SH/SCL = 0.395528 - 0.0515657 Log10 SCL_1

S = 0.0282411   R-Sq = 18.1 %   R-Sq(adj) = 16.1 %
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0072442	0.0072442	9.08292	0.004
Error	41	0.0327000	0.0007976		
Total	42	0.0399442			

Regression Analysis: *Amyda cartilaginea* Asin SH/SCL versus Log10 SCL

The regression equation is
ARCSINE SH/S = 0.403814 - 0.0535123 Log10 SCL_1

S = 0.0293417   R-Sq = 18.1 %   R-Sq(adj) = 16.1 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0078014	0.0078014	9.06162	0.004
Error	41	0.0352982	0.0008609		
Total	42	0.0430997			

Regression Analysis: *Cuora amboinensis* SCW/SCL versus SCL
The regression equation is
SCW/SCL = 6.85487 + 0.0169679 Str.CaraLeng

S = 4.98507   R-Sq = 2.9 %   R-Sq(adj) = 0.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	13.153	13.1534	0.529291	0.476
Error	18	447.317	24.8509		
Total	19	460.470			

Regression Analysis: *Cuora amboinensis* SCW/SCL versus LOG 10 SCL
The regression equation is
SCW/SCL = 3.68129 + 2.55875 LOG 10 SCL

S = 5.03092   R-Sq = 1.1 %   R-Sq(adj) = 0.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	4.886	4.8863	0.193058	0.666
Error	18	455.584	25.3102		
Total	19	460.470			

Regression Analysis: *Cuora amboinensis* SCW/SCL versus LOG 10 SCL
The regression equation is
SCW/SCL = 1.16342 - 0.164640 LOG 10 SCL

S = 0.0522758   R-Sq = 29.1 %   R-Sq(adj) = 25.2 %
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0202302	0.0202302	7.40285	0.014
Error	18	0.0491898	0.0027328		
Total	19	0.0694200			

Regression Analysis: *Cuora amboinensis* Asin SCW/SCL versus LOG 10 SCL

The regression equation is
ARCSINE = 1.54673 - 0.276234 LOG 10 SCL

S = 0.0978696   R-Sq = 24.8 %   R-Sq(adj) = 20.7 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.056949	0.0569487	5.94549	0.025
Error	18	0.172412	0.0095785		
Total	19	0.229361			

Regression Analysis: *Cuora amboinensis* SH/SCL versus SCL
The regression equation is
SH/SCL = 0.508685 - 0.0004475 Str.CaraLeng

S = 0.0494386   R-Sq = 17.0 %   R-Sq(adj) = 12.1 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0085122	0.0085122	3.48265	0.079
Error	17	0.0415510	0.0024442		
Total	18	0.0500632			

Regression Analysis: *Cuora amboinensis* SH/SCL versus LOG 10 SCL
The regression equation is
SH/SCL = 0.681809 - 0.111192 LOG_ 10 SCL

S = 0.0493295   R-Sq = 17.4 %   R-Sq(adj) = 12.5 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0086953	0.0086953	3.57333	0.076
Error	17	0.0413678	0.0024334		
Total	18	0.0500632			

Regression Analysis: *Cuora amboinensis* AsinSH/SCL versus LOG 10 SCL
The regression equation is
ARCSINE SH/S = 0.725764 - 0.123831 LOG_ 10 SCL

S = 0.0545950   R-Sq = 17.5 %   R-Sq(adj) = 12.7 %
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0107845	0.0107845	3.61820	0.074
Error	17	0.0506705	0.0029806		
Total	18	0.0614549			

Regression Analysis: *Cyclemys dentata* SCW/SCL versus SCL

The regression equation is
SCW/SCL = 1.01010 - 0.0011520 Str.CaraLeng

S = 0.102598   R-Sq = 35.7 %   R-Sq(adj) = 33.8 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.198727	0.198727	18.8791	0.000
Error	34	0.357895	0.010526		
Total	35	0.556622			

Regression Analysis: *Cyclemys dentata* SCW/SCL versus LOG 10 SCL
The regression equation is
SCW/SCL = 1.50417 - 0.314297 LOG 10 SCL

S = 0.103051   R-Sq = 35.1 %   R-Sq(adj) = 33.2 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.195559	0.195559	18.4150	0.000
Error	34	0.361064	0.010620		
Total	35	0.556622			

Regression Analysis: *Cyclemys dentata* AsinSCW/SCL versus LOG 10 SCL
The regression equation is
ARCSINE SCW/ = 2.31314 - 0.598464 LOG 10 SCL

S = 0.183561   R-Sq = 38.2 %   R-Sq(adj) = 36.4 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.70904	0.709042	21.0431	0.000
Error	34	1.14562	0.033695		
Total	35	1.85466			

Regression Analysis: *Cyclemys dentata* SH/SCL versus SCL
The regression equation is
SH/SCL = 0.403595 + 0.0000823 Str.CaraLeng

S = 0.108548   R-Sq = 0.2 %   R-Sq(adj) = 0.0 %
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.000712	0.0007123	6.05E-02	0.807
Error	32	0.377044	0.0117826		
Total	33	0.377756			

Regression Analysis: *Cyclemys dentata* SH/SCL versus Log10 SCL

The regression equation is
SH/SCL = 0.374845 + 0.0190400 Log10 SCL

S = 0.108566   R-Sq = 0.2 %   R-Sq(adj) = 0.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.000582	0.0005823	4.94E-02	0.826
Error	32	0.377174	0.0117867		
Total	33	0.377756			

Regression Analysis: *Cyclemys dentata* AsinSH/SCL versus Log10 SCL
The regression equation is
ARCSINE SH/S = 0.419175 + 0.0058302 Log10 SCL

S = 0.142515   R-Sq = 0.0 %   R-Sq(adj) = 0.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.000055	0.0000546	2.69E-03	0.959
Error	32	0.649941	0.0203106		
Total	33	0.649995			

Regression Analysis: *Heosemys spinosa* SCW/SCL versus SCL
The regression equation is
SCW/SCL = 1.21368 - 0.0021883 Str.CaraLeng

S = 0.0293250   R-Sq = 93.5 %   R-Sq(adj) = 92.4 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0743278	0.0743278	86.4319	0.000
Error	6	0.0051597	0.0008600		
Total	7	0.0794875			

Regression Analysis: *Heosemys spinosa* SCW/SCL versus LOG 10 SCL
The regression equation is
SCW/SCL = 2.30354 - 0.660664 LOG 10 SCL

S = 0.0284680   R-Sq = 93.9 %   R-Sq(adj) = 92.9 %
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0746249	0.0746249	92.0807	0.000
Error	6	0.0048626	0.0008104		
Total	7	0.0794875			

Regression Analysis: *Heosemys spinosa* Asin SCW/SCL versus LOG 10 SCL

The regression equation is
ARCSINE SCW/ = 5.12528 - 1.84464 LOG 10 SCL

S = 0.0640120   R-Sq = 86.4 %   R-Sq(adj) = 83.6 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.129857	0.129857	31.6916	0.002
Error	5	0.020488	0.004098		
Total	6	0.150345			

Regression Analysis: *Heosemys spinosa* SH/SCL versus SCL
The regression equation is
SH/SCL = 0.497298 - 0.0003165 Str.CaraLeng

S = 0.0324209   R-Sq = 22.4 %   R-Sq(adj) = 6.9 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0015159	0.0015159	1.44215	0.284
Error	5	0.0052556	0.0010511		
Total	6	0.0067714			

Regression Analysis: *Heosemys spinosa* SH/SCL versus LOG 10 SCL
The regression equation is
SH/SCL = 0.621662 - 0.0803886 LOG10 SCL

S = 0.0337618   R-Sq = 15.8 %   R-Sq(adj) = 0.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0010721	0.0010721	0.940568	0.377
Error	5	0.0056993	0.0011399		
Total	6	0.0067714			

Regression Analysis: *Heosemys spinosa* Asin SH/SCL versus LOG 10 SCL
The regression equation is
ARCSINE SH/S = 0.656202 - 0.0886089 LOG10 SCL

S = 0.0375117   R-Sq = 15.6 %   R-Sq(adj) = 0.0 %
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0013026	0.0013026	0.925710	0.380
Error	5	0.0070356	0.0014071		
Total	6	0.0083382			

Correlations: *Heosemys spinosa* SCW vs. SCL

Correlations

		VAR00001	VAR00002
VAR00001	Pearson Correlation	1.000	.988*
	Sig. (2-tailed)	.	.000
	N	8	8
VAR00002	Pearson Correlation	.988**	1.000
	Sig. (2-tailed)	.000	.
	N	8	8

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations: *Heosemys spinosa* SH vs. SCL

Correlations

		VAR00005	VAR00006
VAR00005	Pearson Correlation	1.000	.960*
	Sig. (2-tailed)	.	.001
	N	7	7
VAR00006	Pearson Correlation	.960**	1.000
	Sig. (2-tailed)	.001	.
	N	7	7

**. Correlation is significant at the 0.01 level (2-tailed).

Regression Analysis: *Notochelys platynota* SCW/SCL versus SCL
The regression equation is
SCW/SCL = 0.749541 + 0.0004738 Str.CaraLeng

S = 0.0881392 R-Sq = 2.7 % R-Sq(adj) = 0.0 %

Analysis of Variance

Source DF SS MS F P
Regression 1 0.0008592 0.0008592 0.110606 0.756
Error 4 0.0310741 0.0077685
Total 5 0.0319333

Regression Analysis: *Notochelys platynota* SCW/SCL versus LOG 10 SCL
The regression equation is
SCW/SCL = 0.519279 + 0.140008 LOG 10 SCL

S = 0.0887091 R-Sq = 1.4 % R-Sq(adj) = 0.0 %
Analysis of Variance
Source DF SS MS F P
Regression 1 0.0004561 0.0004561 5.80E-02 0.822
Error 4 0.0314772 0.0078693
Total 5 0.0319333
Regression Analysis: *Notochelys platynota* Asin SCW/SCL versus LOG 10 SCL

The regression equation is
ARCSINE SCW/ = 0.0797905 + 0.410377 LOG 10 SCL

S = 0.168627   R-Sq = 3.3 %   R-Sq(adj) = 0.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.003919	0.0039187	0.137812	0.729
Error	4	0.113740	0.0284350		
Total	5	0.117659			

Regression Analysis: *Notochelys platynota* SH/SCL versus SCL
The regression equation is
SH/SCL = 0.340663 + 0.0002624 Str.CaraLeng

S = 0.0411913   R-Sq = 4.3 %   R-Sq(adj) = 0.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0002298	0.0002298	0.135459	0.737
Error	3	0.0050902	0.0016967		
Total	4	0.0053200			

Regression Analysis: *Notochelys platynota* SH/SCL versus LOG10 SCL
The regression equation is
SH/SCL = 0.223999 + 0.0725537 LOG10 SCL

S = 0.0416900   R-Sq = 2.0 %   R-Sq(adj) = 0.0 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0001058	0.0001058	6.09E-02	0.821
Error	3	0.0052142	0.0017381		
Total	4	0.0053200			

Regression Analysis: *Notochelys platynota* Asin SH/S versus LOG 10 SCL
The regression equation is
ARCSINE SH/S = 0.215597 + 0.0810429 LOG10 SCL
S = 0.0451570   R-Sq = 2.1 %   R-Sq(adj) = 0.0 %
Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0001320	0.0001320	6.48E-02	0.816
Error	3	0.0061175	0.0020392		
Total	4	0.0062495			

Correlations: *Notochelys platynota* SCW vs. SCL

Correlations

		VAR00001	VAR00002
VAR00001	Pearson Correlation	1.000	.874*
	Sig. (2-tailed)	.	.023
	N	6	6
VAR00002	Pearson Correlation	.874*	1.000
	Sig. (2-tailed)	.023	.
	N	6	6

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations: *Notochelys platynota* SH vs. SCL

Correlations

		VAR00005	VAR00006
VAR00005	Pearson Correlation	1.000	.889*
	Sig. (2-tailed)	.	.044
	N	5	5
VAR00006	Pearson Correlation	.889*	1.000
	Sig. (2-tailed)	.044	.
	N	5	5

*. Correlation is significant at the 0.05 level (2-tailed).

DIETARY ANALYSIS *Amyda cartilaginea*

Correlations: Identifiable Prey Items in the Stomach & Body Mass

Correlations

		MASS	ID-PreyS
MASS	Pearson Correlation	1.000	-.313
	Sig. (2-tailed)	.	.412
	N	9	9
ID-PreyS	Pearson Correlation	-.313	1.000
	Sig. (2-tailed)	.412	.
	N	9	9

Correlations: Volume of Stomach Contents & Body Mass

Correlations

		MASS	Vol-Stom
MASS	Pearson Correlation	1.000	-.518
	Sig. (2-tailed)	.	.153
	N	9	9
Vol-Stom	Pearson Correlation	-.518	1.000
	Sig. (2-tailed)	.153	.
	N	9	9

Correlations: Identifiable Prey Items in Faeces & Body Mass

Correlations

		Mass	ID-PreyF
Mass	Pearson Correlation	1.000	.005
	Sig. (2-tailed)	.	.987
	N	13	13
ID-PreyF	Pearson Correlation	.005	1.000
	Sig. (2-tailed)	.987	.
	N	13	13

Correlations: Volume of Faeces Contents & Body Mass

Correlations

		Mass	Vol-Faec
Mass	Pearson Correlation	1.000	-.101
	Sig. (2-tailed)	.	.742
	N	13	13
Vol-Faec	Pearson Correlation	-.101	1.000
	Sig. (2-tailed)	.742	.
	N	13	13

APPENDIX III
Raw Data

Amyda cartilaginea

Field Number	Date	Location	Wild	Gender	Lunar Phase	Weather	Season	SCL	SCW	SH
KJ-1	27/10/03	Sungei Melenau/Mulu	y	male	new	cloudy	Non Monsoon	246	234	51
KJ-2	29/10/03	sungei Tutong/Mulu	n	juvenile				47	45	
KJ-5	30/10/03	sungei tutoh/LongPanai	n	unk				400	316	99
KJ-6	30/10/03	sungei tutoh/LongPanai	n	unk				482	376	100
KJ-7	30/10/03	sungei tutoh/LongPanai	n	unk				601	484	181
KJ-10	30/10/03	sungei tutoh/LongTerawan	n	unk				221	204	57
KJ-16	5/12/2003	Sarikei	n	unk				208	170	58
KJ-17	4/2/2004	Balai Ringin	y	female	full	cloudy	Northeast	220	201	
KJ-18	4/2/2004	Simunjon	n	female				238	224	
KJ-22	5/4/2004	Loagan Bunut	y	juvenile	full	rain	Non Monsoon	77	69	
KJ-23	29/4/04	Balai Ringin	y	female	1st quarter	rain	Non Monsoon	348	279	87
KJ-24	30/4/04	Bala Ringin	y	female	1st quarter	rain	Non Monsoon	209	182	54
KJ-25	4/2/2004	Simunjon	n	male				151	143	
KJ-28	7/7/2004	Loagan Bunut	y	male	last quarter	cloudy	Southwest	244	211	59
KJ-29	7/7/2004	Loagan Bunut	y	male	last quarter	cloudy	Southwest	193	177	59
KJ-31	7/6/2004	Balai Ringin	y	female	last quarter	cloudy	Southwest	526	370.4	110.5
KJ-32	10/6/2004	Balai Ringin	y	juvenile	last quarter	clear	Southwest	133	117	39
KJ-33	10/7/2004	Loagan Bunut	y	juvenile	last quarter	clear	Southwest	85	82	24
KJ-34	15/7/04	Loagan Bunut	y	female	new	cloudy	Southwest	255	225	68
KJ-35	17/7/04	Loagan Bunut	y	male	new	cloudy	Southwest	308	261	74
KJ-47	26/01/05	SM-KCH	museum	juvenile				112	99	33
KJ-48	26/01/05	SM-KCH	museum	juvenile				102	95	30
KJ-49	26/01/05	SM-KCH	museum	juvenile				105	89	31
KJ-50	26/01/05	SM-KCH	museum	juvenile				53	49	16
KJ-51	26/01/05	SM-KCH	museum	juvenile				142	118	33
KJ-52	26/01/05	SM-KCH	museum	juvenile				96	83	28
KJ-53	26/01/05	SM-KCH	museum	juvenile				75	66	23

Field Number	Date	Location	Wild	Gender	Lunar Phase	Weather	Season	SCL	SCW	SH
KJ-54	26/01/05	SM-KCH	museum	juvenile				86	72	25
KJ-55	26/01/05	SM-KCH	museum	juvenile				117	101	38
KJ-67	26/01/05	SM-KCH	museum	juvenile				102	86	30
KJ-75	26/01/05	SM-KCH	museum	female				155	136	48
KJ-76	26/01/05	SM-KCH	museum	female				144	125	40
KJ-77	26/01/05	SM-KCH	museum	female				125	112	37
KJ-82	18/02/05	LBNP	y	female	1st quarter	cloudy	Northeast	232	208	62
KJ-83	19/02/05	LBNP	y	female	1st quarter	cloudy	Northeast	293	254	84
KJ-84	21/02/05	LBNP	y	female	full	rain	Northeast	256	219	75
KJ-85	22/02/05	LBNP	y	female	full	cloudy	Northeast	210	187	57
KJ-86	24/02/05	LBNP	y	female	full	rain	Northeast	338	285	85
KJ-108	20/03/05	Bintulu/Rumah Biol	n	female				207	183	46
KJ-109	20/03/05	Bintulu/Rumah Bial	n	male				293	252	85
KJ-112	20/03/05	Bintulu/Rumah Suran	n	female				194	175	56
KJ-119	20/03/05	Bintulu/Rh. Ngumbang	n	female				220	172	63
KJ-120	20/03/03	Bintulu/Rh. Ngumbang	n	female				223	183	65
KJ-126	8/4/2005	LBNP	y	male	new	cloudy	Non Monsoon	284	242	79
KJ-127	14/04/05	LBNP	y	male	last quarter	cloudy	Non Monsoon	231	209	68
KJ-128	17/04/05	LBNP	y	male	last quarter	clear	Non Monsoon	190	166	66
KJ-140	7/10/2005	SM-KCH	museum	female				490	368	145
KJ-144	7/10/2005	KCH/ Charles Leh	museum	male				664	524	182

Cuora amboinensis

Field Number	Date	Location	Wild	Gender	Lunar Phase	Weather	Season	SCL	SCW	SH
KJ-3	30/10/03	Sungei Melenau/Mulu	n	male				144	134	45
KJ-8	30/10/03	sungei tutoh/LongPanai	n	male				139	105	54
KJ-15	31/10/03	Sungei Melenau/Mulu	n	female				136	124	66
KJ-20	31/3/04	Loagan Bunut	n	female				176	145	
KJ-37	17/7/04	Loagan Bunut	y	juvenile	New	Cloudy	Southwest	77	67	38
KJ-39	25/11/04	LBNP	y	juvenile	Full	Cloudy	Northeast	160	132	80
KJ-42	2/12/2004	LBNP	y	juvenile	Last Quarter	Cloudy	Northeast	117	104	56
KJ-61	26/01/05	SM-KCH	museum	juvenile				71	61	34
KJ-62	26/01/05	SM-KCH	museum	juvenile				62	55	29
KJ-63	26/01/05	SM-KCH	museum	juvenile				60	53	29
KJ-68	26/01/05	SM-KCH	museum	juvenile				77	64	40
KJ-69	26/01/05	SM-KCH	museum	juvenile				66	56	34
KJ-70	26/01/05	SM-KCH	museum	juvenile				61	52	29
KJ-71	26/01/05	SM-KCH	museum	juvenile				54	45	24
KJ-114	20/03/05	Bintulu/Rumah Suran	n	female				170	131	70
KJ-115	20/03/05	Bintulu/Rumah Ngumbang	n	female				173	135	81
KJ-116	20/03/05	Bintulu/Rumah Ngumbang	n	female				174	131	83
KJ-125	21/03/05	Bintulu	n	male				169	121	67
KJ-133	7/10/2005	SM-KCH	museum	unk				187	138	84
KJ-141	7/10/2005	SM-KCH	museum	unk				149	116	59

Cyclemys dentata

Field Number	Date	Location	Wild	Gender	Lunar Phase	Weather	Season	SCL	SCW	SH
KJ-4	30/10/03	Sungei Melenau/Mulu	n	m				124	103	55
KJ-9	30/10/03	sungei tutoh/LongPanai	n	male				154	115	114
KJ-21	5/4/2004	Loagan Bunut	y	female	full	rain	non monsoon	209	178	
KJ-30	30/5/04	Balai Ringin (sungei Great)	y	female	full	cloudy	non monsoon	210	160	85
KJ-36	17/7/04	Loagan Bunut	y	juvenile	new	cloudy	southwest	87	82	34
KJ-38	17/7/04	Loagan Bunut	y	unk/ carapace				292	223	
KJ-40	25/11/04	LBNP	y	juvenile	full	cloudy	northeast	130	118	47
KJ-41	25/11/04	LBNP	y	juvenile	full	cloudy	northeast	140	132	55
KJ-43	2/12/2004	LBNP	y	juvenile	last quarter	cloudy	northeast	68	64	24
KJ-44	26/01/05	SM-KCH	museum	juvenile				75	75	32
KJ-45	26/01/05	SM-KCH	museum	juvenile				57	54	21
KJ-46	26/01/05	SM-KCH	museum	juvenile				52	50	19
KJ-56	26/01/05	SM-KCH	museum	juvenile				59	52	22
KJ-57	26/01/05	SM-KCH	museum	juvenile				73	69	29
KJ-58	26/01/05	SM-KCH	museum	juvenile				67	63	25
KJ-59	26/01/05	SM-KCH	museum	juvenile				69	65	27
KJ-60	26/01/05	SM-KCH	museum	juvenile				50	47	19
KJ-64	26/01/05	SM-KCH	museum	juvenile				74	68	28
KJ-65	26/01/05	SM-KCH	museum	juvenile				54	53	19
KJ-66	26/01/05	SM-KCH	museum	juvenile				55	52	20
KJ-72	26/01/05	SM-KCH	museum	juvenile				57	51	20
KJ-73	26/01/05	SM-KCH	museum	juvenile				56	54	20
KJ-78	26/01/05	SM-KCH	museum	juvenile				50	44	44
KJ-80	26/01/05	SM-KCH	museum	juvenile						
KJ-87	24/02/05	Mentawai	museum	unk				61.3	56.4	19.5
KJ-88	24/02/05	Mentawai	museum	unk				98.4	91.9	35.5
KJ-89	24/02/05	Mentawai	museum	unk				95.4	86.8	33.4

Field Number	Date	Location	Wild	Gender	Lunar Phase	Weather	Season	SCL	SCW	SH
KJ-90	24/02/05	Mentawai	museum	unk				81.9	78.1	29
KJ-91	24/02/05	sungei sadong	museum	unk				72.9	67.1	24.9
KJ-92	24/02/05	pontianak	museum	unk				64.2	59.7	25.7
KJ-93	24/02/05	Brunei	museum	unk				67.5	63.3	27.8
KJ-94	24/02/05	bako National Park	museum	unk				60.5	58.7	24.3
KJ-95	24/02/05	pontianak	museum	unk				57.1	55.1	22.1
KJ-96	24/02/05	sungei Sambas,Kalimantan	museum	unk				102	94.3	46.6
KJ-97	24/02/05	Johor	museum	unk				111.5	99.5	46.5
KJ-98	24/02/05	Riau, Indon	museum	unk				104	95.6	42.5
KJ-99	24/02/05	Riau, Indon	museum	unk				111.6	100.5	42.2
KJ-100	24/02/05	Singapore	museum	unk				155.5	120.7	75.4
KJ-101	24/02/05	Singapore	museum	unk				162.4	126.4	60.7
KJ-102	24/02/05	Johor	museum	unk				115.4	105	46.3
KJ-103	24/02/05	Johor	museum	unk				112.7	102.1	41.2
KJ-104	24/02/05	Johor	museum	unk				159.6	122.8	64.4
KJ-105	24/02/05	Johor	museum	unk				115.5	109.3	46
KJ-106	24/02/05	Johor	museum	unk				144.3	131.8	56.7
KJ-110	20/03/05	Bintulu/Log Pond	n	unk				179	50	76
KJ-111	20/03/05	Bintulu/Rumah Suran	n	unk				142	142	49
KJ-113	20/03/05	Bintulu/Rumah Suran	n	m				176	147	78
KJ-118	20/03/05	Bintulu/Rh. Ngumbang	n	m				192	160	80
KJ-121	20/03/05	Bintulu/Rh. Ngumbang	n	female				200	161	75
KJ-135	7/10/2005	SM-KCH		unk				204	160	87
KJ-143	7/10/05	SM-KCH		unk				217	164	74

Heosemys spinosa

Field Number	Date	Location	Wild	Gender	Lunar Phase	Weather	Season	SCL	SCW	SH
KJ-26	8/2/2004	Balai Ringin	y	m	full	cloudy	northeast	184	146	
KJ-117	20/03/05	Bintulu/Gabung Camp	n	female				124	120	57
KJ-122	21/03/05	Bintulu/Log Pond	n	female				159	135	70
KJ-124	21/03/05	Bintulu/GP Nursery	n	female				188	149	84
KJ-129	13/05/05	Matang	y	female	first quarter	rain	non monsoon	179	139	87
KJ-130	28/05/05	Matang	y	male	last quarter	rain	non monsoon	202	161	88
KJ-131	20/07/05	Matang	y	juvenile	full	rain	southwest	72	76	33
KJ-137	7/10/2005	SM-KCH	museum	male				217	168	83

Notochelys platynota

Field Number	Date	Location	Wild	Gender	SCL	SCW	SH
KJ-00012	31/10/03	Sungei Melenau/Mulu	n	female	176	155	63
KJ--00013	31/10/03	sungei Melenau/Mulu	n	male	176	133	59
KJ-00014	31/10/03	Sungei Melenau/Mulu	n	unk	141	125	58
KJ-00019	29/3/04	Loagan Bunut	n	unk	197	148	
KJ-00123	21/03/05	Bintulu/Log Pond	n	unk	154	120	60
KJ-00142	7/10/2005	SM-KCH	n	unk	217	205	93

Faeces Volume - *Amyda cartilaginea*

	female	female	female	female	female	female	female	female	male	male	male	male	male	Totals	
Plants	0.5	1.5	1	1.6	0.5	0.2	0.2	0.3	0.3	0.3	2.5	0.5	4.4	13.8	56
Insect	0.2	0.1	0	0	0.1	0.1	0	0.1	0.1	0	0.2	0.1	0	1	4
Diptera	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0.2	<1
Hymenoptera	0.1	0	0	0	0	0.1	0	0	0	0	0.1	0	0	0.3	1
Coleoptera	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.1	<1
Odonata	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0.1	<1
Gastropod	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0.1	<1
Pisces	0.1	0	0	0	0.1	0.1	0	0.2	0.2	2.6	0.1	0.1	0.5	4	16
Aves	0	0	0	0	0	0	0	0	0	0	1.5	0	0	1.5	6
Unk.Vert	0.1	1.1	0.2	0	0.1	0.1	0.1	0	0.2	0.3	0.2	0.1	1	3.5	14
Total Vol.(ml)	1.2	2.8	1.2	1.6	0.8	0.6	0.3	0.7	0.8	3.2	4.6	0.9	5.9	24.6	
	KJ-23	KJ-24	KJ-31	KJ-82	KJ-83	KJ-84	KJ-85	KJ-86	KJ-28	KJ-29	KJ-126	KJ-127	KJ-128		

Stomach Volume - *Amyda cartilaginea*

	Female	Female	Female	Female	Female	Male	Male	Male	Male
Plants	0	0.2	0.1	0	0.1	0.1	0.1	0.1	0.2
Unk. Arthropod	0	0	0	0.1	0	0	0	0	0
Odonata	0	0	0	0.1	0	0	0	0	0
Arachnid	0	0	0	0.1	0	0	0	0	0
Pisces	0.1	0	0	0	0	0	0	0	0.1
Unknown Vert	0	0	0.2	0.5	0	0.1	0.1	0	0.4
	KJ-035	KJ-083	KJ-084	KJ-085	KJ-086	KJ-028	KJ-029	KJ-034	KJ-128